



Modelling and Estimating Models of Physician Labour Supply and Productivity

Thèse

Nibene Habib SOMÉ

Doctorat en économie
Philosophiæ doctor (Ph.D.)

Québec, Canada

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Résumé

Ma thèse s'intéresse aux politiques de santé conçues pour encourager l'offre de services de santé. L'accessibilité aux services de santé est un problème majeur qui mine le système de santé de la plupart des pays industrialisés. Au Québec, le temps médian d'attente entre une recommandation du médecin généraliste et un rendez-vous avec un médecin spécialiste était de 7,3 semaines en 2012, contre 2,9 semaines en 1993, et ceci malgré l'augmentation du nombre de médecins sur cette même période. Pour les décideurs politiques observant l'augmentation du temps d'attente pour des soins de santé, il est important de comprendre la structure de l'offre de travail des médecins et comment celle-ci affecte l'offre des services de santé. Dans ce contexte, je considère deux principales politiques. En premier lieu, j'estime comment les médecins réagissent aux incitatifs monétaires et j'utilise les paramètres estimés pour examiner comment les politiques de compensation peuvent être utilisées pour déterminer l'offre de services de santé de court terme. En second lieu, j'examine comment la productivité des médecins est affectée par leur expérience, à travers le mécanisme du "learning-by-doing", et j'utilise les paramètres estimés pour trouver le nombre de médecins inexpérimentés que l'on doit recruter pour remplacer un médecin expérimenté qui va à la retraite afin de garder l'offre des services de santé constant.

Ma thèse développe et applique des méthodes économique et statistique afin de mesurer la réaction des médecins face aux incitatifs monétaires et estimer leur profil de productivité (en mesurant la variation de la productivité des médecins tout le long de leur carrière) en utilisant à la fois des données de panel sur les médecins québécois, provenant d'enquêtes et de l'administration.

Les données contiennent des informations sur l'offre de travail de chaque médecin, les différents types de services offerts ainsi que leurs prix. Ces données couvrent une période pendant laquelle le gouvernement du Québec a changé les prix relatifs des services de santé. J'ai utilisé une approche basée sur la modélisation pour développer et estimer un modèle structurel d'offre de travail en permettant au médecin d'être multitâche. Dans mon modèle les médecins choisissent le nombre d'heures travaillées ainsi que l'allocation de ces heures à travers les différents services offerts, de plus les prix des services leurs sont imposés par le gouvernement. Le modèle génère une équation de revenu qui dépend des heures tra-

vaillées et d'un indice de prix représentant le rendement marginal des heures travaillées lorsque celles-ci sont allouées de façon optimale à travers les différents services. L'indice de prix dépend des prix des services offerts et des paramètres de la technologie de production des services qui déterminent comment les médecins réagissent aux changements des prix relatifs. J'ai appliqué le modèle aux données de panel sur la rémunération des médecins au Québec fusionnées à celles sur l'utilisation du temps de ces mêmes médecins.

J'utilise le modèle pour examiner deux dimensions de l'offre des services de santé. En premier lieu, j'analyse l'utilisation des incitatifs monétaires pour amener les médecins à modifier leur production des différents services. Bien que les études antérieures ont souvent cherché à comparer le comportement des médecins à travers les différents systèmes de compensation, il y a relativement peu d'informations sur comment les médecins réagissent aux changements des prix des services de santé. Des débats actuels dans les milieux de politiques de santé au Canada se sont intéressés à l'importance des effets de revenu dans la détermination de la réponse des médecins face à l'augmentation des prix des services de santé. Mon travail contribue à alimenter ce débat en identifiant et en estimant les effets de substitution et de revenu résultant des changements des prix relatifs des services de santé. En second lieu, j'analyse comment l'expérience affecte la productivité des médecins. Cela a une importante implication sur le recrutement des médecins afin de satisfaire la demande croissante due à une population vieillissante, en particulier lorsque les médecins les plus expérimentés (les plus productifs) vont à la retraite.

Dans le premier essai, j'ai estimé la fonction de revenu conditionnellement aux heures travaillées, en utilisant la méthode des variables instrumentales afin de contrôler pour une éventuelle endogénéité des heures travaillées. Comme instruments j'ai utilisé les variables indicatrices des âges des médecins, le taux marginal de taxation, le rendement sur le marché boursier, le carré et le cube de ce rendement. Je montre que cela donne la borne inférieure de l'élasticité-prix direct, permettant ainsi de tester si les médecins réagissent aux incitatifs monétaires. Les résultats montrent que les bornes inférieures des élasticités-prix de l'offre de services sont significativement positives, suggérant que les médecins répondent aux incitatifs. Un changement des prix relatifs conduit les médecins à allouer plus d'heures de travail au service dont le prix a augmenté.

Dans le deuxième essai, j'estime le modèle en entier, de façon inconditionnelle aux heures travaillées, en analysant les variations des heures travaillées par les médecins, le volume des services offerts et le revenu des médecins. Pour ce faire, j'ai utilisé l'estimateur de la méthode des moments simulés. Les résultats montrent que les élasticités-prix direct de substitution sont élevées et significativement positives, représentant une tendance des médecins à accroître le volume du service dont le prix a connu la plus forte augmentation. Les élasticités-prix croisées de substitution sont également élevées mais négatives. Par ailleurs, il existe un effet de revenu associé à l'augmentation des tarifs. J'ai utilisé les paramètres estimés du mo-

dèle structurel pour simuler une hausse générale de prix des services de 32%. Les résultats montrent que les médecins devraient réduire le nombre total d'heures travaillées (élasticité moyenne de -0,02) ainsi que les heures cliniques travaillées (élasticité moyenne de -0.07). Ils devraient aussi réduire le volume de services offerts (élasticité moyenne de -0.05).

Troisièmement, j'ai exploité le lien naturel existant entre le revenu d'un médecin payé à l'acte et sa productivité afin d'établir le profil de productivité des médecins. Pour ce faire, j'ai modifié la spécification du modèle pour prendre en compte la relation entre la productivité d'un médecin et son expérience. J'estime l'équation de revenu en utilisant des données de panel asymétrique et en corrigeant le caractère non-aléatoire des observations manquantes à l'aide d'un modèle de sélection. Les résultats suggèrent que le profil de productivité est une fonction croissante et concave de l'expérience. Par ailleurs, ce profil est robuste à l'utilisation de l'expérience effective (la quantité de service produit) comme variable de contrôle et aussi à la suppression d'hypothèse paramétrique. De plus, si l'expérience du médecin augmente d'une année, il augmente la production de services de 1003 dollar CAN. J'ai utilisé les paramètres estimés du modèle pour calculer le ratio de remplacement : le nombre de médecins inexpérimentés qu'il faut pour remplacer un médecin expérimenté. Ce ratio de remplacement est de 1,2.

Abstract

My thesis considers health-care policies that are designed to affect the supply of health services. Waiting times for health care are a major health policy concern in many industrialized countries. In Quebec, the median time between a referral from a general practitioner and an appointment with specialist was 7.3 weeks in 2012, compared to 2.9 weeks in 1993, despite increases in number of physicians over the same period. For policy makers contemplating such outcomes, it is of particular importance to understand the structure of physician labour supply and how it affects the supply of health services. I consider two main policies in this respect. First, I estimate how physicians react to monetary incentives and I use my estimates to consider how compensation policy can be used to determine the short-term supply of services. Second, I consider how physician productivity is affected by experience, through learning-by-doing, and I use my estimates to determine how many inexperienced physicians must be hired to replace a retiring experienced physician in order to keep the supply of services constant.

My dissertation develops and applies economic and statistical methods to measure the reaction of physicians to monetary incentives and to estimate their productivity profiles (measuring how productivity varies with experience throughout a physician's career) using survey and administrative panel data on Quebec physicians.

Our data contain information on the labour supply of each physician, the different types of services they produce and their prices. These data cover a period during which the Quebec government changed the relative prices of medical acts. I use a model-based approach to develop and estimate a structural model of physician behaviour with multitasking. In my model, physicians take the prices of different services as given and choose the number of hours they wish to work as well as how those hours are distributed across different services. The model generates an earnings equation that depends on the total hours worked and a price index that gives the marginal return to hours when hours are optimally distributed across services. The price index depends on the prices of services and technology parameters that determine how physicians react to changes in relative prices. I apply the model to panel data on payments to Quebec physicians matched to time-use data on the same physicians.

I use the model to investigate two dimensions of the supply of health services. First, I look

at the use of monetary incentives to induce physicians to alter their supply of different services. While previous studies have often sought to compare physician behaviour across different compensation systems, relatively little is known about how physicians respond to fee changes. Recent debates in Canadian health policy circles have focussed on the importance of income effects in determining the response of physicians to fee increases. My work contributes to this debate by identifying and estimating the substitution and income effects resulting from changes in the relative fees paid for services. Second, I look at how experience affects physician productivity. This has important implications for the hiring of physicians to meet increased demand from an ageing population, particularly when experienced physicians are retiring.

First, I estimate the earnings function conditional on hours worked, using instrumental variables to control for the potential endogeneity of hours worked. As instruments, I use dummies of age, marginal tax rate, returns on market investments, its squared and cubed. I show that this provides a lower bound to the own-price elasticity of any particular service. This allows me to test if physicians respond to monetary incentives. I find that the lower bounds of own-price elasticities of services are positive and statistically significant, suggesting that physicians do respond to monetary incentives. A relative change in prices leads physicians to supply more of the services whose prices have risen.

Second, I estimate the full model by explaining the variation in hours worked by physicians, the volume of services supplied, and individual earnings. I do so using a Simulated Method of Moment estimator. The results show that the own-price elasticities for services are large and positive, implying that the volume-increasing response of services to their own-price is strong. Cross-price elasticities are also large but negative. Furthermore, there is an income effect associated with fee increases. I use the structural model estimates to simulate the total effect of a recently observed price increase that was offered to physicians in Quebec, increasing the prices of all services by 32%. The results show that physicians would reduce their total hours worked (average elasticity of -0.02) and clinical hours worked (average elasticity of -0.07). They would also reduce the volume of services provided (average elasticity of -0.05).

Third, I exploit the link between fee-for-service physicians' earnings and their productivity to estimate physician productivity profiles. To do so, I modify the specification of the model to take into account the relationship between a physician's productivity and his/her experience. I estimate the earnings equation using an unbalanced panel dataset, correcting for non-randomly missing observations by estimating a selection model. The results suggest that productivity profiles are increasing concave functions of experience. Furthermore, the shape of the profile is robust to parametric assumptions. A one-year increase in experience increases the production of services by approximately 1,003 CAN dollars. I use the model estimates to calculate the replacement ratio: the number of inexperienced physicians needed

to replace an experienced one. I find that this ratio to be 1.2 to 1, suggesting that more than one inexperienced physician is needed to replace an experienced one.

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À mon défunt Père, À ma Mère...
Que le combat soit encore plus dur...

Success comes not by wishing
But by hard work bravely done

The Unknown Wise man

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Introduction

Health care expenditures in Canada varies across the country, but on average provinces spend approximately 40% of their total budgets on healthcare (Canadian Institute for Health Information, 2013). Spending on physicians remains the third-largest source of health care spending, behind hospitals and pharmaceuticals.¹ Despite the increased spending in physicians compensation, multiple sources show that accessibility to health services remains unsatisfactory (CSBE 2013 ; Health Council of Canada 2013 ; Hutchison 2013). What is more, this massive funding, together with provincial wait time strategies has not significantly reduced waiting times for health care. For instance, in Quebec,² the median time between referral from a general practitioner and an appointment with specialist was 7.3 weeks in 2012, compared to 2.9 weeks in 1993.

For policy makers contemplating such outcome, it is of particular importance to understand the structure of physician labour supply and how it affects the supply of health services. Two important factors affecting the supply of health services are how physicians react to monetary incentives and how their productivity is affected by experience. Firstly, knowing how physicians respond to monetary incentives can help policy makers ensure the supply of health services in response to changing demand, due to the aging of Canada's population. Secondly, It is also important to understand how physician's productivity varies over time throughout their career, for a realistic long-term planning of the number of physicians needed to meet societies demand for health care.

0.1 Reaction to incentives

Previous studies carried out to investigate whether and how the changes in relative fees affect the quantities of medical services provided by physicians, often compare physician behaviour across different compensation systems. Such comparisons have revealed that fee-for-service physicians spend more time seeing patients [Ferrall, Gregory, and Tholl, 1998] and conduct more patient visits [Devlin and Sarma, 2008, Gaynor and Gertler, 1995] than do

1. Hospitals, pharmaceuticals and physician spending represent 29.6%, 15.8% and 15.5% of total health spending, respectively (CIHI 2014).

2. Health care falls under the jurisdiction of provincial governments under the Canadian constitution.

physicians paid according to other compensation systems, including salary or hourly pay. Evidence also suggests that fee-for-service physicians complete a higher volume of services than do physicians who are paid a mixed compensation system [Dumont, Fortin, Jacquemet, and Shearer, 2008].¹ Other work highlights how incentives can be used to affect physician location decisions and ensure the supply of services in outlying regions [Bolduc, Fortin, and Fournier, 1996]. These results are consistent with the existence of incentive effects, suggesting that compensation policy is a viable tool to affect physician behaviour and meet short-term demand fluctuations.

Perhaps the simplest and most direct way to alter incentives is to change the relative prices that are paid for different services. The price policy is often used by the government of Quebec. In 2001, government services fees were increased, on average by 18% for specialists and between 2007 and 2011 the fees were increased by 32%. Yet, relatively little is known as to how physicians react to such changes. The studies that do exist typically rely on geographically-aggregated service-utilization data, often with mixed results. Hurley and Labelle [1995] considered how changes in the relative fee paid for given services affected the utilization rates of those service-utilizations in Canadian provinces. They found little consistency across services, either in terms of the statistical significance of the relative fee as a determinant of the utilization rate, or in the direction (sign) of the effect. Similar findings were reported by JJ [1993], providing little consensus as to either the importance (or even the sign) of such effects. Whether this is a consequence of particularities in the data, physician preferences for leisure, or technological constraints on physician behaviour is unclear. However, if price (or fee) controls are to be used as an efficient policy instrument, more evidence is required on how physicians react to changes in direct monetary incentives.

0.2 Experience Profiles

To address the long waiting times for health care, one policy response could focus on training more physicians rather than using monetary incentives as policy instrument. In that case, an understanding of how physician's productivity changes over time is important for the long-term planning of the physician workforce. Another benefit of having physicians productivity profiles is that governments can use targeted incentive policies, in order to encourage the most productive physicians to work more and meet the increasing demand.

The change in physicians productivity may be attributable to human capital accumulation and the learning-by-doing process since past work experience has a direct effect on their current practices. Namely, as they gain experience they become better (and quicker) at performing diagnoses. Evidence that does exist suggests that physician productivity increases with experience. Dormont and Samson [2008] studied French physicians using primary care

1. Under a mixed compensation system, physicians receive a daily wage (or per diem) accompanied by a reduced fee-for-service.

physicians data. [Fjeldvig \[2009\]](#) studied Norwegian physicians using specialist and primary care physicians data. To date, little is known as to the nature of these profiles for Canadian physicians.

In this thesis, we use Quebec physician-level data on the number of services completed, along with the fees paid for those services firstly, to estimate whether, and how physicians react to changes in relative prices. Secondly, we also exploit the link between fee-for-service¹ (FFS) physician earnings and their productivity to measure how productivity varies with experience throughout a physician's career.² FFS compensation system provides economists with a natural link between observed earnings and physician productivity. Thus, we avoid interpreting wage profiles as productivity profiles. This is another contribution of our thesis, because in most datasets, the link between wages and productivity is unknown. See for example [Hutchens \[1989\]](#).

0.3 The Approach

Our approach is model based – we develop and estimate a structural model of physician behaviour with multitasking. Physicians choose the total hours they work and the manner in which those hours are allocated to different services, given the relative prices of those services. We specify a Constant elasticity of substitution (CES) utility function for physicians, which is general enough to permit unrestricted responses to incentives, yet parsimonious in parameters, allowing for simple and direct interpretations of the results. Our model generates a wage index that measures the marginal return to an hour worked when that hour is optimally allocated across different services. The wage index is a non-linear function of the prices of different services and the elasticity of substitution between those services.

Optimal behaviour implies an earnings function that depends on total hours worked and the wage index; its parameters include the elasticity of substitution between services and the elasticity of hours worked in response to changes in prices. The earnings function measures the ability of physicians to produce services at different relative prices. It captures all economically relevant information about the response to incentives in the presence of multitasking.

The earnings function can be estimated either conditionally or unconditionally on clinical hours worked. Conditional estimation is less demanding econometrically and can be accomplished by (non-linear) least squares or instrumental variables (Chapter 5). It fixes hours worked and explains their allocation across different tasks in response to changes in rela-

1. We use the term fee-for-service to refer to a payment scheme under which physicians receive a fee for each service provided. In Quebec, before 1999, the vast majority of physicians (92%).

2. [Gunderson \[1975\]](#) used piece-rate data to control for productivity differences across workers in his study of male-female wage differences. Similarly, [Weiss \[1994\]](#) used piece-rate data to estimate the learning curve for manufacturing workers.

tive prices. Since the variation in hours is not explained within the model, income effects are not identified. Some elements of the substitution effects are identified, permitting relevant, but limited, conclusions over physician behaviour. The conditional estimation is a limited-information approach, because it ignores the variation in clinical hours.

Explaining the variation in hours worked requires modelling the choice of hours by individual physicians. This implies additional assumptions but has the advantage of identifying the full response of physicians to changes in relative prices, including both income and substitution effects. The additional hours equation in the estimation problem allows for the identification of income effects in response to variation in relative prices. To explain hours worked, we first assume that there is no institutional constraints imposed on physicians contracts, in particular, no income ceilings and no taxes. Then, we account for income ceilings¹, and the Québec progressive income tax system², successively to check the robustness of our results. In Chapter 7 we estimate the full-information model to answer how physicians react to changes in prices.

In the Chapter 8, we modify the specification of our model to take into account the relationship between the productivity of physicians and their experience. We estimate a selection model to correct for non-randomly missing observations.

0.4 Results

Our results suggest that physicians do respond to incentives. Conditional on hours worked, physicians responded to price increases by producing more of those services whose prices were increased. The lower bound to the own-price elasticity of substitution is quite small for volume of service 2 and equal to 0.26 for volume service 1, when physicians who provide 2 services. For those who provide 3 services, the lower bond to the own-price elasticity of substitution is ranging between 0.14 and 0.83. Yet, for physicians who provide 4 services the own-price elasticity of substitution is between 0.24 and 1.38.

Unconditional estimation gives own-price elasticities of substitution of hours supplied in producing the service (volume of the service provided) are 2.97 (2.07) and 0.41 (0.28) for physicians who provide 2 aggregated services, between 2.68 (2.07) and 3.02 (2.33) for those providing 3 aggregated services ; and between 7.11 (6.53) and 11.98 (11.00) for those providing 4 aggregated services. The cross-price elasticities of substitution of hours (volume) are -0.22 (-0.16) and -2.89 (-2.02) for physicians who provide 2 aggregated services, between -1.34 (-1.04) and -1.69 (-1.69) for those providing 3 aggregated services ; and between -0.24 (-0.22) and -5.12 (-4.70) for those providing 4 aggregated services. The income effects are smaller,

1. Prior to 1999, the government imposes half-yearly ceilings on physician's gross income, beyond which the price paid for each service is reduced by 75%.

2. We combine provincial and the federal tax system and end up with six progressive income brackets and marginal tax rate increasing from 33% to 53.5%.

with elasticities ranging from -0.005 for total hours worked to -0.03 for clinical hours and hours devoted to services for physicians who provide 2 aggregated services. It is between -0.001 and -0.008 for those providing 3 aggregated services and between -0.001 and -0.007 for those providing 4 aggregated services. Moreover, the fee increase affects very slightly weekly total hours and clinical hours (extensive margin). The elasticities are small, ranging from -0.023 to 0.011 for total hours worked and from -0.115 to 0.066. That is, both total and clinical hours worked decrease slightly for physicians providing 3 or 4 services while they remain almost the same for those providing 2 services.

We also estimate the full model accounting for taxes and income ceilings (Prior to 1999, the government imposes ceilings, on physicians gross income) and we use our estimates to simulate the effect of recently observed price increases in physician contracts. We perform simulations, increasing fees of services by 32%. Our results suggest that when physician are paid FFS, a policy increasing the price of services (simultaneously) would reduce the total hours worked (an average elasticity of -0.02) and clinical hours worked (an average elasticity of -0.07). What is more, physicians would reduce the volume of services provided (an average elasticity of -0.05), this result qualitatively similar to those reported by [Contandriopoulos and Perroux \[2013\]](#) using data on Quebec physicians and consistent with the target "income hypothesis".

The results also suggests that productivity profiles are increasing concave functions of experience. More precisely, after being authorized to practice, physician earnings increase for the first 25 years reflecting increasing productivity. After reaching a peak at 25 years of experience, their earnings decline slightly toward the end of the career. Furthermore, the shape of the profile is robust to controlling for actual experience and to parametric assumption. While the effect of experience on productivity is statistically significant, it is small. A one-year increase in experience increased productivity by 0.003 percent, this represents an increase of service production by approximately 1,003 CAN dollar. We relate this result to the argument that over time physicians gain ability to compare the present day patient against similar past patients. That is, they can be more efficient in providing care to patients which is consistent with learning-by-doing process.

We use the model estimates to simulate the effect of replacing experienced physicians with unexperienced physicians. The result suggests that the replacement ratio is 1.2, when physicians with less than 25 years of experience is considered as unexperienced. These ratio could explain why the increasing number of physicians has not reduce the wait times because more new physicians is needed to replace experienced one.

The rest of the thesis is organized as follows. Chapter 1 provides a literature review. Chapter 2 describes the data. Chapter 3 develops the theoretical model. Chapter 4 describes the aggregation strategy and the variables used in our empirical analysis. It also presents des-

criptive statistics. Chapter 5 explains our empirical model, while Chapter 6 discusses the limited information estimation and presents its results. Chapter 7 presents full information estimation results and policy simulations. The last Chapter presents physicians productivity profiles.

Chapitre 1

Literature Review

1.1 Empirical Labour Supply

A vast literature exists on understanding labour supply behaviour and many research questions have been addressed by the labour economists, ranging from the impact of tax and welfare programs to the determinants of wages and labour supply. The majority of these studies use reduced form model to estimate wage elasticity.

Regarding studies evaluating the effect of public or private intervention on labour supply, the seminal work by [Ashenfelter and Card \[1985\]](#) provides researchers with difference-in-differences methods. They compare the earnings of trainees and a comparison group to estimate the effectiveness of training for participants in 1976 Comprehensive Employment and Training Act (CETA). They use a reduced form model with a policy dummy, which indicates whether an individual participate in the training during a period. The coefficient of this dummy variable is interpreted as the effect of the program. They find that a participant to the CETA program earn between \$200 and \$2000 than a non-participant.

Since the work by [Ashenfelter and Card \[1985\]](#), the use of difference-in-differences methods has become very widespread. For example, [Eissa \[1995\]](#) uses difference-in-differences estimator to analyze the response of married women to changes in the tax rate due to the US Tax Reform Act of 1986. The Tax Reform Act of 1986 reduced the top marginal tax rate (high-income) from 50% to 28%, but changed less the marginal tax rate for the low-income. She uses the March Current Population Surveys data from 1984 to 1986, and from 1990 to 1992. She finds evidence that the labour supply of high-income, married women increased due to the Tax Reform Act of 1986. The increase in total labour supply of married women at the top of the income distribution (relative to married women at the 75th percentile of the income distribution) implies an elasticity with respect to the after-tax wage of approximately 0.8.

However, the estimated parameters do not provide sufficient information for extrapolation or simulation. To perform simulations of tax and welfare proposals a structural model is

needed. Indeed, the estimated parameters of a structural model can be used to predict behaviour after a change in the economic environment and comparing this predicted behaviour with a benchmark allows us to simulate policies. Structural modelling leads to economic and statistical assumptions on agents' behaviour (particularly individual preferences, the consumption technology, and the decision process, as well as the timing). Arrufat and Zabalza [1986] develop a structural labour supply model, based on a CES family utility index defined over net family income, and wife's leisure. They use British cross-sectional data on married women from the 1974 General Household Survey to estimate the model. They find an estimated elasticity of substitution of 1.21. The elasticities with respect to own wages, husband's wages, and unearned family income are 2.03, -1.27, and -0.20. This own wage elasticity of approximately 2 is larger than those estimated in previous studies using British data.

Regarding policy simulation, for example Blundell et al. [1988] uses data on 1400 married women from the British Family Expenditure Survey for 1980, to estimate a labour supply model based on a generalized version of the Stone-Geary utility function. They use the model estimates to simulate a number of reforms to the British tax system.

Within the labour supply literature, structural models allowing for discrete hours choices are used in numerous studies. These models have the advantage to incorporate more easily nonlinearities in the tax system, unemployment benefits, compensation system, etc. This approach can be used to analyse all sorts of (non-linear) tax and benefits reforms. See for example Kapteyn et al. 1989, van Soest [1995], and Apps, Kabátek, Rees, and van Soest [2012]. For example, Kapteyn et al. 1989 analyze a cross-section of Dutch households from a 1985 labour mobility survey by the Organization of Strategic labour Market Research, using structural discrete choice model. Their results imply wage-rate elasticities of 0.65 and 0.79 for women and 0.12 and 0.10 for men. These and the estimated income elasticities are in harmony with previous work using Dutch data.

The literature also shows many contributions on household labour supply. The original work of Ashenfelter and Heckman [1974], Wales and Woodland [1976] and Smith [1977] have treated the household as if it was a single decision making agent, with a single budget constraint and maximizing a single utility function in which each household member's consumption enters as an argument. This approach is known in the literature, as the unitary model of the household.

1.2 Physician Labour Supply

The earliest studies on the supply of physician services, for example Feldstein [1970], Fuchs and Kramer [1972] and Brown and Lapan [1972], run OLS regressions of the quantity of services provided by a Generalist on different control variables and a fee measure. Using

different data sources from the US, these studies generally find small negative fee elasticities that are measured imprecisely due to the small sample sizes. The literature on physician labour supply appears with the work of Sloan [1975]. He estimates the wage elasticities on weekly hours worked (and weeks worked per year) using US census data from 1960 and 1970. He finds small positive wage elasticities (less than 0.1) on average. Progressively the estimation methods are evolved, Rizzo and Blumenthal [1994] use instrumental variable method to estimate wage elasticity. They model labour supply and the wage rate jointly based on a sample of young self-employed physicians from the 1987 Practice Patterns of Young Physicians Survey. They instrument the wage rate using professional experience. They find a positive wage elasticity of 0.23 which they decompose into an income (-0.26) and a substitution effect (0.49). Showalter and Thurston [1997], allows the wage elasticity to depend on age. They use data from the 1983-1985 Physicians' Practice Costs and Income Survey (PP-CIS). They find significant positive wage elasticities for self-employed physicians (0.33), but small (0.10) and insignificant wage elasticities for doctors on wages or salaries.

Only a small number of studies on the labour supply of physicians use a structural model and the majority of these studies uses a discrete-choice approach. Using administrative data on Norwegian physicians in 1995 and 1997, Sæther [2005] estimates a structural discrete choice labour supply model for doctors aged 28-66, both employed and self-employed. He finds wage elasticities for hospital physicians ranging broadly from 0.1 to 0.2.

More recently, Andreassen et al. [2013] use a panel of 6,564 married employed Norwegian physicians data from 1997-1999 to estimate a structural labour supply model that allows physicians to choose among 10 different job packages which are a combination of part time/full time, hospital/primary care, private/public sector, and not working. They find an average wage elasticity of 0.04. The paper demonstrates the flexibility of the discrete choice approach by presenting estimated wage elasticities, and sectoral employment changes, that result from simulated changes to the taxation schedule.

1.3 Measuring the response to monetary Incentives

Measuring how workers react to monetary incentives is an important question for labour economists, particularly in the field of contract theory [Hart and Holmstrom, 1986] as well as personnel economics [Lazear, 1996]. Early empirical work in this area has concentrated on using firm-level data to measure the productivity effects of different compensation schemes [Paarsch and Shearer, 1999, 2000, Lazear, 2000]. However, the possible endogeneity of the compensation system renders the identification of incentive effects more challenging for the econometrician [Prendergast, 1999, Chiappori and Salanié, 2002].

To solve the compensation system endogeneity problem, some researchers have used instrumental variables approaches. For example, Akerberg and Botticini [2002], address this

endogenous matching problem using a data set on agricultural contracts between landlords and tenants in early Renaissance Tuscany. They regress the type of contract on crop riskiness and tenant's wealth, using geographical variables to instrument the crop riskiness variable. They find that the instrumental variables estimates are more compatible with theory than a naive regression would suggest.

Shearer [2004] proposes an experimental setting to solve this endogeneity problem. An experimental setting permits the compensation system to be varied exogenously allowing direct measurement of the incentive effect within the experiment. Shearer combines structural econometric methods with the experimental data (following Heckman and Smith [1995], Keane and Wolpin [1997] and Ferrall [2002] discussions), to estimate the gain in productivity that is realized when workers are paid piece rates rather than fixed wages. The experiment was conducted within a tree-planting firm and provides daily observations on individual worker productivity under both compensation systems. He finds with an unrestricted statistical methods estimate that the productivity gain is 20%. Since planting conditions potentially affect incentives, he uses structural econometric methods to generalize the experimental results to out-of-sample conditions. His structural results suggest that the average productivity gain, outside of the experimental conditions, would be at least 21%.

1.4 Measuring Physicians Response to Incentives

A few studies have been carried out to investigate theoretically whether and how the changes in relative fees paid for services affect the quantities of medical services provided by physicians. McGuire and Pauly [1991] develops a general model which integrates inducement behaviour¹ encompassing the two benchmark cases of profit maximization and target-income behaviour into a utility framework. They use the model to analyse physician responses to relative fee changes by Medicare (one payer) when the physician supplies services to patients. Using the comparative static techniques, they derive own and cross-price elasticities and demonstrate that the expected quantity response of physicians will depend on the size of the income effect. In presence of "very large" income effect, physicians are following a "target income" model, that is, they will increase volume of services in response to price cuts. When there is zero income effect fee decreases leads physicians to reduce quantity of services.

Empirical evidence also suggests that physicians do respond to incentives. A significant amount of researches on physician behaviour relates to measuring physician response to changes in services fees. Recent empirical work in this area has concentrated on using physician-level data to measure the reaction of physicians to changes in their contract. Baltagi, Bratberg, and Holmås [2003] estimate the labour supply model by GMM, they find significant posi-

1. The standard model of induced demand states that in face of negative income shocks, as a cut in fees, physician may exploit their agency relationship with patients by providing excessive care in order to maintain their incomes.

tive wage elasticities of around 0.3. They use data on Norway physicians covering a period where doctors received a 15% hourly wage increase in average. Recently, [Kalb et al. \[2015\]](#) use structural discrete choice model to examine the response of Australian General Practitioners (GPs) and specialists to 5 and 10% wage increases. They find that such wage increases substantially reduce the full-time equivalent supply and that working hours reduction is largest for male GPs, followed by male specialists and female GPs. Physicians also react to geographic discrimination in their payment. The study by [Clemens and Gottlieb \[2014\]](#), estimating the influence of prices on health care supply using changes induced by an administrative shift in the system of geographic adjustments, in the US, finds that areas with higher payment shocks experience significant increases in health care supply. On average, a 2% increase in payment rates leads to a 3% increase in care provision, using county-level data.

Within the health-economics literature, many authors have concentrated on measuring how physician behaviour relates to physician-induced demand for services.¹ These studies show that a fee reduction leads to an increase in quantities of services, although the magnitude of inducement is uncertain. [Rice \[1984\]](#) provides evidence for quantity inducement by studying a Medicare fee reduction in Colorado. He finds that a 10% decline in physician reimbursements leads to a 6.1% increase in volume of medical services and a 2.7% increase in intensity of surgical services. However, a similar study by [Hurley and Labelle \[1995\]](#) for four provinces of Canada found a mixed responses to fee changes across medical procedures. Evidence from the USA and Canada with fee controls offers a similarly mixed picture of the role of induced demand; see [Mitchell, Wedig, and Cromwell \[1989\]](#), [Feldman and Sloan \[1988\]](#), and [Rice and Labelle \[1989\]](#) for a discussion. Furthermore, [Bradford and Martin \[1995\]](#) find with data from the Physician's Practice Cost and Income Survey, that the income effects is relatively weak and so that demand inducement is not likely to be a significant problem. A recent study on demand inducement, using 2,650 fee-for-service physicians in Norway confirms these results [[Grytten et al., 2008](#)].

1.5 Measuring experience profiles

Earnings functions are the most widely used empirical equations in labour economics and the economics of education [[Heckman et al., 2005](#)]. The human capital earning function was developed by Mincer seminal work on the effect of experience or on-the-job training on the determination and distribution of earnings [[Mincer, 1958](#)]. He extends his work with his study in [Mincer \[1974\]](#) and provides the most widely used specification of empirical earnings

1. The standard model of induced demand states that in face of negative income shocks, as a cut in fees, physician may exploit their agency relationship with patients by providing excessive care in order to maintain their incomes.

equations :

$$\ln[Y(s, x)] = \alpha + \rho_s s + \beta_0 x + \beta_1 x^2 + \epsilon, \quad (1.1)$$

where $Y(s, x)$ is the wage or earnings at schooling level s and work experience x and ϵ is a mean zero residual with $E(\epsilon s, x) = 0$. Mincer's log earnings equation was developed to explain cross sections of earnings.

Mincer also shows the concave shape of the experience earnings profiles. This shape is confirmed by more recent studies using different approaches. Indeed, [Eckstein and Wolpin \[1989\]](#) use the standard Mincer earnings function to model the wife's earnings in a structural dynamic model of married female labour force participation and fertility. In their setting, the effect of work experience on wages is explicitly taken into account. The model is estimated using the National Longitudinal Surveys mature women's cohort (between 39 and 44 years old in 1967). They find that although work experience increases the disutility of further work, the effect is overwhelmed by the positive effect of experience on wages, leading to persistence in the employment patterns of these women. In addition, [Shearer \[1996\]](#) uses data on British Columbia copper mine workers during the period from the beginning of 1926 through the end of 1928, to estimate worker productivity profiles. His sample contains 871 men, in 1927, receiving piece rate compensation. He develops and estimates a model a censored wage equation using parametric and semi-parametric estimation with tenure and tenure squared as explanatory variables. His empirical results suggest that productivity profiles were increasing concave functions of tenure.

There is an important distinction between age earnings profiles and experience earnings profiles [[Mincer, 1974](#)], where experience means years since leaving school. Concerning age earning profiles, he finds that older workers earn more because they spend less time investing in human capital and also earn the returns to earlier investments. Studies by [Becker \[1962\]](#) and [Borjas \[2006\]](#) use mincer type earning equation highlight three important properties of the age earnings profiles :

1. *That high educated workers earn more than less educated either because of a correlation between productivity and education or as a signal of the workers ability.*
2. *Earnings rise over time, but at a decreasing rate. The increase in income over the life cycle may be a result of a rise in productivity even post school, mainly because of some on-the-job investment/experience.*
3. *The age earning profiles of the different education groups diverge over time, the profile slope is steeper the more education, implying the ones that invest much in education also invest the most after in their career.*

Much of the recent studies on age earnings profiles in the literature find a concave shape. For example, [Imai and Keane \[2004\]](#) simulate age profiles of wages and the marginal rate of

substitution between labour supply and consumption using data from the 1979 youth cohort of the National Longitudinal Survey of Labour Market Experience (NLSY79). First, they estimate the life cycle labour supply model using maximum likelihood estimation based on a full solution of agents' dynamic programming problem allowing human capital accumulation. Second, they simulate data from the estimated model. They find a concave age-wage profiles and this fits with their data.

1.6 Measuring physicians experience profiles

Relatively few studies have directly investigated how productivity varies with experience throughout a physician's career. One study by [Baker \[1996\]](#) examines the differences in earnings between male and female physicians, using data on earnings from the 1991 Survey of Young Physicians. He runs OLS regressions on male-female earnings ratio for young physicians in 1990 controlling for variables such as, specialty, practice setting, educational variables, experience, personal characteristics, and characteristics of community. His results show that in 1990, young male physicians earned 41 percent more per year than young female physicians. Per hour, young men earned 14 percent more than young women. However, differences in earnings between men and women remain among older physicians and in some specialties.

Study by [Dormont and Samson \[2008\]](#) provides a direct empirical evidence of physicians experience-earnings profiles shape. They estimate an earnings function to identify experience, time and cohort effects. Using a representative panel of 6,016 French self-employed general practitioners over the years 1983 to 2004. They find that earnings are a reversed u-shaped function of experience. [Fjeldvig \[2009\]](#) also finds a similar results when estimating age-earnings profiles for Norwegian physicians. He uses Mincer types earnings functions to generate his age-earning profiles, that he estimates by fixed effect and cross-sectional regressions controlling , respectively for cohort effects, period effects. He finds that the age-earnings profiles are upward sloping and concave. When looking at profiles in terms of gender he finds that there are large differences between the earnings of male and female physicians.

Chapitre 2

Data Description

2.1 Background : Physician payment mechanism in Quebec and fee increases

In Canada, the health care system is administered by the Provincial governments although the Federal government controls that the national standards in accordance with the Canadian Health Act. The public health policy is mainly determined by each province. In Québec, the fee-bargaining process is between the government and two distinct associations : *la Fédération des médecins spécialistes (FMSQ)* and *la Fédération des médecins omnipraticiens*. This tripartite does not negotiate directly on the medical services fee levels, but on the global allocations to the medical care sector and the structure of their own fee schedule. The medical services fee are set by the government and administrated according the National Health Insurance Plan.¹

In 1996, the Quebec government signed a three year agreement with FMSQ fixing the budget for specialist physicians until 1999. The consequence was that the price of medical services provided by specialists were to remain stable. In this agreement the government also imposed income ceilings on physicians.

Quebec physicians have traditionally been paid by fee-for-service mechanism (FFS)². Under this system, physicians receive a fee for each service provided. In 1999, a new agreement introduced a Mixed Remuneration (MR) scheme but the global allocation for specialist physicians stayed the same and billing ceilings were removed. Adoption of the MR system was optional. Physicians who chose the MR scheme received a fixed wage, called a per diem, and a reduced (relative to the FFS contract) fee for services provided. But the decision to switch to the MR system must be voted within departments in hospitals among specialists perfor-

1. Most doctors participate in the Health Insurance Plan, which means that they accept the Health Insurance Card as payment for their fees. In that case, insured persons have nothing to pay. The National Health Insurance remunerates these doctors directly for the services they provide.

2. Before 1999, 92% of specialist physicians were paid FFS.

ming similar tasks. In 2000, about 31.03% of the specialists were paid, at least in part, by the new system.

Between 1997 and 2001, the budget allocated to specialists were frequently exceeded because of the increasing number of physicians and the aging population which increased demand for medical care. During this period, there was an increase in the fees paid for some services due mainly to unanticipated technological shocks, including new medical machines and diagnostic techniques and procedures. In 2001, another agreement was signed between the government and specialist physicians association causing a budget increase, implying increases in medical services fees. These fee increases were in the order of 18%.

2.2 Description of the dataset and sample selection

The data used for this study contain information on specialist physicians practicing in Quebec between 1996 and 2002. These data are derived from two sources : the Quebec College of Physicians (CMQ) and the Health Insurance Organization of Quebec (RAMQ). The Quebec College of Physicians conducts an annual time-use survey of its members. This survey contains information on labour supply behaviour, captured by time spent at work h_t , measured as the average (over the whole year) number of hours per week and time devoted to seeing patients h_s . The survey also has information on physician personal characteristics such as speciality, age, gender and experience.

Our second source of data comes from the RAMQ administrative files used to pay physicians. These files give information on the medical service fees α_i , and the number of services performed by each physician A_i . They also include information on income, speciality, services provided, rates paid and the physicians' compensation system. These data are available on a quarterly basis for each physician.

The data from the Quebec College of Physicians and from RAMQ were matched on the basis of an anonymous payroll number attributed to each physician. This allows us to keep track of each physician in our sample across time periods.

To take advantage of panel data we restrict our sample to specialists who were present before and after 2001, the year in which prices changed. This restriction leads us to eliminate 3808 physicians of the 5904 in the initial database because we cannot keep track of them throughout the sample period. At the same time, we eliminate 183 medical services. The Quebec government introduced the mixed compensation system (MC) for specialists in 1999. We kept in our sample only physicians who received their earned income under FFS schemes over the whole sample period.¹ Restricting the sample to FFS physicians eliminates 590 specialists and 41 services. Also, we dropped the following specialities : electroencephalo-

1. Dumont *et al.* found that FFS and MC physicians have different behaviour regarding their labor supply.

graphy, urology, pneumology, rheumatology, physiatry and plastic surgery which represented each between 0.4% and 2% of the sample. Thus, we eliminated 277 specialists with their 123 services. After correcting the sample from duplicates, this leaves 1231 physicians performing 406 different services, over a period of 7 years.

Physicians conduct a large number of medical services. Empirical tractability requires aggregating medical services. To do so, we first dropped medical services which are not present over the whole sample period, 98 services are concerned. Secondly, in order to concentrate on the change in prices that occurred in 2001, we removed services for which prices increased between the year 1996 and 2000.¹ Thus in our data the fees paid for services remained constant before 2001 and then increased. Note that the increase was not immediate in all cases. For some services the agreement between the government and *la Fédération des médecins spécialistes du Québec (FMSQ)* induced a gradual increase between 2001 and 2002.

The final sample contains the following specialties : cardiac and vascular surgery (19 physicians), nephrology (54 physicians), radio-oncology (6 physicians), anesthesiology (41 physicians), endocrinology (30 physicians), gastroenterology (74 physicians), cardiology (149 physicians), pediatrics (93 physicians), internal medicine (127), neurology (63 physicians), general surgery (97 physicians), dermatology (76 physicians), gynecology and obstetrics (127 physicians), orthopedics surgery (84 physicians) and otorhinolaryngology (62 physicians). The final sample contains 1231 specialists² performing 221 services.

1. There were 85 such services. We suspect these price changes reflect technological change and are hence endogenous.

2. Our model allows physicians to perform at least 2 services. Thus, the behaviour of specialists which provide only one service will not be analyzed in this paper. This is the case for cardiac and Vascular Surgery, nephrology, radiation oncology and anesthesiology.

Chapitre 3

General presentation of the model

3.1 Model with two services

3.1.1 The Technology

Let A_i denote the quantity of services of type i provided by a physician which depends on the input of hours h_i :

$$A_i = h_i^\delta \quad (3.1)$$

where δ determines the marginal return to time spent by the physician to produce a given service. This marginal return is common across services.¹ We assume $\delta \in (0, 1)$ so that hours spent seeing patients increase output (services) at a decreasing rate.

3.1.2 Physician's problem

Physician utility is defined over consumption M , pure leisure, denoted by l_p , and "on-the-job" leisure, l_o . The latter includes all those activities at work except seeing patients or providing services (clinical work), such as teaching, research and administrative tasks, that are not remunerated under a FFS scheme. It may seem rather strange to call these activities "leisure", however, since such activities do not increase income, it is reasonable to assume that they increase utility.² Physician preferences are assumed to be CES which is general enough to permit unrestricted responses to incentives, yet parsimonious in parameters, allowing for simple and direct interpretations of the results.

$$U(M, l_o, l_p) = (M^\rho + l_o^\rho + l_p^\rho)^{\frac{1}{\rho}}. \quad (3.2)$$

1. Allowing the marginal return to be heterogeneous will be an interesting extension. That is, the technology will be $A_i = h_i^{\delta_i}$, where the δ_i is the marginal return to time spent to produce the service i and will be estimated for each service.

2. For instance, performing teaching or research activities may increase the physician influence and prestige.

Here $l_o = h_t - h_s$, h_t is total hours spent at work and h_s , denotes time spent providing services. The pure leisure is $l_p = T - h_t$ with T the maximum amount of time available, and $-\infty < \rho < 1$. We allow pure leisure and "on-the-job" leisure to be substitutes. The budget constraint is given by

$$M = \alpha_1 A_1 + \alpha_2 A_2 + y, \quad (3.3)$$

where α_i represents the fee paid for service A_i and y is the non-labour income. Substituting (3.3) into (3.2), imposing $h_s = h_1 + h_2$ and taking account of the definition of the leisure, we can rewrite the utility function as

$$U(h_1, h_s, h_t) = \left((\alpha_1 h_1^\delta + \alpha_2 (h_s - h_1)^\delta + y)^\rho + (h_t - h_s)^\rho + (T - h_t)^\rho \right)^{\frac{1}{\rho}}. \quad (3.4)$$

The physician chooses total hours worked, h_t , clinical hours, h_s as well as hours devoted to each service h_1 and h_2 to maximize utility. This problem can be solved in three steps. First, fixing h_t and h_s the physician chooses h_1 and h_2 to maximize income. The first-order condition for the choice of h_1 is

$$\alpha_1 h_1^{\delta-1} - \alpha_2 (h_s - h_1)^{\delta-1} = 0, \quad (3.5)$$

or

$$h_1(h_s) = \frac{P_1}{P_1 + P_2} h_s, \quad (3.6)$$

where $P_j = \alpha_j^{1/(1-\delta)}$; $j = 1, 2$. As we have imposed $h_s = h_1 + h_2$, the optimal choice of hours devoted to service 2 is

$$h_2(h_s) = \frac{P_2}{P_1 + P_2} h_s. \quad (3.7)$$

Substituting $h_1(h_s)$ into (3.4) gives (indirect) utility as a function of h_s and h_t

$$V(h_t, h_s) = \left((\omega h_s^\delta + y)^\rho + (h_t - h_s)^\rho + (T - h_t)^\rho \right)^{\frac{1}{\rho}}. \quad (3.8)$$

Here $\omega = [P_1 + P_2]^{1-\delta}$, determines the marginal return to an hour worked when that hour is optimally allocated across services. Maximizing (3.8) with respect to h_t gives the following first-order condition :

1. Note that this budget constraint account for FFS contract. An interesting extension of the model will be to have a budget constraint general enough to account for both FFS and Mixed remuneration contracts.

$\frac{\partial V(\cdot)}{\partial h_t} = (h_t - h_s)^{\rho-1} - (T - h_t)^{\rho-1} = 0$, or $h_t(h_s) = \frac{T+h_s}{2}$. Finally, substituting $\hat{h}_t(h_s)$ into (3.8) gives (indirect) utility as a function of h_s

$$W(h_s) = \left((\omega h_s^\delta + y)^\rho + 2^{1-\rho} (T - h_s)^\rho \right)^{\frac{1}{\rho}}. \quad (3.9)$$

Here $T - h_s = l_p + l_o$ is the total leisure. The first-order condition for utility maximization in the choice of h_s is

$$\frac{\partial W(h_s)}{\partial h_s} = \omega \delta h_s^{\delta-1} (\omega h_s^\delta + y)^{\rho-1} - 2^{1-\rho} (T - h_s)^{\rho-1} = 0. \quad (3.10)$$

The second-order condition is

$$\begin{aligned} W_{h_s h_s} &= \omega \delta (\delta - 1) h_s^{\delta-2} (\omega h_s^\delta + y)^{\rho-1} + (\rho - 1) (\omega \delta h_s^{\delta-1})^2 (\omega h_s^\delta + y)^{\rho-2} \\ &\quad + 2^{1-\rho} (\rho - 1) (T - h_s)^{\rho-2} < 0. \end{aligned} \quad (3.11)$$

This inequality holds for all $0 < h_s < T$ given $0 < \delta < 1$ and $\rho < 1$. From (3.10) it is not possible to write an explicit functional form for the optimal hours h_s . But, by the implicit function theorem (3.10) gives a implicit form of h_s that depends on prices (ω) and on non-labour income y .

Let

$$F(h_s, \alpha_1, \alpha_2, y) = \omega \delta h_s^{\delta-1} (\omega h_s^\delta + y)^{\rho-1} - 2^{1-\rho} (T - h_s)^{\rho-1} \quad (3.12)$$

and note that optimal \hat{h}_s solves

$$F(\hat{h}_s, \alpha_1, \alpha_2, y) = 0; \quad (3.13)$$

$$\frac{\partial F(\hat{h}_s, \alpha_1, \alpha_2, y)}{\partial \hat{h}_s} < 0. \quad (3.14)$$

By the implicit function theorem, there exists a real valued function ψ continuously differentiable on a neighborhood of $(\hat{h}_s, \alpha_1, \alpha_2, y)$; such that

$$\hat{h}_s = \psi(\alpha_1, \alpha_2, y). \quad (3.15)$$

Furthermore,

$$\frac{d\hat{h}_s}{d\alpha_1} = - \frac{\frac{\partial F}{\partial \alpha_1}}{\frac{\partial F}{\partial \hat{h}_s}}, \quad (3.16)$$

$$\frac{d\hat{h}_s}{d\alpha_2} = - \frac{\frac{\partial F}{\partial \alpha_2}}{\frac{\partial F}{\partial \hat{h}_s}}, \quad (3.17)$$

and,

$$\frac{d\hat{h}_s}{dy} = -\frac{\frac{\partial F}{\partial y}}{\frac{\partial F}{\partial \hat{h}_s}}. \quad (3.18)$$

The optimal choices of \hat{h}_1 , \hat{h}_2 and the ensuring quantities \hat{A}_1 and \hat{A}_2 satisfy

$$\hat{h}_s = \psi(\alpha_1, \alpha_2, y); \quad (3.19)$$

$$\hat{h}_t = \frac{T + \hat{h}_s}{2}; \quad (3.20)$$

$$\hat{h}_1 = \frac{P_1}{P_1 + P_2} \hat{h}_s; \quad (3.21)$$

$$\hat{h}_2 = \frac{P_2}{P_1 + P_2} \hat{h}_s; \quad (3.22)$$

$$\hat{A}_1 = \hat{h}_1^\delta; \quad (3.23)$$

$$\hat{A}_2 = \hat{h}_2^\delta. \quad (3.24)$$

3.1.3 Theoretical predictions

We are interested in the change in optimal behaviour described by (3.19) to (3.24) as non-labour income and different service prices are changed. The impact of a change in each exogenous variable α_1, α_2 and y on h_s, h_t, h_i and A_i ($i = 1, 2$) is obtained using comparative static techniques. We differentiated each expression with respect to α_1, α_2 and y and calculated $\frac{dk}{d\alpha_i}$ and $\frac{dk}{dy}$ ($k = h_s, h_t, h_i, A_i$), the effect of change in α_i and y respectively on k . These are then converted into elasticity terms, expressing the percentage change in hours or quantities supplied in terms of the percentage change in the price or non-labour income: $\zeta_{k/\alpha_i} = \frac{\alpha_i}{k} \frac{dk}{d\alpha_i}$ or $\zeta_{k/y} = \frac{y}{k} \frac{dk}{dy}$. These elasticities are given in Appendix A. With these elasticities it is possible to examine how the practice variables change with respect to non-labour income, and fees per service. The relevant formulas for elasticities and their signs are shown in Table 3.1.

Changes in non-labor income

Table 3.1 shows that the income effect on practice variables are negative because clinical hours have diminishing marginal utility of hours worked as, $W_{h_s h_s} < 0$ ¹ due to the second

1. Note that, $F_{\hat{h}_s} = W_{h_s h_s}$.

TABLE 3.1 – Income, own and cross-price elasticities of physician labor supply

	Elasticity	Sign
Change in non-labor income		
Income elasticity, h_s	$\zeta_{h_s/y} = \frac{(1-\rho)\delta\omega y h_s^{\delta-2} M^{\rho-2}}{W_{hs} h_s}$	(-)
Income elasticity, h_t	$\zeta_{h_t/y} = \frac{h_s}{T+h_s} \zeta_{h_s/y}$	(-)
Income elasticity, h_i	$\zeta_{h_i/y} = \zeta_{h_s/y}$	(-)
Income elasticity, A_i	$\zeta_{\hat{A}_i/y} = \delta \zeta_{h_s/y}$	(-)
Change in price		
Price elasticity, h_s	$\zeta_{h_s/\alpha_i} = -\frac{\delta\alpha_i A_i M^{\rho-1}}{h_s^2 W_{hs} h_s} + \frac{\alpha_i A_i}{y} \zeta_{h_s/y}$	(unsigned)
Price elasticity, h_t	$\zeta_{h_t/\alpha_i} = \frac{h_s}{T+h_s} \zeta_{h_s/\alpha_i}$	(unsigned)
Own-price elasticity, h_i	$\zeta_{h_i/\alpha_i} = \left[\frac{1}{(1-\delta)} \frac{P_j}{P_i+P_j} - \frac{\delta\alpha_i A_i M^{\rho-1}}{h_s^2 W_{hs} h_s} \right] + \frac{\alpha_i A_i}{y} \zeta_{h_i/y}$	(unsigned)
Own-price elasticity, A_i	$\zeta_{A_i/\alpha_i} = \delta \zeta_{h_i/\alpha_i}$	(unsigned)
Cross-price elasticity, h_i	$\zeta_{h_i/\alpha_j} = -\left[\frac{1}{(1-\delta)} \frac{P_j}{P_i+P_j} + \frac{\delta\alpha_j A_j M^{\rho-1}}{h_s^2 W_{hs} h_s} \right] + \frac{\alpha_j A_j}{y} \zeta_{h_i/y}$	(unsigned)
Cross-price elasticity, A_i	$\zeta_{A_i/\alpha_j} = \delta \zeta_{h_i/\alpha_j}$	(unsigned)
Note : $i \neq j \in \{1, 2\}$		

order condition. We note from (3.20) to (3.24) that income effects are present in total hours worked, hours spent for each service, and the quantity of services through clinical hours. In fact, when y increases a physician will increase her/his time enjoyed outside work (pure leisure) since it is a normal good. Consequently, she/he would reduce his or her total time spent at work ($\zeta_{h_t/y} < 0$). Recalling that $h_t = h_s + l_o$ and that on-the-job leisure, l_o , is a normal good, the rise of y will increase l_o and decrease h_t . Therefore the clinical hours will decline significantly to make the global income effect on total hours worked negative, so that $|\zeta_{h_s/y}| > |\zeta_{h_t/y}|$.

The non-labor income elasticities terms are the same for clinical hours and hours devoted to each service. When non-labor income increases both clinical hours and hours devoted to each service decrease by the same percentage. This is because the marginal return to time

spent by the physician to produce a service, δ is common across the services. The decrease in hours spent seeing patients leads to a decrease in the quantities of services provided. However this reduction is smaller in absolute value than that of the clinical hours.

Changes in fees : Own and cross-price elasticities

In our model physicians choose their total hours spent at work, their total amount of time allocated to providing medical services and how to allocate that time across different services. This creates both substitution and income effects when fees change. The income effects is generated by the change in time spent at work after the fees change. In fact, a change in relative fees alters the return to hours worked, hence hours adjusts leading to an increase in income for a given level of services. The relevant equations for own and cross price elasticities are :

$$\zeta_{h_i/\alpha_i} = \underbrace{\left[\frac{1}{(1-\delta)} \frac{P_j}{P_i + P_j} - \frac{\delta \alpha_i \hat{A}_i M^{\rho-1}}{h_s^2 W_{h_s h_s}} \right]}_{\text{Substitution effect}} + \underbrace{\frac{\alpha_i A_i}{y} \zeta_{h_i/y}}_{\text{Income effect}} \quad (3.25)$$

$$\zeta_{h_j/\alpha_i} = - \underbrace{\left[\frac{1}{(1-\delta)} \frac{P_i}{P_i + P_j} + \frac{\delta \alpha_i A_i M^{\rho-1}}{h_s^2 W_{h_s h_s}} \right]}_{\text{Substitution effect}} + \underbrace{\frac{\alpha_i A_i}{y} \zeta_{h_j/y}}_{\text{Income effect}} \quad (3.26)$$

$$\zeta_{A_i/\alpha_i} = \delta \zeta_{h_i/\alpha_i} \quad (3.27)$$

$$\zeta_{A_j/\alpha_i} = \delta \zeta_{h_j/\alpha_i} \quad (3.28)$$

The signs of these derivatives are ambiguous due to income effects. Thus, it cannot be said *ex ante* whether hours devoted to a service or its quantity will increase, decrease or remain the same following a change in its price or the price of another service. In equation (3.25) the first term represents the global substitution effect which is positive¹ and the second term represents the income effect which is negative. Examining equation (3.26) reveals that the the global substitution effect of the cross-price elasticity is unsigned since $\frac{1}{(1-\delta)} \frac{P_i}{P_i + P_j} > 0$ and $\frac{\delta \alpha_i A_i M^{\rho-1}}{h_s^2 W_{h_s h_s}} < 0$.

3.2 Model with Multiple services

In this section, we are generalized our model to allow for n services. We assume that each physician is trained to perform a fixed number of services. This implies that n is fixed. We

1. $W_{h_s h_s}$ is negative and $\delta \in (0, 1)$.

write physician's problem as

$$\text{Max } U(M, h_t, h_s) = (M^\rho + l_o^\rho + l_p^\rho)^{\frac{1}{\rho}} \quad (3.29)$$

subject to

$$M = \sum_{i=1}^n \alpha_i A_i + y \quad (3.30)$$

$$A_i = h_i^\delta, \quad \forall i \quad (3.31)$$

$$h_s = \sum_{i=1}^n h_i, \quad T = h_t + l_p, \quad h_t = l_o + h_s \quad (3.32)$$

where A_i is the volume of service type i , h_i is hours of work devoted to produce service i at the price α_i and δ represent the marginal return to time spent by the physician to produce a service. h_t is total hours spent at work and h_s represents clinical hours. M represents consumption. Equation (3.30) is the budget constraint; (3.31) represents the technology and (3.32) the time constraint.

The physician's problem is to choose $\{h_i\}_{i=1,\dots,n}$, h_t and h_s . As in the 2 services case, we solve this problem in three steps. First we fix h and solve for $\{h_i\}_{i=1,\dots,n}$.

Using equations (3.30) to (3.32), we can write the utility function as

$$U(h_1, h_2, \dots, h_{n-1}, h_t, h_s) = \left[\left(\sum_{i=1}^{n-1} \alpha_i h_i^\delta + \alpha_n (h_s - h_1 - h_2 - \dots - h_{n-1})^\delta + y \right)^\rho + (h_t - h_s)^\rho + (T - h_t)^\rho \right]^{\frac{1}{\rho}}.$$

The first-order conditions are

$$\alpha_i h_i^{\delta-1} - \alpha_n (h_s - h_1 - h_2 - \dots - h_{n-1})^{\delta-1} = 0 \quad \forall i \in [1; n-1]. \quad (3.33)$$

We solve for the optimal choice of $\{\hat{h}_i\}_{i=1,\dots,n}$ from (8.3). This gives

$$h_i = \frac{\alpha_1^{\frac{1}{\delta-1}}}{\alpha_i^{\frac{1}{\delta-1}}} h_1 \quad \forall i \in 2, 3, \dots, n-1. \quad (3.34)$$

Substituting h_i into the first-order condition for service 1, we get

$$h_1 = \frac{P_1}{D} h_s, \quad (3.35)$$

where $D = \sum_{i=1}^n P_i$ and $P_i = \alpha_i^{\frac{1}{1-\delta}}$, $\forall i$.

Finally, (3.30) and (3.31) give

$$h_i = \frac{P_i}{D} h_s \quad \forall i \in [1, n-1]. \quad (3.36)$$

Recall that the time constraint gives $h_n = h_s - \sum_{i=1}^{n-1} h_i$. It then follows

$$h_n = \frac{P_n}{D} h_s.$$

The physician's optimal choice of hours devoted to the service i with a given clinical hours h_s is given by

$$h_i = \frac{P_i}{D} h_s \quad \forall i \in [1, n]$$

In the second step we substitute h_i into (8.3) to find the indirect utility function

$$V(h_t, h_s) = \left[(wh_s^\delta + y)^\rho + (h_t - h_s)^\rho + (T - h_t)^\rho \right]^{\frac{1}{\rho}}. \quad (3.37)$$

Where

$$w = \left(\sum_{i=1}^n \alpha_i^{\frac{1}{1-\delta}} \right)^{1-\delta}$$

Holding h_s constant, we maximize (3.37) with respect to h_t . The first-order condition is

$$\frac{\partial V(\cdot)}{\partial h_t} = (h_t - h_s)^{\rho-1} - (T - h_t)^{\rho-1} = 0 \quad (3.38)$$

solving (3.38) for h_t gives $h_t(h_s) = \frac{T+h_s}{2}$.

The third step consists of substituting $h_t(h_s)$ into (3.37) to obtain utility as a function of h_s

$$W(h_s) = \left[(wh_s^\delta + y)^\rho + 2^{1-\rho} (T - h_s)^\rho \right]^{\frac{1}{\rho}}.$$

This indirect utility function allows us to choose the optimal clinical hours h_s using the following equation

$$\frac{\partial W(h_s)}{\partial h_s} = w\delta h_s^{\delta-1} (wh_s^\delta + y)^{\rho-1} - 2^{1-\rho} (T - h_s)^{\rho-1} = 0,$$

which defines h_s implicitly, as in two services case.

The optimal choices of the physician in multiple services model are :

$$\hat{h}_s = \Phi(\alpha_1, \dots, \alpha_n, y); \quad (3.39)$$

$$\hat{h}_t = \frac{T + \hat{h}_s}{2}; \quad (3.40)$$

$$\hat{h}_i = \frac{P_i}{\sum_{j=1}^n P_j} \hat{h}_s, \quad \forall i \in [1, n]; \quad (3.41)$$

$$\hat{A}_i = \hat{h}_i^\delta, \quad \forall i \in [1, n]. \quad (3.42)$$

The comparative statics of this model give the same predictions as in 2 services case.

Chapitre 4

Aggregation and Variable Construction

Recall that the data cover a period during which the Quebec government has changed the relative prices of medical acts. We use these changes to aggregate services and render the model empirically tractable. This provides six groups of services, whose prices increased by 0, 5, 10, 15, 20 and 25 percent.¹

4.1 Aggregation

To aggregate services we use the Hicks composite commodity theorem. This theorem states that ... *if a group of prices move in parallel, then the corresponding group of commodities can be treated as a single good*².

Assume that there are n services that can be provided by a physician. The vector of services quantities is given by (A_1, A_2, \dots, A_n) and the associated price vector is $(\alpha_1, \alpha_2, \dots, \alpha_n)$. The physicians' utility is CES and is given by (8.3) with constraints (3.30), (3.1) and (3.32). To fix ideas consider the case where n equals 3, and suppose that the prices for services 2 and 3 change in the same proportion $\theta > 0$ with respect to some base period ($t = 0$) prices α_2^0 and α_3^0 . Then prices for any period t can be written as follows :

$$\alpha_{2t} = \theta_t \alpha_2^0, \quad \alpha_{3t} = \theta_t \alpha_3^0.$$

The relative price of services 2 and 3 is constant between the period of interest and the base

1. The aggregate is the income generated by the supply of those services. It can be treated as one service because the relative price of all its constituent individual services is constant.

2. Deaton and Muellbauer [5, p. 121]

period, because

$$\frac{\alpha_2^0}{\alpha_3^0} = \frac{\alpha_{2t}}{\alpha_{3t}}.$$

Now consider the case with $n > 3$ services and $q < n$ different changes in services fees. Let $\theta_1, \theta_2, \dots, \theta_q$ denote changes in fees and Θ_i the set of services with the same change in price in proportion θ_i , where $i \in \{1, 2, \dots, q\}$.

Proposition : If (A_1, A_2, \dots, A_n) solves (8.3) s.t (3.30), (3.1) and (3.32) then medical acts can be aggregated in $q < n$ groups of services. The aggregate quantity vector is $(\sum_{i \in \Theta_1} \alpha_i^0 A_i, \sum_{i \in \Theta_2} \alpha_i^0 A_i, \dots, \sum_{i \in \Theta_q} \alpha_i^0 A_i)$ and the associated price vector is $(\theta_1, \theta_2, \dots, \theta_q)$.

Proof : Recall that the indirect utility function is $V(w, y) = [(wh_s^\delta + y)^\rho + (h_t - h_s)^\rho + (T - h_t)^\rho]^\frac{1}{\rho}$, where $w = \left(\sum_{i=1}^n \alpha_i^{\frac{1}{1-\delta}} \right)^{1-\delta}$. The expenditure function $e(w, u^0)$, is the amount of non labor income needed to set to $V(w, e(w, u^0)) = u^0$. That gives

$$\begin{aligned} (wh_s^\delta + e(w, u^0))^\rho + (h_t - h_s)^\rho + (T - h_t)^\rho &= u^0 \\ (wh_s^\delta + e(w, u^0))^\rho &= u^0 - (h_t - h_s)^\rho - (T - h_t)^\rho \\ wh_s^\delta + e(w, u^0) &= (u^0 - (h_t - h_s)^\rho - (T - h_t)^\rho)^{1/\rho} \\ e(w, u^0) &= (u^0 - (h_t - h_s)^\rho - (T - h_t)^\rho)^{1/\rho} - wh_s^\delta \end{aligned}$$

Taking the derivative with respect to θ_i (conditional on h_t and h_s), we have

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

The derivative of w with respect to θ_i is

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

where

$$D = \sum_{i \in \Theta_1} (\theta_1 \alpha_i^0)^{\frac{1}{1-\delta}} + \sum_{i \in \Theta_2} (\theta_2 \alpha_i^0)^{\frac{1}{1-\delta}} + \dots + \sum_{j \in \Theta_i} (\theta_i \alpha_j^0)^{\frac{1}{1-\delta}} + \dots + \sum_{i \in \Theta_q} (\theta_q \alpha_i^0)^{\frac{1}{1-\delta}}$$

But from (3.36), $h_j = \frac{\alpha_j^{\frac{1}{1-\delta}}}{D} h_s$.

Therefore,

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

or,

$$-\frac{de}{d\theta_i} = \sum_{j \in \Theta_i} \alpha_j^0 A_j, \text{ total revenue from services in } \Theta_i.$$

By Shephard's lemma the composite service quantity is defined as the sum of individual quantities weighted by base-period prices. Its price is the relative price θ •

4.1.1 Aggregating services

We created 6 groups of services depending on the rate at which their prices change between the years 2000 and 2002. The composite services volume and its price are calculated in the data as follows.

Let α_j^t be the price of service j at 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 denote θ as the geometric average rate of growth of the price of service j between 2000 and 2002. We have $\theta = \left(\frac{\alpha_j^{2002}}{\alpha_j^{2000}} \right)^{0.5} - 1$.

Suppose that there are $m > 2$ services for which prices increased by θ between 2000 and 2002. The composite service volume is calculated as, $\sum_{j=1}^m \alpha_j^{2000} A_{ij}^t$, where A_{ij}^t is the number of services j performed by physician i at time t . The price of this composite service is $\theta + 1$.

TABLE 4.1 – Distribution of composite services

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

The distribution of composite services is presented in Table 4.1. Our composite service 1 is an aggregation of medical acts for which the price remained constant for the whole sample period. This first group contains 59.38% of services . The composite service 2 contains services

whose prices increased by 5% between 2000 and 2002. This amounts to 29.17% of services. Composite service 3 contains services whose prices rose by 10% and represents 7.3% of services. The composite service 4 is the group of medical services whose prices increased by 15%. This represents 2.08% of services. The composite service 5 represents services whose prices increased by 20%. It represents 1% of services. The composite service 6 represents services whose prices increased by 25%. It represents 1% of services. The nominal price of each service is calculated by adding 1 to the percent increase. These prices are then translated into real terms by dividing by the price index of health care services.¹

4.2 Variable construction

4.2.1 Earnings

Physician's earnings are calculated as the sum of (aggregate) services provided times the price of those services. In our sample each physician did not necessarily provide the same type of services, nor did they perform each of the 6 types of service. We take the aggregate services provided by a given physician as fixed.² We separate physicians into groups according to the set of medical services provided. This gives us 3 disjoint groups of physicians.³

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 specialties Endocrinology, Otorhinolaryngology, Gastroenterology, and Cardiology. G_{13} is made up of neurologists who supplied services 1 and 3. Earnings for specialist s in G_2 are calculated as

$$E_s = \alpha_1 A_{1s} + \alpha_2' A_{2's}, \quad (4.1)$$

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

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

The subgroup G_{125} contains physicians who provided services 1, 2 and 5. It is made up of pediatricians. G_{126} represents physicians who offered services 1, 2 and 6. It is made up of

1. <http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/econ161f-eng.htm>

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

3. Grouping physicians avoids censored data that would arise from physicians not providing some services. It is possible from the assumption that the number of services that each physician provides is fixed.

internal medicine physicians. Earnings for each specialist s in this case is computed as

$$E_s = \alpha_1 A_{1s} + \alpha_2 A_{2s} + \alpha_{3'} A_{3's} \quad (4.2)$$

where

$$\begin{aligned} \alpha_{3'} &= \alpha_3 \mathbb{1}_{G_{123}}(s) + \alpha_5 \mathbb{1}_{G_{125}}(s) + \alpha_6 \mathbb{1}_{G_{126}}(s) \\ A_{3's} &= A_3 \mathbb{1}_{G_{123}}(s) + A_5 \mathbb{1}_{G_{125}}(s) + A_6 \mathbb{1}_{G_{126}}(s) \end{aligned}$$

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

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

$$E_s = \alpha_1 A_{1s} + \alpha_2 A_{2s} + \alpha_4 A_{4s} + \alpha_{4'} A_{4's}, \quad (4.3)$$

where

$$\begin{aligned} \alpha_{4'} &= \alpha_3 \mathbb{1}_{G_{1234}}(s) + \alpha_5 \mathbb{1}_{G_{1245}}(s) \\ A_{4's} &= A_3 \mathbb{1}_{G_{1234}}(s) + A_5 \mathbb{1}_{G_{1245}}(s) \end{aligned}$$

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

4.2.2 Descriptive Statistics

Table 4.2 shows summary statistics on the personal characteristics of physicians before and after the sample reduction. We report statistics separately for all physicians, the FFS physicians' set and for the sampled data set. The first column presents statistics from all physicians. In the complete sample, 76% of physicians are male and 83% are francophone. Age is classified into 10 groups.¹ The average value is 5.04 meaning that the average age is between 45 and 49 years old. Statistics for FFS physician show a similar characteristics, as do the statistics for the sampled physicians.

1. There are 10 groups of age ranked from 1 to 10. The value 1 means 30 years old and less and the value 10 means 70 years old and more.

TABLE 4.2 – Descriptive statistics : Personal Characteristics of physicians before and after the sample reduction

	All Physicians		FFS physicians		Sampled physicians	
	mean	sd	mean	sd	mean	sd
Male	0.76	0.43	0.80	0.40	0.84	0.37
Language (French=1)	0.83	0.38	0.81	0.40	0.80	0.40
Age	5.04	2.12	5.24	2.14	5.47	1.95
Number of physicians	5,904	-	4,012	-	1,231	-
Number of observations	965,822	-	637,544	-	8,119	-

In Table 4.3, we provide descriptives statistics on the supply of services and hours worked. We note that the variation (before and after fees rise) in average volume of services depends on the number of services provided. In fact, G_2 physicians increased services 1 and 2 by 1.2% and 16.55% respectively, but the volume of service 3 remains largely unchanged. Concerning the 3 services, we note that after the fee increase physicians sharply increased their supply of services 5 and 6, for which fees increased greatly. For service 5, for which the fee increase by 20%, the average volume went from 5.82 thousand \$ to 6.98 thousand \$, an increase of 20%. Similarly service 6, for which the fee increased by 25%, volume has risen by 39%. With 4 service providers things are quiet similar. They reduced the volume of services for which fee increase were low or moderate (services 1, 2 and 3) and increased the volume of services for which fee increases much high (services 4 and 5).

Table 4.3 also shows that subsequent to the fee increase, physicians earned higher incomes (20.4% for those who gave 2 services , 5% for G_3 and 13.7% for G_4), and worked, on average, slightly fewer hours per week than they did the period before 2000. This is consistent with income effects. Physicians spend part of the fee increase on consuming extra leisure.

TABLE 4.3 – Descriptive statistics : Supply of services and hours worked

	Price rise (%)	2 services		3 services		4 services	
		Before	After	Before	After	Before	After
		mean (sd)	mean (sd)	mean (sd)	mean (sd)	mean (sd)	mean (sd)
Volume Serv.1	0	9.46 (13.30)	9.57 (14.38)	47.62 (46.84)	48.50 (47.98)	7.12 (11.05)	6.34 (10.37)
Volume Serv.2	5	82.69 (57.32)	96.38 (65.16)	55.86 (66.56)	55.56 (70.76)	21.02 (13.05)	19.22 (12.74)
Volume Serv.3	10	36.98 (25.58)	36.96 (25.47)	85.01 (37.58)	84.43 (35.06)	43.16 (24.36)	35.62 (20.60)
Volume Serv.4	15	- -	- -	- -	- -	23.05 (18.45)	25.94 (19.76)
Volume Serv.5	20	- -	- -	5.82 (5.55)	6.98 (7.91)	18.54 (11.10)	18.58 (9.18)
Volume Serv.6	25	- -	- -	2.33 (2.35)	3.24 (3.05)	- -	- -
Earnings		86.30 (65.18)	103.95 (77.59)	142.97 (67.99)	150.19 (76.28)	80.20 (28.19)	91.16 (33.82)
Total Hours worked		54.08 (10.59)	52.62 (11.33)	51.85 (10.69)	51.39 (11.26)	56.04 (9.93)	54.45 (13.42)
Clinical hours		44.61 (11.65)	43.49 (12.58)	42.77 (11.44)	43.18 (12.05)	47.27 (10.70)	46.67 (13.62)

Chapitre 5

Presentation of the empirical model

5.1 Empirical Model with two services

We consider an empirical version of the model developed in Chapter 3. Production of service j is assumed to be a function of hours devoted to it h_j , a service specific parameter b_j and a production shock ϵ_j . The production shock captures random elements that affect the time spent per service. These include variation in the complexity of particular cases, variation in the functioning of equipment needed to perform services and elements that are specific to the physician, such as random variation his or her health. The output of a physician in service j is now

$$A_j = b_j h_j^\delta \epsilon_j, \quad (5.1)$$

where δ represents the service specific marginal return to time spent by the physician to provide service $j = 1, 2$. When a physician provides 2 services, this means he/she performs service 1 and either service 2 or service 3. Let

$$D_2 = \begin{cases} 1 & \text{if physician perform service 2} \\ 0 & \text{otherwise} \end{cases} \quad (5.2)$$

Utility of a physician is given by

$$U = \left[\left(\alpha_1 b_1 h_1^\delta \epsilon_1 + D_2 \alpha_2 b_2 h_2^\delta \epsilon_2 + (1 - D_2) \alpha_3 b_3 h_3^\delta \epsilon_3 + y \right)^\rho + (h_t - h_s)^\rho + (T - h_t)^\rho \right]^{\frac{1}{\rho}}, \quad (5.3)$$

where

$$h_1 + D_2 h_2 + (1 - D_2) h_3 = h_s. \quad (5.4)$$

The timing of events in our model is as follows :

1. For service 1, 2 and 3, nature chooses ϵ_1 , ϵ_2 and ϵ_3 , where $\ln \epsilon_j \sim N(0, 1)$;

2. The physician observes ϵ_1, ϵ_2 and ϵ_3 and chooses h_1, h_2 and h_3 conditional on clinical hours h_s ;
3. The physician chooses h_t (and pure leisure) conditional on clinical hours h_s ;
4. The physician chooses h_s and receives his/her payment.

We solve the model in three steps. We maximize utility in (5.3) with respect to h_1 and h_t conditional on h_s . The first-order condition for h_1 is

$$\alpha_1 b_1 h_1^\delta \epsilon_1 - D_2 \alpha_2 b_2 (h_s - h_1)^\delta \epsilon_2 - (1 - D_2) \alpha_3 b_3 (h_s - h_1)^\delta \epsilon_3 = 0 \quad (5.5)$$

Conditional on clinical hours h_s , the optimal time spent providing service 1 can be derive from (5.5)

$$h_1(h_s) = \begin{cases} \frac{\tilde{P}_1}{\tilde{P}_1 + \tilde{P}_2} h_s, & \text{if } D_2 = 1; \\ \frac{\tilde{P}_1}{\tilde{P}_1 + \tilde{P}_3} h_s & \text{otherwise;} \end{cases} \quad (5.6)$$

where $\tilde{P}_j = (\alpha_j b_j \epsilon_j)^{\frac{1}{1-\delta}}$, $j = 1, 2, 3$ represents a random price. Substituting equilibrium hours devoted to service 1 into equation (5.4) gives the following optimal amount of time devoted to service 2 and 3

$$h_2(h_s) = \begin{cases} \frac{\tilde{P}_2}{\tilde{P}_1 + \tilde{P}_2} h_s, & \text{if } D_2 = 1; \\ 0 & \text{otherwise;} \end{cases} \quad (5.7)$$

$$h_3(h_s) = \begin{cases} \frac{\tilde{P}_3}{\tilde{P}_1 + \tilde{P}_3} h_s, & \text{if } D_2 = 0; \\ 0 & \text{otherwise} \end{cases} \quad (5.8)$$

Fixing h_s , the first-order condition for h_t is

$$(h_t - h_s)^{\rho-1} - (T - h_t)^{\rho-1} = 0, \quad (5.9)$$

and from (5.9) we get

$$h_t(h_s) = \frac{T + h_s}{2}. \quad (5.10)$$

That is, total hours worked h_t and hours devoted to provide each service depend on clinical hours h_s . Thus, substituting them back into (5.3) gives an indirect utility as a function of h_s

$$V(h_s) = \left[\left[(\tilde{P}_1 + D_2 \tilde{P}_2 + (1 - D_2) \tilde{P}_3)^{1-\delta} h_s^\delta + y \right]^\rho + 2^{1-\rho} [T - h_s]^\rho \right]^{\frac{1}{\rho}}. \quad (5.11)$$

Recall that $\tilde{w} = (\tilde{P}_1 + D_2 \tilde{P}_2 + (1 - D_2) \tilde{P}_3)^{1-\delta}$ determines the marginal return to an hour worked when that hour is optimally allocated across services. The physician's optimal hours spent seeing patients solves

$$\tilde{w} \delta h_s^{\delta-1} (\tilde{w} h_s^\delta + y)^{\rho-1} - 2^{1-\rho} (T - h_s)^{\rho-1} = 0 \quad (5.12)$$

5.1.1 Simplifying Assumptions

We assume common shocks in our analysis. That is, we focus on random elements that are specific to the physician, such as health. That means $\epsilon_1 = \epsilon_2 = \epsilon_3 = \epsilon$. This implies

$$h_1(h_s) = \begin{cases} \frac{P_1}{P_1 + P_2} h_s, & \text{if } D_2 = 1; \\ \frac{P_1}{P_1 + P_3} h_s & \text{otherwise;} \end{cases} \quad (5.13)$$

$$h_2(h_s) = \begin{cases} \frac{P_2}{P_1 + P_2} h_s, & \text{if } D_2 = 1; \\ 0 & \text{otherwise;} \end{cases} \quad (5.14)$$

$$h_3(h_s) = \begin{cases} \frac{P_3}{P_1 + P_3} h_s, & \text{if } D_2 = 0; \\ 0 & \text{otherwise} \end{cases} \quad (5.15)$$

for $P_j = (b_j \alpha_j)^{\frac{1}{1-\delta}}$ $j = 1, 2, 3$ and substituting equation 5.13, 5.14 and 5.15, respectively, in equation 5.1 gives the optimal quantity of services as a function of h_s and ϵ

$$A_1(h_s, \epsilon) = \begin{cases} b_1 \left[\frac{P_1}{P_1 + P_2} \right]^\delta h_s^\delta \epsilon, & \text{if } D_2 = 1; \\ b_1 \left[\frac{P_1}{P_1 + P_3} \right]^\delta h_s^\delta \epsilon & \text{otherwise;} \end{cases} \quad (5.16)$$

$$A_2(h_s, \epsilon) = \begin{cases} b_2 \left[\frac{P_2}{P_1 + P_2} \right]^\delta h_s^\delta \epsilon, & \text{if } D_2 = 1; \\ 0 & \text{otherwise;} \end{cases} \quad (5.17)$$

$$A_3(h_s, \epsilon) = \begin{cases} b_3 \left[\frac{P_1}{P_1 + P_3} \right]^\delta h_s^\delta \epsilon, & \text{if } D_2 = 0; \\ 0 & \text{otherwise} \end{cases} \quad (5.18)$$

Substituting into the utility function in (5.3) gives

$$V(h_t, h_s) = \left[(wh_s^\delta \epsilon + y)^\rho + (h_t - h_s)^\rho + (T - h_t)^\rho \right]^{\frac{1}{\rho}}. \quad (5.19)$$

Maximizing (5.19) for h_t , conditional to h_s , we obtain

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

Finally, the indirect utility depends on h_s and the production shock ϵ by

$$V(h_s, \epsilon) = \left[(wh_s^\delta \epsilon + y)^\rho + 2^{1-\rho}(T - h_s)^\rho \right]^{\frac{1}{\rho}}, \quad (5.20)$$

with $w = (P_1 + D_2 P_2 + (1 - D_2) P_3)^{1-\delta}$. Note that the price index w is now independent of ϵ . Maximizing indirect utility implies that optimal h_s solves

$$w\delta h_s^{\delta-1} \epsilon (wh_s^\delta \epsilon + y)^{\rho-1} - 2^{1-\rho}(T - h_s)^{\rho-1} = 0. \quad (5.21)$$

The optimal h_s depends on ϵ , w and y .

Given optimal quantities of services in (5.16), (5.17) and (5.18), it is straightforward to derive an estimable earnings equation. Recalling that all physicians here are practising under FFS, the expected earnings of a physician providing 2 services depends on price index, w , clinical hours work, h_s and the production shock, ϵ

$$\text{Earnings} = \alpha_1 A_1 + D_2 \alpha_2 A_2 + (1 - D_2) \alpha_3 A_3; \quad (5.22)$$

$$= wh_s^\delta \epsilon; \quad (5.23)$$

That is, we have two equations in interest, the (log) earnings function which measures the ability of physicians to produce services at different relative prices and an equation explaining the variation in hours worked.

$$\begin{cases} \ln \text{Earnings} = \ln w + \delta \ln h_s + \ln \epsilon, & \text{Earnings function;} \\ w\delta h_s^{\delta-1} \epsilon (wh_s^\delta \epsilon + y)^{\rho-1} - 2^{1-\rho}(T - h_s)^{\rho-1} = 0, & \text{Hours Work equation;} \end{cases} \quad (5.24)$$

where ρ , δ , b_1 , b_2 and b_3 are the parameters to be estimated.

5.2 Earnings function for physicians providing 3 and 4 services

Recall that in our model a physician can provide 2, 3 or 4 aggregated services. We estimate the earnings function in each case. For those providing 2 services we specify in Section 5.1, the estimable earning function and hours worked equation.

5.2.1 Physicians providing 3 services

Here we have two specialities represented. Firstly, we have the group of physicians providing services 1, 2 and 5; denoted them G_{125} ; those physicians are pediatricians. Secondly, internal medicine physicians providing services 1,2 and 6. We denoted this group G_{126} . Taking that into account earnings for each specialist s in this case is

$$\text{Earnings} = \alpha_1 A_{1s} + \alpha_2 A_{2s} + \alpha_{3'} A_{3's}; \quad (5.25)$$

where

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

with $\mathbb{1}_{G_{12k}}(s) = 1$ if s belong to the subgroup G_{12k} ($k = 3, 5, 6$) and 0 otherwise; A_{js} is the observed quantity of service $j = 1, 2, 3, 5, 6$ provided by specialist s and α_j the fee of service j . Substituting A_{js} in (5.25) and rearranging gives

$$\text{Earnings} = (P_1 + P_2 + P_{3'})^{1-\delta} h_s^\delta \epsilon, \quad (5.26)$$

with $P_j = (b_j \alpha_j)^{\frac{1}{1-\delta}}$ $j = 1, 2$ and

$$P_{3'} = [(b_3 \alpha_3) \mathbb{1}_{G_{123}} + (b_5 \alpha_5) \mathbb{1}_{G_{125}} + (b_6 \alpha_6) \mathbb{1}_{G_{126}}]^{\frac{1}{1-\delta}}$$

The log-form is

$$\ln \text{Earnings} = (1 - \delta) \ln (P_1 + P_2 + P_{3'}) + \delta \ln h_s + \ln \epsilon. \quad (5.27)$$

5.2.2 Physicians providing 4 services

For physicians providing 4 services, we calculated physician's earnings for this group G_4 as,

$$E = \alpha_1 A_{1s} + \alpha_2 A_{2s} + \alpha_4 A_{4s} + \alpha_{4'} A_{4's}.$$

Where

$$\begin{aligned} \alpha_{4'} &= \alpha_3 \mathbb{1}_{G_{1243}}(s) + \alpha_5 \mathbb{1}_{G_{1245}}(s) \\ A_{4's} &= A_{3s} \mathbb{1}_{G_{1243}}(s) + A_{5s} \mathbb{1}_{G_{1245}}(s) \end{aligned}$$

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

j .

The log-form of earnings equation is

$$\ln \text{Earnings} = (1 - \delta) \ln (P_1 + P_2 + P_4 + P_{4'}) + \delta \ln h_s + \ln \epsilon, \quad (5.28)$$

where $P_j = (b_j \alpha_j)^{\frac{1}{1-\delta}}$ $j = 1, 2, 4$ and $P_{4'} = ((b_3 \alpha_3) \mathbb{1}_{G_{1243}} + (b_5 \alpha_5) \mathbb{1}_{G_{1245}})^{\frac{1}{1-\delta}}$.

Chapitre 6

Limited Information estimation

In this chapter, we address the question : Are the price elasticities of medical services production different from zero? *i.e.*, do physicians respond to monetary incentives? To do so, we estimate, only the log earnings equation conditional on hours worked by matching physicians' predicted and observed earnings, using instrumental variables to control for the potential endogeneity of clinical hours worked. The estimates allow us to calculate a lower bound to the own-price elasticity of substitution and we interpreted its significance as an evidence that physicians respond to medical services fee increases by substituting among services. However, this conditional estimation approach misses income effects.

6.1 Discussion of Advantages and Limitations of approach

The limited information approach consists of estimating only the earnings function, conditional on clinical hours. This conditional estimation is less demanding of the model and can be accomplished by (non-linear) least squares or instrumental variables. More precisely, it fixes hours worked and explains their allocation across different tasks in response to changes in relative prices. Since the variation in hours is not explained within the model, income effects are not identified.¹ Some elements of the substitution effects are identified, permitting relevant, but limited, conclusions over physician behaviour. In terms of parameters, ρ is not identified. The model provides a lower bound to the own-price substitution effect for services, which allows us to test whether or not physicians respond to incentives.

6.1.1 Lower-Bound to price elasticities derivation

Recall from Chapter 3, the relevant equations for own and cross price elasticities are :

1. Recall that income effect operate through clinical hours.

$$\zeta_{h_i/\alpha_i} = \underbrace{\left[\frac{1}{(1-\delta)} \frac{P_j}{P_i + P_j} - \frac{\delta \alpha_i \hat{A}_i M^{\rho-1}}{h_s^2 W_{h_s h_s}} \right]}_{\text{Substitution effect}} + \underbrace{\frac{\alpha_i A_i}{y} \zeta_{h_i/y}}_{\text{Income effect}} \quad (6.1)$$

$$\zeta_{h_j/\alpha_i} = - \underbrace{\left[\frac{1}{(1-\delta)} \frac{P_i}{P_i + P_j} + \frac{\delta \alpha_i A_i M^{\rho-1}}{h_s^2 W_{h_s h_s}} \right]}_{\text{Substitution effect}} + \underbrace{\frac{\alpha_i A_i}{y} \zeta_{h_j/y}}_{\text{Income effect}} \quad (6.2)$$

$$\zeta_{A_i/\alpha_i} = \delta \zeta_{h_i/\alpha_i} \quad (6.3)$$

$$\zeta_{A_j/\alpha_i} = \delta \zeta_{h_j/\alpha_i} \quad (6.4)$$

An examination of equations (6.1) and (6.2) reveals that the substitution effect operates through two separate channels. First, conditional on hours worked, physicians allocate time towards those services for which the price has risen : a rise in the price of service i will lead to more services of type i being provided. This is given by

$$LB_{\hat{h}_i/\alpha_i} = \frac{\alpha_i}{\hat{h}_i} \frac{d\hat{h}_i}{d\alpha_i} \Big|_{h_s} = \frac{1}{(1-\delta)} \frac{P_j}{P_i + P_j} > 0 \quad , \quad (6.5)$$

$$LB_{\hat{h}_j/\alpha_i} = \frac{\alpha_i}{\hat{h}_j} \frac{d\hat{h}_j}{d\alpha_i} \Big|_{h_s} = - \frac{1}{(1-\delta)} \frac{P_i}{P_i + P_j} < 0 \quad . \quad (6.6)$$

Second, the wage index increases through the (optimal) reallocation of hours across services, increasing the marginal return to an hour of work. These additional hours are then allocated across different services optimally. Since $W_{h_s h_s}$ is negative, the second effect given by $-\frac{\delta \alpha_i \hat{A}_i M^{\rho-1}}{\hat{h}_s^2 W_{h_s h_s}} > 0$, reinforces the own-price substitution effect but can counteract the cross-price effects (see equations (6.1) and (6.2)). Consequently, estimating the own-price substitution effect conditional on hours worked provides a lower bound to the overall substitution effect. We will concentrate on estimating this lower bound in (6.5).

To understand the substitution mechanism between hours devoted to services production, consider the two services case. Assuming for simplicity zero non-labour income, the physician income is

$$M = \alpha_1 h_1^\delta + \alpha_2 h_2^\delta. \quad (6.7)$$

The slope of the iso-income curve is derived from equation (6.7), by totally differentiating equation (6.7)

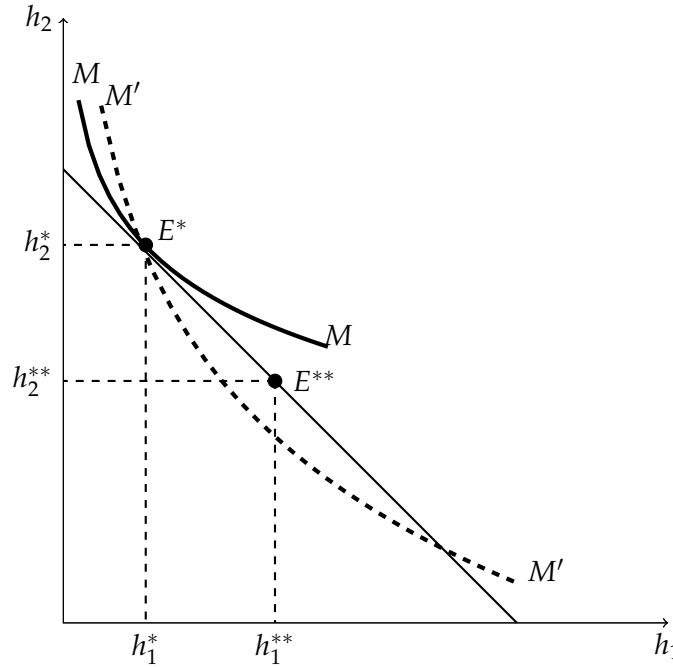
$$dM = \delta\alpha_1 h_1^{\delta-1} dh_1 + \delta\alpha_2 h_2^{\delta-1} dh_2 = 0, \quad (6.8)$$

from equation (6.8), we derive the slope of the iso-income as a function of the fees paid for the services α_1 and α_2 ,

$$\frac{dh_2}{dh_1} = -\frac{\alpha_1}{\alpha_2} \left(\frac{h_1}{h_2} \right)^{\delta-1}. \quad (6.9)$$

The time constraint line $h_s = h_1 + h_2$, whose slope is -1 and is fixed for a given h_s . Both the iso-income curve (MM) and the time constraint line are shown in the Figure 6.1. The physician seeks to get the highest level of (MM) given h_s – a tangency point at E^* . When α_1 increases, the line (MM) gets steeper in absolute value, moving the line (MM) to ($M'M'$) and so the tangency point move at the point E^{**} . This implies more time devoted to produce the service 1 and less time devoted to produce the service 2. That is, when the price of service 1 increases, the physician increases the quantity of service 1 and decreases the quantity of service 2.

FIGURE 6.1 – Iso-income maps for h_1 and h_2



Thus, the model makes the following testable predictions. First, a physician should reallocate their time spent providing medical services if the relative price of services changes. He/she

should increase the time devoted to the production of the most profitable service and use the remaining to provide the other services. The second prediction is a consequence of the first one – the quantity of service which price rises will increase to the detriment of other services.

6.2 Results

We estimated the log-earnings function in (5.24), (5.27) and (5.28) for the set of physicians providing 2 services, 3 services and 4 services, respectively, using both nonlinear least squares and instrumental variables methods. Instrumental variables methods control for the possible endogeneity of h_s as suggested by the second equation in (5.24). The log-earnings function are

$$\ln \text{Earnings} = (1 - \delta) \ln (P_1 + D_2 P_2 + (1 - D_2) P_3) + \delta \ln h_s + \ln \epsilon, \quad \text{for 2 services;}$$

$$\ln \text{Earnings} = (1 - \delta) \ln (P_1 + P_2 + P_{3'}) + \delta \ln h_s + \ln \epsilon, \quad \text{for 3 services;}$$

$$\ln \text{Earnings} = (1 - \delta) \ln (P_1 + P_2 + P_4 + P_{4'}) + \delta \ln h_s + \ln \epsilon, \quad \text{for 4 services;}$$

where $P_j = (b_j \alpha_j)^{\frac{1}{1-\delta}}$ $j = 1, 2, 3, 4$;

$$P_{3'} = [(b_3 \alpha_3) \mathbb{1}_{G_{123}} + (b_5 \alpha_5) \mathbb{1}_{G_{125}} + (b_6 \alpha_6) \mathbb{1}_{G_{126}}]^{\frac{1}{1-\delta}} \quad \text{and}$$

$$P_{4'} = ((b_3 \alpha_3) \mathbb{1}_{G_{1243}} + (b_5 \alpha_5) \mathbb{1}_{G_{1245}})^{\frac{1}{1-\delta}}.$$

6.2.1 Least-Squares Estimates

We first consider nonlinear regression methods to measure the responsiveness of physicians to incentives. The parameter of interest is δ . We estimated the log-form earnings equation (5.24), (5.27) and (5.28). The results are presented in Table 6.1. The estimates for the set of physicians which provided 2 services are presented in first column. Note that the estimate of δ is equal to 0.64, and has a p-value which is virtually zero. The second column contains the estimates for the set of physicians which provided 3 services. Again, the estimate of δ is significant (p-value is also virtually zero) but smaller than the first case, is equal to 0.36. Finally, in the third column, the estimate is for the 4 services physicians. δ is equal to 0.20 and has a p-value of 0.011. These results suggest that physicians respond to incentives. A necessary and sufficient condition for the own-price substitution effect to be positive is $0 < \delta < 1$.

6.2.2 Instrumental Variables

To control for the possible endogeneity of h_s , we turn to instrumental variables method. To do so, we used simulated nonlinear GMM method with weighting matrix $W = (Z'Z)^{-1}$, where Z =(return on market investments, marginal tax rate, age, service prices) is the instruments matrix.

TABLE 6.1 – Least-Squares estimates

Par.	2 services	Par.	3 services	Par.	4 services
δ	0.64*** (0.08)	δ	0.36*** (0.04)	δ	0.20** (0.1)
b_1	0.53 (20.36)	b_1	23.58 (15.6)	b_1	16.31** (7.2)
b_2	7.62*** (2.35)	b_2	0.0007 (6227.9)	b_2	7.09e-06 (81.3)
b_3	3.0** (1.33)	b_3	27.03*** (4.24)	b_3	1.53e-11 (24.15)
		b_5	25.04*** (4.0)	b_4	17.53** (7.87)
		b_6	1.75 (38.0)	b_5	27.10*** (8.82)
Obs.	1,300		1,283		588

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

The theoretical impact of marginal tax rate on clinical hours can be demonstrated in our model with two services¹. To do so, suppose that the income of the physicians is taxed at the combined Canadian federal and provincial tax rate, denoted by τ ². Taking the income tax rate into account, we derive the optimal quantities of services provided (2 services case),

$$A_i = b_i \left[\frac{(b_i \tau \alpha_i)^{1/(1-\delta)}}{(b_i \tau \alpha_i)^{1/(1-\delta)} + (b_j \tau \alpha_j)^{1/(1-\delta)}} \right]^\delta h_s^\delta \epsilon, \forall i \neq j \in \{1, 2\}. \quad (6.10)$$

Simplifying this expression gives

$$A_i = b_i \left[\frac{(b_i \alpha_i)^{1/(1-\delta)}}{(b_i \alpha_i)^{1/(1-\delta)} + (b_j \alpha_j)^{1/(1-\delta)}} \right]^\delta h_s^\delta \epsilon, \forall i \neq j \in \{1, 2\}, \quad (6.11)$$

independent of τ . Since the tax rate affects the marginal return to all services equally, and only relative prices matter, the tax rate does not affect the allocation of hours across services. However, given h_s solves

$$\tau w \delta h_s^{\delta-1} \epsilon (\tau w h_s^\delta \epsilon + y)^{\rho-1} - 2^{1-\rho} (T - h_s)^{\rho-1} = 0. \quad (6.12)$$

1. Extending to multiple services is trivial.

2. This tax rate is assumed to be the same for all the physicians because they typically belong to the highest income bracket.

h_s depends on τ . The optimal quantities are affected by tax rate only through clinical hours. From (6.12) note that h_s also depends on (w, y, ϵ) . Thus, Non-labor income y shifts \hat{h}_s , independent of production shocks ϵ . Variables affecting y and the tax rate can therefore be used to form instruments for h_s e.g. Heckman [1974]. One of these variables is return on market investments.

Table 6.2 reports the pooled LS estimates of the impact of marginal tax rate and the market return on clinical hours worked per week, controlling for the prices of services for each set of physicians. The marginal tax rate has a positive and significant effect on clinical hours worked per week in all cases.¹ The estimates for market return rate² are jointly significant for all groups of physicians. A test of the joint null hypothesis that the coefficients on market return, market return squared and market return cubed are zero, has a p-value of zero for all the 3 groups.

In addition, we measure the instruments relevance by computing the first-stage F-statistic test³ for exclusion restrictions.⁴ These statistics are reported in Table 6.2. We follow Stock and Yogo [2005] to test the null hypothesis that instruments are weak. The value of the F-statistics are higher than Stock and Yogo thresholds for weak instruments⁵ suggesting that the instruments are not weak.

We estimate the structural parameters of our models by using GMM Estimators. We used the marginal tax rate and the market return, its squared and its cubed as instruments for clinical hours. The results are presented in Table 6.3. The first column presents results for behavioural parameter of the physicians who provided 2 services. The second column presents results for the set of physicians who provided 3 services. Finally, the third column is for physicians who gives 4 services.

The estimates (standard errors) of the substitution parameter, δ , in 2 services, 3 services and 4 services sample are 0.21 (0.02), 0.26 (0.02) and 0.29 (0.02). The estimates of δ are positive and statistically significant. They are also relatively homogeneous across specifications.

We note that for each sample in Table 6.3, the J-test statistic used for testing over-identifying restrictions (OIR), (Hansen, 1982) associated with the use of dummies of age, marginal tax rate and market return as instruments. The p-values for this test are reported in square brackets in Table 6.3. The p-values for OIR test suggest that we cannot reject null hypothesis of

1. The coefficient on marginal tax rate is 3.43 with a p-value of 0.000 for the set of physicians who provided 2 services. This coefficient is 3.40 and has a p-value of 0.000 for 3 services. This coefficient is 4.19 with a p-value of 0.000.

2. We used market return, its squared and its cubed as regressors to show the evidence of correlation between clinical hours and market return.

3. See Cameron and Trivedi [2010].

4. This statistic is equal to the Wald chi-square test statistic for exclusion restrictions divided by r^* : the number of instruments that are not regressors in the earnings equation.

5. The F-statistics are 8.85 for 2 services, 9.26 for 3 services and 11.45 for 4 services, and the thresholds value are respectively 5.82 for 2 services and 3 services, and between 3.71 and 5.82 for 4 services.

TABLE 6.2 – Impact of marginal tax rate and Market return rate on clinical Hours Worked

	2 Services	3 Services	4 Services
prix1	-156.4*** (30.66)	-141.9*** (35.25)	194.6*** (60.61)
prix2	4.657 (8.384)	-2.235 (17.65)	-686.3*** (122.4)
prix3	- -	0.487 (3.991)	320.8*** (51.39)
prix4	- -	- -	3.351 (21.24)
age >= 50	-2.086** (0.961)	0.514 (0.930)	-2.778 (1.845)
Marginal tax rate	3.434*** (0.710)	3.399*** (0.763)	4.191*** (0.978)
Market return rate	-0.0628 (0.0406)	-0.0466 (0.0565)	0.699*** (0.120)
Market return rate squared	0.0595*** (0.0115)	0.0629*** (0.0113)	-0.0217*** (0.00367)
Market return rate cubed	-0.00183*** (0.000342)	-0.00196*** (0.000333)	- -
Constant	24.19* (13.86)	14.94 (18.67)	4.480 (37.13)
Wald chi2 test statistic (W)	44.23	46.29	57.24
"First-stage F-statistic test" (W/r*)	8.85	9.26	11.45
Stock and Yogo threshold	5.82	5.82	[3.71 ;5.82]
Observations	1,300	1,283	588
Number of ID	242	244	107

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

instruments exogeneity.¹

Finally, we compute the Hausman test for endogeneity of h_s to compare the least squares and the IV estimates in each case. The chi-square statistics (p-value) for 2 services, 3 services and 4 services groups are respectively 104.65 (1.006e-21), 121.00 (1.005e-23) and 284.73 (1.526e-58). These statistics are large which suggests that the IV approach is consistent with the data.

1. OIR test statistics (p-value) for 2 services, for 3 services and for 4 services are respectively 2.4117 (0.6605), 3.0784 (0.3796) and 0.18052 (0.98067).

TABLE 6.3 – IV estimates from Random Price Model

Par.	2 services	Par.	3 services	Par.	4 services
δ	0.21*** (0.02)	δ	0.26*** (0.02)	δ	0.29*** (0.01)
b_1	0.22 (1.01)	b_1	28.39*** (4.41)	b_1	12.79*** (4.47)
b_2	38.45*** (2.36)	b_2	1.81 (11.29)	b_2	1.39 (15.99)
b_3	13.76*** (0.84)	b_3	69.55*** (4.23)	b_3	7.56 (1.48)
		b_5	2.06 (3.95)	b_4	3.52 (10.08)
		b_6	12.88*** (1.16)	b_5	13.19*** (5.03)
J-test statistic	2.4117 [0.6605]		3.0784 [0.3796]		0.18052 [0.98067]
Obs.	1,300		1,283		588

The p-value for the test of overidentifying restrictions is shown in brackets

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Own-price substitution effects conditional on clinical hours

Our model allows us to estimate elasticities of substitution conditional on clinical hours.¹ This provides a measure of the response of physicians to incentives. Recall from (6.5) that the own-price substitution effect, conditional on h_s , is a lower bound of the global substitution effect. However the cross-price substitution effect is unsigned.

We present the results of the own-price substitution effects in Tables 6.4 to 6.6. In each table, the top panel presents the way the physicians substitute between hours devoted to different services, and the bottom panel gives the substitution between quantities of services provided. Table 6.4 shows that physicians who provided 2 services, allocate more hours to produce service 1 when its price increases (substitution elasticity equal to 1.26). If the total hours h_s are fixed and h_1 increases the h_2 must decrease by the same amount. The own price elasticity of substitution of h_2 is modest but positive 0.003. We obtain similar results with the

1. Hours own-price elasticity

$$\frac{1}{(1-\delta)} \frac{\sum_{j \neq i} P_j}{\sum_k P_k}.$$

Quantities own-price elasticity

$$\frac{\delta}{(1-\delta)} \frac{\sum_{j \neq i} P_j}{\sum_k P_k}.$$

quantity of services. Quantity own-price elasticity of substitution is 0.26 for service 1 and 0.0006 for service 2'.

TABLE 6.4 – Own-price substitution effects conditional on clinical hours for 2 services

	LB_{k/α_1}	$LB_{k/\alpha_{2'}}$
Hours of Serv.1	1.26*** (.0000557)	-
Volume Serv.1	0.26*** (.0000117)	-
Hours of Serv.2'	-	0.003*** (.0000557)
Volume Serv.2'	-	0.0006*** (.0000117)

Table 6.5 provides results on the group of physicians provided 3 services. When a price of service 1 increased by 1% the physician increased the hours devoted to this service by 0.54%. For services 2 and 3 the own-price elasticity is 1.33 and 0.83 respectively, for hours devoted to each service. Again, we get similar results for quantities.¹

TABLE 6.5 – Own-price substitution effects conditional on clinical hours for 3 services

	LB_{k/α_1}	LB_{k/α_2}	$LB_{k/\alpha_{3'}}$
Hours Serv.1	0.54*** (.0107733)	-	-
Volume Serv.1	0.14*** (0.0028011)	-	-
Hours Serv.2	-	1.33*** (.0002677)	-
Volume Serv.2	-	0.35*** (.0000696)	-
Hours Serv.3'	-	-	0.83*** (.0110397)
Volume Serv.3'	-	-	0.22*** (.0028703)

Table 6.6 presents results for physicians who provided 4 services. Here, whatever the service which price increases the hours devoted to its production and its quantity increase. Indeed, the own-price substitution effects range from 0.83 to 1.38 for hours devoted to the production of different services, and from 0.24 to 0.40 for the quantity of services provided.

1. The own-price substitution effect is 0.14, 0.35 and 0.22 respectively for service 1, 2 and 3 quantities.

TABLE 6.6 – Own-price substitution effects conditional on clinical hours for 4 services

	LB_{k/α_1}	LB_{k/α_2}	LB_{k/α_4}	$LB_{k/\alpha_{4'}}$
Hours Serv.1	0.83*** (.0051085)	-	-	-
Volume Serv.1	0.24*** (.0014815)	-	-	-
Hours Serv.2	-	1.38*** (.0002181)	-	-
Volume Serv.2	-	0.40*** (.0000632)	-	-
Hours Serv.4	-	-	1.11*** (.0025949)	-
Volume Serv.4	-	-	0.32*** (.0007525)	-
Hours Serv.4'	-	-	-	0.90*** (.0075658)
Volume Serv.4'	-	-	-	0.26*** (.0021941)

These results suggest that physicians react to fee changes. In fact, a change in price leads physicians to allocate more working hours to the service whose price has risen and produce more of those services.

6.3 Conclusion

We have developed and estimated a structural labour supply model that incorporates the technology of medical services production and the allocation of hours across services into the standard consumption/leisure trade-off. We have applied our model to analyse the response of fee-for-service physicians to change in fees using data from the Province of Quebec. We have estimated the substitution effects of price changes holding total hours of work constant and using instrumental variables to control for the endogeneity of hours worked.

Our results suggest that physicians do react to incentives. A change in price leads physicians to allocate more working hours to the service whose price has risen. 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.

Finally, we note that the elasticities we calculate are conditional on hours worked. They represent a lower bound to the global substitution elasticity for the own price effect. Calculating the global substitution effects as well as the income effects requires solving the complete

model, including optimal hours worked (see the next Chapter).

Chapitre 7

Full Information Estimation

The previous Chapter provides evidence that physicians react to monetary incentives. In this Chapter, we address the question of how and the extent to which physicians respond to changing incentives by estimating the elasticity of substitution, as well as income effects. To do so, We estimate full-information model composed of two equations (5.24) – log form of earning equation and equation explaining variation in clinical hours worked. We use our estimates to simulate the effect of recently observed prices increase in physician contracts.

7.1 Discussion of Advantages and Limitations of approach

The conditional estimation of the earnings function in Chapter 6 gives limited information on the response over physicians behaviour. To have a complete measure of the reaction of physicians to monetary incentives, unconditional estimation is needed. It requires using the full information provided by our model to identify and estimate all the parameters, including explaining hours worked.

Explaining the variation in hours worked requires modelling the choice of hours by physicians. This implies additional assumptions but has the advantage of identifying the full response of physicians to changes in relative prices, including both income and substitution effects.

Our full-information model is composed of two equations (see (5.24)). The additional hours equation is an implicit function of hours worked

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

From this implicit form, deriving an analytical expression of predicted hours is impossible. Therefore, we solve for hours worked numerically to get a vector of optimal hours worked, making our procedure more complex and more time-intensive. However, this approach

allows us to identify all the parameters, including ρ which is needed to estimate the substitution effects, as well as, the income effects.

7.2 Discussion of results

7.2.1 Specification of Non-Labour Income y

One of the problems with the model discussed above is that physicians' non-labor incomes, are not observed. Non-labor income is typically measured as the sum of asset income and other unearned income including social transferts [Ashenfelter and Card, 1999]. For physicians, social transferts can be set to zero making non-labor income depends on asset stocks and the market return on invested assets. Asset stocks are unobserved, we therefore defined the non-labor income as a linear function of the market return rate, physician's personal characteristics (age) and an error term¹

$$y = c_0 + c_1 \text{Market} + c_2 \text{Dage} + \nu, \quad (7.1)$$

where Market is the market return rate and Dage a dummy variable indicating physicians older than 40; ν is the error term. We follow van Soest [1995], replacing the unobserved, y in (5.21) by $y^p = c_0 + c_1 \text{Market} + c_2 \text{Dage}$, ignoring the error term ν . Clinical hours worked now solves

$$w\delta h_s^{\delta-1} \epsilon (wh_s^\delta \epsilon + c_0 + c_1 \text{Market} + c_2 \text{Dage})^{\rho-1} - 2^{1-\rho} (T - h_s)^{\rho-1} = 0 \quad (7.2)$$

This specification adds 4 additional parameters c_0 , c_1 , c_2 and ρ to the model.

7.2.2 Estimation Strategy

The equation to estimate for the sample of physicians providing 2 services is now

$$\ln \text{Earnings} = \ln w + \delta \ln h_s + \ln \epsilon; \quad (7.3)$$

with h_s solving

$$w\delta h_s^{\delta-1} \epsilon (wh_s^\delta \epsilon + c_0 + c_1 \text{Market} + c_2 \text{Dage})^{\rho-1} - 2^{1-\rho} (T - h_s)^{\rho-1} = 0. \quad (7.4)$$

Let Θ_2 be the vector that contains all the unknown parameters, i.e.,

$$\Theta_2 = (\rho, \delta, b_1, b_2, b_3, c_0, c_1, c_2).$$

1. An alternative procedure is to estimate y as a parameter. Preliminary results suggested that the estimate of this parameter is imprecise.

We denote by $h_s^p(\Theta_2, \epsilon)$, $A_j^p(\Theta_2, \epsilon)$, and $\text{Earn}^p(\Theta_2, \epsilon)$ the predicted hours worked, volume of services j and predicted earnings, respectively, conditional on the parameters Θ_2 and ϵ . The estimator is computed using SMM. The basic idea behind SMM is to generate simulated values from the model, and then match their moments with those computed from the data. We follow three steps.

Step 1. Prediction. To predict $\{h_s^p(\Theta_2, \epsilon), A_j^p(\Theta_2, \epsilon), \text{Earn}^p(\Theta_2, \epsilon)\}$.

(i) We draw the production shock

$$\ln \epsilon \sim N(0, 1)$$

and given an admissible Θ_2 we solve numerically, equation (7.4) for $h_s^p(\Theta_2, \epsilon)$.¹

(ii) We Plug $h_s^p(\Theta_2, \epsilon)$ in equations (5.16), (5.17) and (5.18) gives predicted earning from service 1, 2 and 3, respectively

$$A_1^p(\Theta_2, \epsilon) = \begin{cases} b_1 \left[\frac{P_1}{P_1 + P_2} \right]^\delta h_s^p(\Theta_2, \epsilon)^\delta, & \text{if } D_2 = 1; \\ b_1 \left[\frac{P_1}{P_1 + P_3} \right]^\delta h_s^p(\Theta_2, \epsilon)^\delta & \text{otherwise;} \end{cases} \quad (7.5)$$

$$A_2^p(\Theta_2, \epsilon) = \begin{cases} b_2 \left[\frac{P_2}{P_1 + P_2} \right]^\delta h_s^p(\Theta_2, \epsilon)^\delta, & \text{if } D_2 = 1; \\ 0 & \text{otherwise;} \end{cases} \quad (7.6)$$

$$A_3^p(\Theta_2, \epsilon) = \begin{cases} b_3 \left[\frac{P_1}{P_1 + P_3} \right]^\delta h_s^p(\Theta_2, \epsilon)^\delta, & \text{if } D_2 = 0; \\ 0 & \text{otherwise.} \end{cases} \quad (7.7)$$

(iii) We then compute $\ln \text{Earn}^p(\Theta_2, \epsilon)$ as

$$\ln \text{Earn}^p(\Theta_2, \epsilon) = \ln w + \delta \ln h_s^p(\Theta_2, \epsilon). \quad (7.8)$$

Step 2. Iteration. We iterate **Step 1.** 20 times, generating each iteration a different draw for ϵ . That is, we get 20 different vectors of $\{h_s^p(\Theta_2, \epsilon), A_j^p(\Theta_2, \epsilon), \ln \text{Earn}^p(\Theta_2, \epsilon)\}$.

Step 3. Construct the estimator. Given the predicted values using the structure of the model, we calculate average values of the 20 vectors of each predicted variable. That is,

$$\overline{h_s^p}(\Theta_2) = \frac{1}{20} \sum_{k=1}^{20} h_s^p(\Theta_2, \epsilon_k),$$

$$\overline{A_j^p}(\Theta_2) = \frac{1}{20} \sum_{k=1}^{20} A_j^p(\Theta_2, \epsilon_k),$$

1. Note that we assumed that the weekly total amount of time available T is 24×7

$$\overline{\ln \text{Earn}^p}(\Theta_2) = \frac{1}{20} \sum_{k=1}^{20} \ln \text{Earn}^p(\Theta_2, \epsilon_k).$$

Now the average values vectors $\overline{h_s^p}(\Theta_2), \overline{A_j^p}(\Theta_2), \overline{\ln \text{Earn}^p}(\Theta_2)$, depends only on the value of Θ_2 . The idea is then the following : if the model is correctly specified with Θ_2 equal to its true value, then the simulated moments, will be the same as the actual moments that we observe from the sample. We choose parameters to render the predicted values as close as possible to observed values. To do so, we minimize the distance between the sample moments and the predicted moments. Let h_s^o, A_j^o and $\ln \text{Earn}^o$ be the observed average values of hours worked, income from service j , and log earnings, respectively ; and

$$m_{N\Gamma}(\Theta_2) = \frac{1}{N\Gamma} \begin{cases} h_s^o - \overline{h_s^p}(\Theta_2) \\ A_j^o - \overline{A_j^p}(\Theta_2) \\ \ln \text{Earn}^o - \overline{\ln \text{Earn}^p}(\Theta_2); \end{cases} \quad (7.9)$$

where N is the number of physicians and Γ the number of years. The SMM estimator is given by

$$\hat{\Theta}_2 = \arg \min_{\Theta_2} m_{N\Gamma}(\Theta_2)' (Z'Z)^{-1} m_{N\Gamma}(\Theta_2), \quad (7.10)$$

where Z =(return on market investments, marginal tax rate, age, service prices) is the instruments matrix.

7.2.3 Basic unrestricted model estimates

The results are presented in Table 7.1. The first column presents results for the behavioural parameter of the physicians who provided 2 services. The second column presents results for the set of physicians who provided 3 services. Finally, the third column is for physicians who provided 4 services. The parameters of interest are δ , the marginal return to time spent

1. Finally, to estimate Θ_2 for physicians providing 2 services we use the following moments

$$m_{N\Gamma}(\Theta_2) = \frac{1}{N\Gamma} \begin{cases} h_s^o - \overline{h_s^p}(\Theta_2) \\ (A_2^o - \overline{A_2^p}(\Theta_2))D_2 + (A_3^o - \overline{A_3^p}(\Theta_2))(1 - D_2) \\ \ln \text{Earn}^o - \overline{\ln \text{Earn}^p}(\Theta_2). \end{cases}$$

Let Θ_3 and Θ_4 be the vector of parameters to estimate for physicians providing 3 services and 4 services, respectively. We use for estimation

$$m_{N\Gamma}(\Theta_3) = \frac{1}{N\Gamma} \begin{cases} h_s^o - \overline{h_s^p}(\Theta_3) \\ A_1^o - \overline{A_1^p}(\Theta_3) \\ \ln \text{Earn}^o - \overline{\ln \text{Earn}^p}(\Theta_3); \end{cases}$$

and

$$m_{N\Gamma}(\Theta_4) = \frac{1}{N\Gamma} \begin{cases} h_s^o - \overline{h_s^p}(\Theta_4) \\ (A_1^o - \overline{A_1^p}(\Theta_4)) + (A_3^o - \overline{A_3^p}(\Theta_4)) \\ \ln \text{Earn}^o - \overline{\ln \text{Earn}^p}(\Theta_4). \end{cases}$$

by the physician to produce a service, ρ the degree of substitutability between consumption and leisure and b_j the quantity of service j provided by a physician after one hour worked.

The estimate for ρ is positive and statistically significant for the subset of physicians who provided 2 services. It is negative and significant for the subset of physicians providing 3 and 4 services. However, all the estimates satisfy the restriction $-\infty < \rho < 1$. This condition combined with $0 < \delta < 1$ are the necessary and sufficient condition for the second order condition in (3.11) to hold ensuring the concavity of the utility function. The δ -s are positive, highly significant and between 0 and 1, as was the case for those estimated using only the earnings equation (limited information estimation). However, the magnitudes are greater.¹ This suggests that not using the full information to estimate the model leads to under-estimate δ . The estimates of b_j are positive, but not all of them are precisely estimated.

Table 7.1 also gives the J-test statistic used for testing overidentifying restrictions (OIR), see Hansen (1982), associated with the use of dummies of age, marginal tax rate and market return as instruments. The p-values for this test are reported in square brackets. The p-values for OIR test suggest that, for each subsample, we cannot reject null hypothesis of instruments exogeneity.²

7.2.4 Restricted model estimates

In this version of the model, we restrict the parameters $\rho, \delta, b_1, b_2, b_3$, and b_4 to be the same across all physicians, whether they provide 2, 3 or 4 services. The estimation procedure is identical to that described in the previous section. Table 7.1 contains the estimation results of the model with restricted coefficients.

The sample of 3,171 observations includes all the physicians. It is clear that δ is significantly between 0 and 1, but different from the estimates of δ estimated with the unrestricted model. A similar observation can be made with the parameter ρ – the estimate of ρ with the restricted model is smaller (in absolute value) than what we got when using only physicians providing 4 services, however; it is greater than the estimated ρ from the samples of physicians providing 2 services and 3 services.

The OIR test statistic is large (607.96) suggesting the moment conditions are rejected and the IV estimator is inconsistent. The rejection of the moments condition should be interpreted as evidence of model misspecification, not as evidence that the instruments are endogenous. Because previous results in Table 7.1 with the same instruments show that we cannot reject that our instruments are exogenous.

1. As a comparison, the estimates of δ were 0.21, 0.26 and 0.29 for the physician providing 2 services, 3 services and 4 services respectively, when using only earning equation.

2. OIR test statistics (p-value) for 2 services, for 3 services and for 4 services are respectively 8.705 (0.925), 10.649 (0.874) and 8.264 (0.875).

TABLE 7.1 – SMM estimates of the full unrestricted and restricted Model

Unrestricted Model						Restricted Model	
Par.	2 services	Par.	3 services	Par.	4 services	Par.	Estimates
ρ	0.032*** (0.01)	ρ	-0.21*** (0.001)	ρ	-0.77*** (0.017)	ρ	-0.49*** (0.002)
δ	0.69*** (0.005)	δ	0.77*** (0.0004)	δ	0.92*** (0.002)	δ	0.83*** (0.0002)
c_0	2.27*** (0.281)	c_0	0.94*** (0.087)	c_0	0.60** (0.232)	c_0	0.06 (0.065)
c_1	0.01*** (0.001)	c_1	0.03*** (0.001)	c_1	0.01*** (0.002)	c_1	0.16*** (0.0006)
c_2	0.22*** (0.06)	c_2	-0.029 (0.12)	c_2	-0.006 (0.169)	c_2	0.18*** (0.046)
b_1	1.94*** (0.022)	b_1	4.56*** (0.004)	b_1	1.95*** (0.011)	b_1	3.11*** (0.002)
b_2	5.79*** (0.11)	b_2	4.22*** (0.017)	b_2	2.08*** (0.016)	b_2	3.19*** (0.002)
b_3	2.26*** (0.038)	b_3	12.06*** (0.05)	b_3	1.75*** (0.009)	b_3	4.71*** (0.006)
		b_5	0.84 (5.55)	b_4	1.99*** (0.014)	b_4	2.53*** (0.001)
		b_6	0.57 (6.190)	b_5	1.03 (1.254)	b_5	3.21*** (0.003)
						b_6	0.60 (0.857)
J-test stat.	8.705 [0.925]		10.649 [0.874]		8.264 [0.875]		607.96 [0.000]
Obs.	1,300		1,283		588		3,171

The p-value for the test of overidentifying restrictions is shown in brackets

Standard errors in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

7.2.5 Model with income ceilings and taxes

Gross Income Ceilings

Prior to 1999, the government imposes half-yearly ceilings¹ on physician's gross income, beyond which the price paid for each service is reduced by 75%. This penalty only affects high activity physicians (about 11.67%). In this section, we account for government imposed income ceilings.

1. 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.

Let $\bar{E}_{w,c}$ ¹ denote the weekly income ceiling. The (weekly) earnings derived from physicians practice,

$$E = wh_s^\delta \epsilon$$

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

$$\bar{h}_{s,c} = \left(\frac{\bar{E}_{w,c}}{w\epsilon} \right)^{1/\delta}. \quad (7.11)$$

Let τ_c be the penalty for exceeding the income ceiling – typically, the physician receives 25% of all income billed beyond the ceiling which would make $\tau_c = 0.75$. The earnings of the physician would then be given by

$$\text{Earnings} = \begin{cases} wh_s^\delta \epsilon & \text{if } h_s \leq \bar{h}_{s,c} \\ (1 - \tau_c)wh_s^\delta \epsilon & \text{if } h_s > \bar{h}_{s,c}. \end{cases} \quad (7.12)$$

Consider the Figure 7.1. There is a kink point in earnings at $\bar{h}_{s,c}$ which depends on both δ and ϵ , given our estimation method (discussed in Chapter 7) $\bar{h}_{s,c}$ must be updated for each parameter vector and each draw of ϵ . In order to calculate the optimal hours worked, we proceed by section following Hausman [1979] :

1. For a given δ and ϵ , we calculate $\bar{h}_{s,c}$.
2. We maximize the indirect utility in (5.20) subject to the budget constraint (OAB) ignoring the income ceiling, i.e we solve

$$w\delta h_s^{\delta-1} \epsilon (wh_s^\delta \epsilon + y)^{\rho-1} - 2^{1-\rho} (T - h_s)^{\rho-1} = 0, \quad (7.13)$$

for hours worked.

- a) If the optimal hours is less than $\bar{h}_{s,c}$; eg. at e_1 , then that is the optimal hours. Note that the section of the budget constraint AB dominates AC , so if e_1 dominates all hours choices on AB , it must necessarily dominate those on AC as well.
- b) If the optimal hours is greater than $\bar{h}_{s,c}$, (eg, at e_2), then you have to continue to the next budget constraint $\bar{O}AC$.
- c) To calculate the virtual income \bar{O} , we note that income along $\bar{O}AC$ must equal $w\bar{h}_{s,c}^\delta \epsilon$ at $h_s = \bar{h}_{s,c}$, hence

$$\begin{aligned} \bar{O} + (1 - \tau_c)w\bar{h}_{s,c}^\delta \epsilon &= w\bar{h}_{s,c}^\delta \epsilon, \quad \text{or} \\ \bar{O} &= \tau_c w\bar{h}_{s,c}^\delta \epsilon, \quad \text{and from the definition of } \bar{h}_{s,c} \text{ we have} \\ \bar{O} &= \tau_c \bar{E}_{w,c}. \end{aligned} \quad (7.14)$$

1. Obtained 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.

The budget constraint is now (\overline{OAC}) : $(1 - \tau_c)wh_s^\delta \epsilon + \tau_c \overline{E}_{w,c} + y$.

d) We maximize utility to find optimal hours along \overline{OAC} , i.e, we solve

$$(1 - \tau_c)w\delta h_s^{\delta-1}\epsilon \left[(1 - \tau_c)wh_s^\delta \epsilon + \tau_c \overline{E}_{w,c} + y \right]^{\rho-1} - 2^{1-\rho} [T - h_s]^{\rho-1} = 0, \quad (7.15)$$

for hours worked.

e) If the optimum hours along \overline{OAC} is greater than $\overline{h}_{s,c}$, then we find the optimum.

f) if the optimum hours along \overline{OAC} is less than $\overline{h}_{s,c}$, then the optimum is at the kink point $\overline{h}_{s,c}$.

We apply this procedure to find the optimal hours worked for each physician prior to 1999, since the government has removed the ceilings after 1999. Taking off income ceilings can affect incentives, it is basically like reducing the marginal tax rate for high-income earners. However, the ceiling on gross income imposed real constraints to only 11.67% of physicians, its removal may have a negligible effect on physician behaviour. But, estimating the model with the ceilings allows us to simulate the impact of ceiling deregulation.

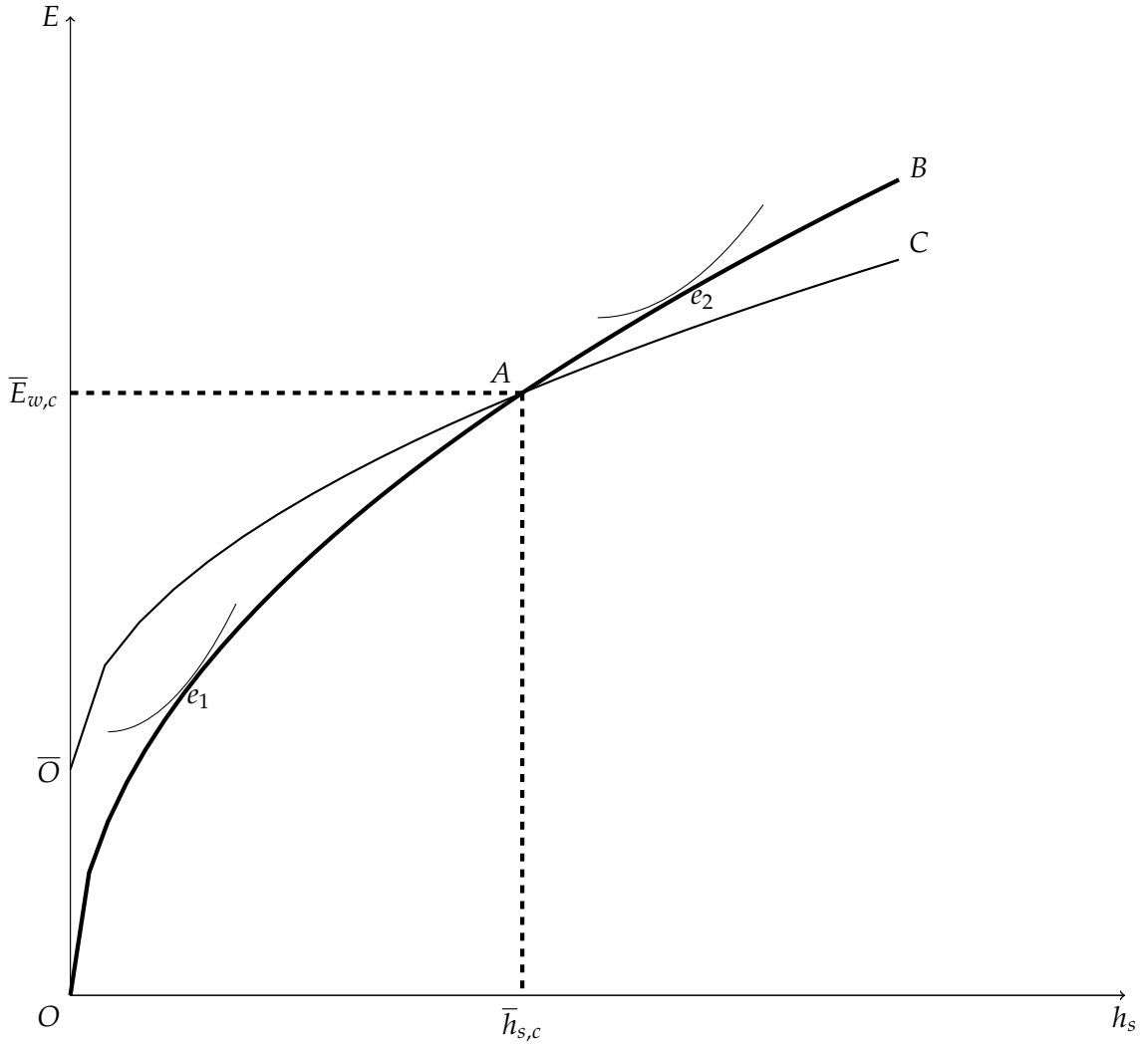
Gross income ceilings and taxes

As shown in the previous section, physicians weekly income is $wh_s^\delta \epsilon$ when hours worked are less than the $\overline{h}_{s,c}$ hours' ceiling and $(1 - \tau_c)wh_s^\delta \epsilon$ when hours worked exceed the ceiling $\overline{h}_{s,c}$ for exceeding the ceiling. That is, the taxable income depends on whether or not hours worked by physicians are below or above the ceiling $\overline{h}_{s,c}$. Namely, If physicians worked less than $\overline{h}_{s,c}$ hours then their taxable income is $wh_s^\delta \epsilon$, otherwise their taxable income is $(1 - \tau_c)wh_s^\delta \epsilon$.

In Québec, the personal income tax is collected by both the provincial and the federal governments. The Table 7.2 shows taxes rates per income bracket collected by Québec government and federal government in 2001.¹ Personal income tax is collected by the Québec government according to three rates – 17%, 21.25% and 24.5%, corresponding to three tax brackets. The federal government collects income tax according to four rates, namely, 16%, 22%, 26% and 29% of taxable income, corresponding to four tax brackets. Some simplifying assumptions are necessary to account for taxes in our estimation, since the data do not give information to allow us to apply the tax reduction for families, as well as refundable tax credits for various expenses, including child-care expenses, real estate tax, sales tax and the cost of housing of a parent.

1. We choose the tax system of 2001 because this tax system was applied to incomes earned in 2000, which is the base year. Then for simplicity, we assume that from 1996 to 2002 the tax income system in Québec does not change.

FIGURE 7.1 – Optimal choices along the efficient budget constraint with income ceilings



Given Table 7.2, the combined federal and provincial tax system consists of six progressive income brackets and marginal tax rate increasing from 33% to 53.5%.¹

The Figure 7.2 shows the budget constraint for a physician practicing in Québec faced with both federal and provincial income taxes, as well as, income ceilings. In the Figure 7.2 "Net E " denotes a physician after-tax income. The arcs of the budget constraint correspond to the different marginal tax rates that a physician faces. He/She faces a tax rate of τ_1 between

1. A physician gross annual earning E is taxed as follows :

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

TABLE 7.2 – Personal income tax structure in Québec in 2001

	Québec		Federal	
Tax rate per taxable income bracket	0-\$26,000	17%	0-\$30,754	16%
	\$26,000-\$52,000	21.25%	\$30,754-\$61,509	22%
	\$52,000 and over	24.5%	\$61,509-\$100,000	26%
			\$100,000 and over	29%

Source : Commission on Fiscal Imbalance, 2001

hours bracket zero and $\bar{h}_{s,1}$ (arc O_1A_1) and tax rates of τ_i , ($i = 2, 3, 4, 5$), and τ_6 , respectively, in hours brackets $[\bar{h}_{s,i-1}, \bar{h}_{s,i}]$ (arc $A_{i-1}A_i$) and $[\bar{h}_{s,5}, T]$ (arc A_5A_cA). Note that in the high-income (income greater than 100,000 CAN dollars) or high-activity (hours worked greater than $\bar{h}_{s,5}$) there is a kink point in earnings at $\bar{h}_{s,c}$ ¹ which represents to income ceiling imposed by the government prior to 1999, adding one more bracket $[\bar{h}_{s,c}, T]$ (Figure 7.2). That is, in the bracket $[\bar{h}_{s,5}, \bar{h}_{s,c}]$ the tax rate is still τ_6 , whereas in the bracket $[\bar{h}_{s,c}, T]$ the tax rate is $\tau_6 + \tau_c - \tau_6\tau_c$.²

Thus, the net earnings associated with each arc are

$$\text{Net Earnings} = \begin{cases} (1 - \tau_1)wh_s^\delta\epsilon & \text{if } 0 \leq E < \bar{E}_{w,1} \Leftrightarrow 0 \leq h_s < \bar{h}_{s,1} \\ (1 - \tau_i)wh_s^\delta\epsilon & \text{if } \bar{E}_{w,i-1} \leq E < \bar{E}_{w,i} \Leftrightarrow \bar{h}_{s,i-1} \leq h_s < \bar{h}_{s,i}, \quad i = 2, \dots, 5 \\ (1 - \tau_6)wh_s^\delta\epsilon & \text{if } \bar{E}_{w,5} \leq E < \bar{E}_{w,c} \Leftrightarrow \bar{h}_{s,5} \leq h_s < \bar{h}_{s,c} \\ (1 - \tau_6 - \tau_c + \tau_6\tau_c)wh_s^\delta\epsilon & \text{if } E \geq \bar{E}_{w,c} \Leftrightarrow h_s \geq \bar{h}_{s,c} \end{cases}$$

where $\bar{h}_{s,i} = \left(\frac{\bar{E}_{w,i}}{w\epsilon}\right)^{1/\delta}$ and $\bar{E}_{w,i}$ correspond to weekly kink point hours and income which occur at the intersection of two tax brackets (see Figure 7.2), respectively, i varies from 1 to 5. Note that the kinks points depend on δ and ϵ .

Letting h_s^* denote the optimal hours choice along the budget constraint, we follow Hausman [1979] approach to determine h_s^* . This procedure is based on solving a necessary condition for utility maximization along each arc of the budget constraint, as following :

1. For a given δ and ϵ , we calculate $\bar{h}_{s,1} = \left(\frac{\bar{E}_{w,1}}{w\epsilon}\right)^{1/\delta}$.
2. We maximize the indirect utility in (5.20) for $h_{s,1}$ subject to the budget constraint (O_1A_1)

-
1. Note that $\bar{h}_{s,c} > \bar{h}_{s,5}$, because $\bar{h}_{s,c} = \left(\frac{\bar{E}_{w,c}}{w\epsilon}\right)^{1/\delta}$ and $\bar{h}_{s,5} = \left(\frac{\bar{E}_{w,5}}{w\epsilon}\right)^{1/\delta}$, where

$$\frac{300,000\text{CAN \$}}{\text{average weeks worked per year}} = \bar{E}_{w,c} > \bar{E}_{w,5} = \frac{100,000\text{CAN \$}}{\text{average weeks worked per year}}.$$

2. When hours worked are above $\bar{h}_{s,c}$, the taxable income becomes $(1 - \tau_c)wh_s^\delta\epsilon$ and the tax rate is τ_6 . Then, the net income is $(1 - \tau_6)(1 - \tau_c)wh_s^\delta\epsilon = (1 - \tau_6 - \tau_c + \tau_6\tau_c)wh_s^\delta\epsilon$.

with τ_1 as tax rate is *i.e* we solve

$$(1 - \tau_1)w\delta h_{s,1}^{\delta-1}\epsilon \left((1 - \tau_1)wh_{s,1}^\delta\epsilon + y \right)^{\rho-1} - 2^{1-\rho}(T - h_{s,1})^{\rho-1} = 0,$$

for hours worked, $h_{s,1}$.

- a) If $h_{s,1} < \bar{h}_{s,1}$, then it is the optimum ; *i.e* $h_s^* = h_{s,1}$.
- b) Otherwise, if $h_{s,1} \geq \bar{h}_{s,1}$; then we move to the next bracket $[\bar{h}_{s,1}, \bar{h}_{s,2}[$, along the second budget constraint $(\bar{O}_2 A_1 A_2)$ and we solve

$$(1 - \tau_2)w\delta h_{s,2}^{\delta-1}\epsilon \left((1 - \tau_2)wh_{s,2}^\delta\epsilon + \bar{O}_2 + y \right)^{\rho-1} - 2^{1-\rho}(T - h_{s,2})^{\rho-1} = 0,$$

for $h_{s,2}$. \bar{O}_2 denotes the virtual income for the secont tax bracket, namely, $\bar{O}_2 = (\tau_2 - \tau_1)\bar{E}_{w,1}$ ¹. Thus, it depends only on the tax system. Given $h_{s,2}$;

- i. if $h_{s,2} \leq \bar{h}_{s,1}$, then the optimum hours worked is $h_s^* = \bar{h}_{s,1}$.
- ii. Otherwise, if $\bar{h}_{s,1} \leq h_{s,2} < \bar{h}_{s,2}$, then $h_s^* = h_{s,2}$.
- iii. And when $h_{s,2} \geq \bar{h}_{s,2}$ we move to the third tax bracket $[\bar{h}_{s,2}, \bar{h}_{s,3}[$ to determine $h_{s,3}$ and repeat step (b), until last the bracket where $h_s \geq \bar{h}_{s,c}$.
- iv. Along the arc $(\bar{O}_c A_c A)$, we determine $h_{s,c}$ by solving

$$(1 - \tau_6)(1 - \tau_c)w\delta h_{s,c}^{\delta-1}\epsilon \left((1 - \tau_6)(1 - \tau_c)wh_{s,c}^\delta\epsilon + \bar{O}_c + y \right)^{\rho-1} - 2^{1-\rho}(T - h_{s,c})^{\rho-1} = 0;$$

where $\bar{O}_c = \bar{O}_6 + \tau_c(1 - \tau_6)\bar{E}_{w,c}$.

- A. If $h_{s,c} < \bar{h}_{s,c}$, the optimum hours worked is then, $h_s^* = \bar{h}_{s,c}$;
- B. Otherwise, if $h_{s,c} \geq \bar{h}_{s,c}$, then $h_s^* = h_{s,c}$.

7.2.6 Model with income ceilings and taxes estimates

In this section, we present the results of estimates of the model accounting for both income ceilings and taxes. We use the procedure that we describe in Section 7.2.5, to determine predicted hours worked and follow the SMM estimation procedure in Section 7.2 to estimate the parameters. Table 7.3 presents the results. The first column of the table contains the estimates from the subsample of physicians providing 2 services. The second column contains the estimates from the subsample of physicians providing 3 services. The third column contains the estimates from the subsample of physicians providing 4 services.

1. At the kink point $\bar{h}_{s,1}$, net income along $(\bar{O}_1 A_1)$ and $(\bar{O}_2 A_1 A_2)$ must be equal, leading to

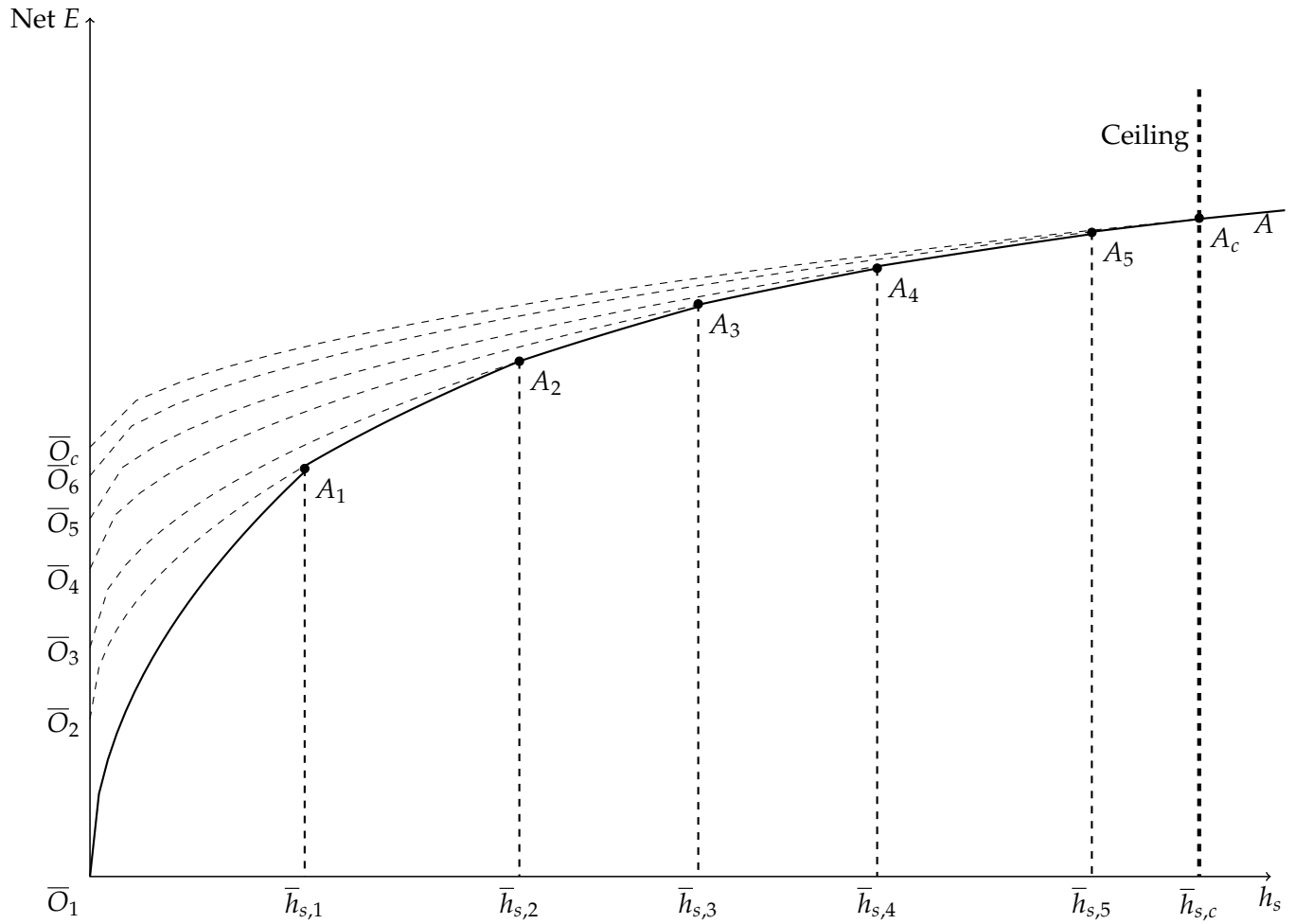
$$\bar{O}_2 + (1 - \tau_2)w\bar{h}_{s,1}\epsilon = 0 + (1 - \tau_1)w\bar{h}_{s,1}\epsilon \Leftrightarrow \bar{O}_2 = \bar{O}_2 = (\tau_2 - \tau_1)w\bar{h}_{s,1}\epsilon = (\tau_2 - \tau_1)\bar{E}_{w,1}.$$

In general, the virtual income

$$\bar{O}_i = \sum_{j=2}^i (\tau_i - \tau_{j-1})\bar{E}_{w,j-1}$$

with $i = 2, \dots, 6$.

FIGURE 7.2 – Budget constraint with income ceilings and taxes



For physicians providing 2 services, the estimate of ρ is -0.38, and statistically different from zero. It is different from ρ estimated with the basic unrestricted model in Table 7.1. The estimate of δ is 0.57, significant and smaller than the delta estimated from both the unrestricted model (0.69).

For physicians providing 3 services, the estimates of δ are rather similar in Table 7.1 and 7.3, it is about 0.75 – 0.77; they are statistically significant at the 1% level. ρ is estimated at -0.16 different from ρ estimated from the basic unrestricted model (-0.21); it is significantly negative and between zero and one in absolute value.

The last column of the Table 7.3 shows that the estimate of ρ is -0.27 and is significant at 1% level. This estimate is rather different from the one obtained using the unrestricted model. Also, there is a slight difference between the estimates of δ . It is estimated at 0.73 with taxes and income ceilings, and 0.92 with the unrestricted model. The estimates of b_j are positive but greater when accounting for income ceilings and taxes in the estimation.

The p-values (in square brackets in Table 7.3) of the J-test statistics associated with the use of dummies of age, marginal tax rate and market return as instruments; are greater than 5%, suggesting that, we cannot reject null hypothesis that the instruments are exogenous.

However, when accounting for income ceilings and taxes the values of the GMM function are greater than when estimating the basic unrestricted model.

TABLE 7.3 – SMM estimates of the full model with income ceilings and taxes

Par.	2 services	Par.	3 services	Par.	4 services
ρ	-0.38*** (0.025)	ρ	-0.16*** (0.001)	ρ	-0.27*** (0.017)
δ	0.57*** (0.003)	δ	0.75*** (0.0003)	δ	0.73*** (0.003)
c_0	0.004 (0.321)	c_0	0.01 (0.029)	c_0	0.01 (0.251)
c_1	0.01*** (0.002)	c_1	-0.01*** (0.001)	c_1	-0.005*** (0.001)
c_2	0.11*** (0.030)	c_2	-0.03 (0.023)	c_2	-0.01 (0.031)
b_1	2.49*** (0.015)	b_1	4.58*** (0.003)	b_1	2.69*** (0.013)
b_2	9.33*** (0.102)	b_2	4.15*** (0.020)	b_2	3.68*** (0.039)
b_3	3.21*** (0.033)	b_3	13.55*** (0.066)	b_3	2.80*** (0.029)
		b_5	0.69 (6.52)	b_4	3.82*** (0.053)
		b_6	0.56 (4.030)	b_5	1.05*** (0.214)
J-test statistic	11.542 [0.775]		15.751 [0.542]		10.550 [0.721]
Obs.	1,300		1,283		588

The p-value for the test of overidentifying restrictions is shown in brackets

Standard errors in parentheses

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

7.2.7 Elasticities

Estimation of the complete structural model allows us to provide a complete characterization of the reaction of physicians to monetary incentives,. Table 7.4 to 7.6 provide results on the elasticities of practice variables with respect to non-labour income, and fees per service using Table 3.1 formulas, based on unrestricted estimates. In Table 7.4, we present results for

physicians who provide 2 services. Table 7.5 and Table 7.6 contains elasticities for physicians who provide 3 and 4 services respectively. In each table the first column presents the income elasticity, $\zeta_{k/y}$, for each practice variable : Weekly Total hours, Weekly clinical hours, hours devoted to services production and quantities of services. The following panel presents three elasticities for each practice variable, k . The first column contains the uncompensated price elasticity, ζ_{k/α_i} , the second column presents the compensated price elasticity, $\tilde{\zeta}_{k/\alpha_i}$ and third column presents the total income elasticity, $\frac{\alpha_i A_i}{y} \zeta_{k/y}$.

The results from the first columns of Table 7.4 to 7.6 indicate that, as expected, physicians' weekly total hours of work, clinical weekly hours of work, hours devoted to each service production, and the volume of services are negatively affected by an increase in non-labor income. Overall, for 2 services case, the elasticities are modest (in absolute value) though, ranging between -0.005 for weekly total hours of work and -0.030 for clinical hours worked. Moreover, the volume of service 1 and 2', decrease with non-labour income but very slightly, with an elasticity of -0.021. For 3 services case, the elasticities are more modest, ranging between -0.001 for weekly total hours worked and -0.008 for the clinical hours. The income elasticities of volume of service 1, 2 and 3' is quite small (-0.006). For 4 services case, the elasticities goes from -0.001 for weekly total hours of work to -0.007 for clinical hours worked. Moreover the volume of service 1, 2, 4 and 4' decrease with the non-labour income, with an elasticity of -0.006.

TABLE 7.4 – Elasticity of practice variables 2 services case

	Income	Fee per unit of service 1			Fee per unit of service 2'		
	$\zeta_{k/y}$	ζ_{k/α_1}	$\tilde{\zeta}_{k/\alpha_1}$	$\frac{\alpha_1 A_1}{y} \zeta_{k/y}$	$\zeta_{k/\alpha_{2'}}$	$\tilde{\zeta}_{k/\alpha_{2'}}$	$\frac{\alpha_{2'} A_{2'}}{y} \zeta_{k/y}$
Weekly Total hours (h_t)	-0.005	0.001	0.021	-0.020	0.011	0.168	-0.157
Weekly clinical hours (h_s)	-0.030	0.010	0.117	-0.107	0.066	0.881	-0.815
Hours service 1 (h_1)	-0.030	2.975	3.083	-0.108	-2.899	-2.084	-0.815
Hours service 2 (h_2)	-0.030	-0.333	-0.225	-0.107	0.410	1.224	-0.814
Vol. service 1 (A_1)	-0.021	2.076	2.151	-0.075	-2.022	-1.454	-0.568
Vol. service 2 (A_2)	-0.021	-0.232	-0.157	-0.075	0.286	0.854	-0.568

Results from second and third panel of Table 7.4 indicate that uncompensated weekly total hours and clinical hours elasticities with respect to changes in the fee for service 1 (2') are 0.001 (0.011) and 0.01 (0.066) respectively. This suggests that physicians' labour supply curves for weekly total hours and clinical hours are upward sloping but with a modest response of these variables to a change in the fee rate. Interestingly, the compensated elasticities are positive, although physicians react more to an increase in the fee of service 2' than service 1, regarding both total hours worked and clinical hours. The elasticities are estimated at 0.021 (0.168) and 0.117 (0.881) respectively with respect of service 1 (2') fee. The own-price

uncompensated hours spent providing service 1 and volume of service 1 elasticities are positive and larger (2.975 and 2.076 respectively) than on hours spent providing service 2' and on the volume of service 2' (=0.41 and 0.286 respectively). Thus, the labour supply curve for services (hours and volume) is upward sloping. The compensated own-price services (hours and volume) elasticity is positive as expected [see eq. (3.25)], and quite large, ranging from 0.854 for volume of service 2' to 2.151 for volume of service 1.

TABLE 7.5 – Elasticity of practice variables 3 services case

	Income	Fee per unit of service 1			Fee per unit of service 2			Fee per unit of service 3'		
	$\zeta_{k/y}$	ζ_{k/α_1}	$\tilde{\zeta}_{k/\alpha_1}$	$\frac{\alpha_1 A_1}{y} \zeta_{k/y}$	ζ_{k/α_2}	$\tilde{\zeta}_{k/\alpha_2}$	$\frac{\alpha_2 A_2}{y} \zeta_{k/y}$	$\zeta_{k/\alpha_{3'}}$	$\tilde{\zeta}_{k/\alpha_{3'}}$	$\frac{\alpha_{3'} A_{3'}}{y} \zeta_{k/y}$
Weekly Total hours (h_t)	-0.001	-0.010	0.053	-0.063	-0.013	0.064	-0.077	-0.004	0.020	-0.024
Weekly clinical hours (h_s)	-0.008	-0.055	0.283	-0.338	-0.070	0.355	-0.425	-0.022	0.110	-0.132
Hours service 1 (h_1)	-0.008	2.682	3.020	-0.338	-1.343	-0.918	-0.425	-1.486	-1.354	-0.132
Hours service 2 (h_2)	-0.008	-1.687	-1.349	-0.338	3.026	3.451	-0.425	-1.486	-1.354	-0.132
Hours service 3' ($h_{3'}$)	-0.008	-1.687	-1.349	-0.338	-1.343	-0.918	-0.425	2.883	3.015	-0.132
Vol. service 1 (A_1)	-0.006	2.068	2.329	-0.261	-1.036	-0.708	-0.328	-1.146	-1.044	-0.102
Vol. service 2 (A_2)	-0.006	-1.301	-1.040	-0.261	2.334	2.662	-0.328	-1.146	-1.044	-0.102
Vol. service 3' ($A_{3'}$)	-0.006	-1.301	-1.040	-0.261	-1.036	-0.708	-0.328	2.2243	2.325	-0.102

Also both uncompensated cross-price elasticities of hours (and volume) are negative, suggesting that hours devoted to service 1 and 2' are gross complements. A closer look at the calculations reveals that, a compensated increase in the fee per unit of service 1 negatively affects the hours devoted to the production of service 2' as well as its quantity, with an elasticities of -0.225 and -0.157 respectively. Notice also that the compensated cross-price elasticity of service 1 (hours and volume) with respect to fee of service 2' is negative and quite high in absolute value (= -2.084 for hours and = -1.454 for volume). This indicates that a compensated increase in the fee of service 2' induces the physician to spend less time in producing service 1 and more time to perform service 2'.

The next results in Table 7.5 provides the elasticities for physicians providing 3 services. Notice the fee rises decreased both, the number of weekly hours worked and the weekly clinical hours, with an modest uncompensated price elasticities, ranging between -0.013 and -0.004 for the total hours and, -0.070 and -0.022 for clinical hours. Moreover, the compensated price elasticities are positive, and quite higher for the clinical hours (from 0.11 to 0.355). The own-price uncompensated hours (volume) per service elasticities are positive and large, ranging from 2.682 (2.068) for hours (volume) spent providing service 1 to 3.026 (2.334) for hours (volume) spent providing service 2. All the own-price compensated elasticities are positive, as expected. Yet, the cross-price uncompensated elasticities are negative for both hours per service and volume of services, suggesting that services are gross complements.

Table 7.6 shows results for physicians who perform 4 services. Both total hours and clinical hours decrease slightly when the fee per service rises. The elasticities are small, ranging from -0.005 (-0.024) to -0.023 (-0.115) for total hours (clinical hours). The own-price uncompensa-

ted elasticities are again all positive and much larger than in the other cases. The elasticities are ranging from 7.107 to almost 12.0 for hours ; and from 6.526 to 11.0 for volume. Also, the cross-price uncompensated elasticities are negative.

In short, our results on elasticities suggest that physicians react to incentives in the directions predicted by the theory. However, the income elasticity are small for all the practice variables. The uncompensated own-price elasticities are large and positive for hours spent providing services and volume of services. On the other hand, the compensated hours per service and service volume own-price elasticities are positive and considerably larger. The uncompensated cross-price elasticities are also large but negative. Another important result is that, while total hours of work and clinical hours are slightly (and negatively) affected by a uncompensated change in the fee for service, these variables seem to be quite strongly (and positively) influenced by a compensated change in the fee for service.

7.3 Policy simulations

Estimation of the structural model allows us to predict how physicians would respond to recent price increases enacted by the government. Given knowledge of the model parameters, we simply calculate the predicted behaviour. We use our model to simulate the effect of recently observed prices increase in physician contract. In 2013 the government of Quebec increased the prices paid for physician services by 32%.¹ We use our model to simulate the effect of this increase, simultaneously increasing prices by 32%. The simulations results refer to elasticities and are presented in Table 7.7.

The impact of price changes is measured in terms of aggregate elasticities – the ratio of the percentage changes in practice variables to the percentage change in the prices (32%). To do so, we first calculate the expected values of practice variables before the prices increase based on the estimates of our model. Then, we use the model to predict the values of practices variables after the prices increase. Having the before and after values of practice variables, we averaged them and the computation of elasticities is straightforward. We perform the simulation using the estimates in Table 7.3, accounting for income ceilings and taxes. The rows 1, 3 and 5 provide our benchmark ; this is computed as the average practice choice simulated from the estimated model.

Results from the first panel of Table 7.7 indicate that, for physicians providing 2 services, the average total weekly hours work, clinical weekly hours of work, hours devoted to produce each service, and the ensuring volume of services would be negatively affected by an increase in prices. The simulated elasticities range between -0.01 for total hours worked and

1. Meanwhile, the average quantity of services has declined by 5% [Contandriopoulos and Perroux, 2013]. This implies an elasticity of $-5\%/32\% = -0.16$.

-0.06 for clinical hours worked. The volume of services provided would decrease, with an elasticity of -0.03 for service 1 and -0.04 for service 2'.

The second panel of Table 7.7 shows that physicians providing 3 services would also decrease their activity level. They would decrease weekly total hours worked and clinical hours, with an elasticity of -0.01 and -0.03, respectively. They would decrease the hours devoted to each service. Therefore, the volume of services would decrease, with an elasticity of -0.02.

The last panel shows, that physicians providing 4 services would decrease the weekly hours worked, with an elasticity of -0.03. They would also decrease clinical hours and hours devoted to each service by the same rate (elasticity=-0.13). The volume of services would decrease, with an elasticity of -0.10.

In short, the simulation results suggest that when physician are paid FFS, a policy increasing the price of services (simultaneously) would reduce the total hours worked and clinical hours worked. What is more, physicians would reduce volume of services provided, this result qualitatively similar to those reported by [Contandriopoulos and Perroux \[2013\]](#) using data on Quebec physicians. The average volume elasticity is -0.035, -0.02, -0.10, for 2 services, 3 services and 4 services respectively.

Therefore, increasing services fees when physician are paid FFS creates a disincentive for physicians to work and provide services. Our findings are important for policymakers because, it provides a direct evidence of the importance of the income effect on the response of physicians to monetary incentives. This is also consistent with the "target income hypothesis" [[Kantarevic et al., 2008](#), [Rizzo and Blumenthal, 1994](#), [McGuire and Pauly, 1991](#)].

7.4 Conclusion

We have developed and estimated a structural labour supply model that incorporates the technology of medical services production and the allocation of hours across services into the standard consumption/leisure trade-off. An equilibrium model provides us with a price index for clinical hours when they are optimally distributed across different medical services. We use this index to predict physician's earnings conditional to clinical hours worked. Our model also provides an implicit function defining optimal clinical hours worked. We have applied our model to analyze the response of fee-for-service physicians to change in fees using data from the Province of Quebec. To estimate the parameters of the model we have used simulated methods of moments. We matched the predicted and observed first moment of both earnings, services and clinical hours. This requires solving the complete model, including optimal clinical hours worked. We then used the estimates to calculate the global substitution (compensated and uncompensated) and income effects.

Our results suggest that physicians do react to incentives. A change in price leads physi-

cians to allocate more working hours to the service whose price has risen. The own-price elasticities of substitution of hours (volume) are positive, while the cross-price elasticities of substitution of hours (volume) are negative. We also provide a direct evidence of income effect existence these effects are very small. Moreover, the fee rise affects very slightly weekly total hours and clinical hours (extensive margin).

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. However, increasing medical services fees would not lead physicians to increase substantially their time spent at work. Such a change in price will affect the time allocation across services : physicians will spend more time providing the more lucrative services and reduce the time for the other services.

We have used our estimates to simulate how physicians would respond to price increases enacted by the government. The results of our simulations suggest that a reform increasing all services fees creates a disincentive for physicians to work and provide service – total hours worked, clinical hours and the volume of services provided would decrease. The fee increases simulation results, highlights the importance of income effect in the responsiveness of physicians to fee rises. Our findings are important for policymakers because, it provides a direct evidence of the importance of income effect on the response of physicians to monetary incentives. Ignoring such changes would vastly misrepresent the effects of policies on the supply of health services.

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

TABLE 7.6 – Elasticity of practice variables 4 services case

	Income	Fee per unit of service 1			Fee per unit of service 2			Fee per unit of service 4			Fee per unit of service 4'		
		$\zeta_{t/y}$	ζ_{t/α_1}	$\frac{\alpha_1 A_1}{y} \zeta_{t/y}$	ζ_{k/α_2}	$\tilde{\zeta}_{k/\alpha_2}$	$\frac{\alpha_2 A_2}{y} \zeta_{k/y}$	ζ_{k/α_4}	$\tilde{\zeta}_{k/\alpha_4}$	$\frac{\alpha_4 A_4}{y} \zeta_{k/y}$	$\zeta_{k/\alpha_{4'}}$	$\tilde{\zeta}_{k/\alpha_{4'}}$	$\frac{\alpha_{4'} A_{4'}}{y} \zeta_{k/y}$
Weekly Total hours (h_t)	-0.001	-0.005	0.006	-0.011	-0.019	0.025	-0.044	-0.023	0.030	-0.053	-0.020	0.026	-0.046
Weekly clinical hours (h_s)	-0.007	-0.024	0.032	-0.056	-0.096	0.126	-0.222	-0.115	0.152	-0.267	-0.100	0.131	-0.231
Hours service 1 (h_1)	-0.007	10.077	10.134	-0.057	-5.116	-4.894	-0.222	-5.055	-4.787	-0.268	-0.241	-0.010	-0.231
Hours service 2 (h_2)	-0.007	-2.146	-2.089	-0.057	7.107	7.329	-0.222	-5.055	-4.787	-0.268	-0.241	-0.010	-0.231
Hours service 4 (h_4)	-0.007	-2.146	-2.090	-0.056	-5.116	-4.894	-0.222	7.168	7.436	-0.268	-0.241	-0.010	-0.231
Hours service 4' ($h_{4'}$)	-0.007	-2.146	-2.090	-0.056	-5.116	-4.894	-0.222	-5.055	-4.787	-0.268	11.982	12.213	-0.231
Vol. service 1 (A_1)	-0.006	9.253	9.305	-0.052	-4.697	-4.493	-0.204	-4.642	-4.396	-0.256	-0.221	-0.009	-0.212
Vol. service 2 (A_2)	-0.006	-1.971	-1.919	-0.052	6.526	6.730	-0.204	-4.642	-4.396	-0.246	-0.221	-0.009	-0.212
Vol. service 4 (A_4)	-0.006	-1.971	-1.919	-0.052	-4.697	-4.493	-0.204	6.582	6.828	-0.246	-0.221	-0.009	-0.212
Vol. service 4' ($A_{4'}$)	-0.006	-1.971	-1.919	-0.052	-4.697	-4.493	-0.204	-4.642	-4.396	-0.246	11.002	11.214	-0.212

TABLE 7.7 – Price increases (32%) simulation with model accounting for income ceilings and taxes estimates

2 services										
	Average Hours per Week				Average Quantities					
	h_1	$h_{2'}$	h_s	h_t	A_1	$A_{2'}$				
1. Benchmark	5.23	37.68	42.91	105.46	5.55	63.71				
2. Elasticities	-0.05	-0.06	-0.06	-0.01	-0.03	-0.04				
3 services										
	Average Hours per Week					Average Quantities				
	h_1	h_2	$h_{3'}$	h_s	h_t	A_1	A_2	$A_{3'}$		
3. Benchmark	17.73	12.85	14.18	44.75	106.38	36.34	25.81	75.74		
4. Elasticities	-0.03	-0.03	-0.03	-0.03	-0.01	-0.02	-0.02	-0.02		
4 services										
	Average Hours per Week						Average Quantities			
	h_1	h_2	h_3	$h_{4'}$	h_s	h_t	A_1	A_2	A_3	$A_{4'}$
5. Benchmark	7.66	26.25	11.09	4.28	49.28	108.64	11.85	40.13	16.21	7.22
6. Elasticities	-0.13	-0.13	-0.13	-0.13	-0.13	-0.03	-0.10	-0.10	-0.10	-0.10

Note : The Benchmark quantities are measured in Thousands of (2000) Can. Dollars.

Chapitre 8

Estimation of Productivity Profiles

In this Chapter, we modify the specification of our model to take into account the relationship between the productivity of physicians and their experience. We estimate a selection model to correct for non-randomly missing observations using data from on FFS physicians, practising in Quebec between 1996 and 2002.

The rest of the chapter is organized as follows. The next section explains why it is important to have physicians productivity profiles. Section 8.2 develops the structural model. Section 8.3 describes the data and presents descriptive statistics. Section 8.4 explains our empirical strategy, while Section 8.5 discusses the results. Section 8.6 discusses the implications of our results in term of policy and the last section concludes.

8.1 Motivation

Waiting times for health care are a major health policy concern in many industrialized countries. In Quebec,¹ the median time between referral from a general practitioner and an appointment with specialist was 7.3 weeks in 2012, compared to 2.9 weeks in 1993.² Meanwhile, the number of physician increased 21.3% over the same period. Thus, despite provincial wait time strategies, high levels of health expenditure and the increasing number of physicians, it is clear that patients in Quebec are still waiting too long to receive treatment. Long-term planning of the number of physicians needed to meet societies demand for health care, requires that the government gain knowledge of the determinants of physician productivity. An important aspect of this is knowing how productivity changes as the age structure of physicians is changing. In this chapter, I measure how physician productivity changes over the course of their career as they develop experience treating patients. This change in productivity is attributable to human capital accumulation and the learning-by-doing. These

1. Health care falls under the jurisdiction of provincial governments under the Canadian constitution.

2. Waiting Your Turn : Wait Times for Health Care in Canada, 2012 Report

mechanisms allow the physician to become more efficient in performing diagnoses and treating patients.

Evidence that does exist on these effects suggests that physician productivity does increase with experience. [Dormont and Samson \[2008\]](#) studied French physicians using primary care physicians data. [Fjeldvig \[2009\]](#) studied Norwegian physicians using specialist and primary care physicians data. However, other work highlights how years of experience can affect the quality of services provided [[Elstad et al., 2010](#)].¹ These results suggest that physician productivity increases with experience. To date, little is known as to the nature of these profiles for Canadian physicians.

In many studies wage profiles have traditionally been interpreted as productivity profiles. See for example [Hutchens \[1989\]](#). However, in most data sets, the link between wages and productivity is unknown. As well, several well-known papers have derived positively sloped wage profiles in the absence of any productivity growth [[Salop and Salop, 1976](#), [Lazear, 1979](#), [Jovanovic, 1979](#)]. To avoid this interpretation problem, I use data from fee-for-service (FFS) physicians as in [Gunderson \[1975\]](#), and [Weiss \[1994\]](#). In Quebec, before 1999, the vast majority of physicians (92%) were paid according to a fee-for-service scheme, under which physicians receive a fee for each service provided. This compensation system provides a natural link between observed earnings and physician productivity that I exploit to estimate how physician productivity changes with experience.

I develop and estimate a structural model of physician behaviour with multitasking. This model extends the one presented in Chapter 3, to incorporate experience directly into the production function for physician services. That allows me to estimate how productivity changes with physician experience.

8.2 The Model

I present a structural model of labour supply behaviour under linear contracts. My goal is to motivate my empirical analysis and my estimation strategy within a simplified setting. The number of services j provided by physician i is assumed to be a function of hours devoted to produce j , h_{ij} , and physician personal characteristics X_i . The production function is given by

$$A_{ij} = b(X_i)h_{ij}^\delta, \quad (8.1)$$

where δ determines the marginal return to time spent by the physician to produce a service.² This marginal return is common across services. I assume $\delta \in (0, 1)$ so that hours

1. The parallel, but related, empirical literature on worker productivity profiles provides evidence of increasing concave productivity profiles [[Shearer, 1996](#)]; see [Hutchens \[1989\]](#) for a review of this literature.

2. An interesting generalization can be obtained by allowing δ to be a function of the physician personal characteristics X_i .

spent seeing patients increase output (services) at a decreasing rate. For the purposes of this paper, X_i includes the variable experience and its square. If the partial derivative of $b(X_i)$ with respect to experience is positive, then the quantity of services produced by a physician increases in experience. Note that $b(X_i)$ is common across services.

Physician utility is defined over consumption M , pure leisure, denoted by l_p , and "on-the-job" leisure, l_o . The latter includes all those activities at work except seeing patients or providing services (clinical work), such as teaching, research and administrative tasks, that are not remunerated under a FFS scheme. It may be seem rather strange to call these activities "leisure". However, since such activities do not increase income, it is reasonable to assume that they increase utility.¹ Physician's preferences are given by

$$U(M, l_o, l_p) = (M^\rho + l_o^\rho + l_p^\rho)^{\frac{1}{\rho}}. \quad (8.2)$$

Here $l_o = h_t - h_s$, h_t is total hours spent at work and h_s , denote time spent providing services. The pure leisure is $l_p = T - h_t$ with T the maximum amount of time available, and $-\infty < \rho < 1$. I allow pure leisure and "on-the-job" leisure to be perfect substitutes. The optimization program, conditional on a FFS contract is

$$\begin{aligned} \max_{\{M, h_1, h_2, h_t, h_s\}} U &= (M^\rho + (h_t - h_s)^\rho + (T - h_t)^\rho)^{\frac{1}{\rho}} \\ \text{s.t. } (i) \quad M &= \alpha_1 A_1 + \alpha_2 A_2 + y \\ (ii) \quad A_j &= b(X) h_j^\delta, \quad j = 1, 2 \\ (iii) \quad h_s &= h_1 + h_2 \end{aligned} \quad (8.3)$$

Where (i) is the budget constraint with α_j the fee paid for service A_j and y non-labour income. Substituting (ii) into (i), and imposing $h_s = h_1 + h_2$, we can rewrite the utility function as :

$$U(h_1, h_s, h_t) = \left(\left[\alpha_1 b(X) h_1^\delta + \alpha_2 b(X) (h_s - h_1)^\delta + y \right]^\rho + (h_t - h_s)^\rho + (T - h_t)^\rho \right)^{\frac{1}{\rho}}. \quad (8.4)$$

The first-order condition for the choice of h_1 is

$$\alpha_1 h_1^{\delta-1} - \alpha_2 (h_s - h_1)^{\delta-1} = 0 \quad (8.5)$$

Solving (8.5) gives

$$h_1(h_s) = \frac{P_1}{P_1 + P_2} h_s \quad (8.6)$$

1. For instance, performing teaching or research activities may increase the physician's influence and prestige.

where $P_j = (\alpha_j)^{1/(1-\delta)}$; $j = 1, 2$. As we have imposed $h_s = h_1 + h_2$, the optimal choice of hours devoted to service 2 is

$$h_2(h_s) = \frac{P_2}{P_1 + P_2} h_s. \quad (8.7)$$

The first-order condition for h_t is

$$(h_t - h_s)^{\rho-1} - (T - h_t)^{\rho-1} = 0. \quad (8.8)$$

Solving (8.8) gives

$$h_t = \frac{T + h_s}{2} \quad (8.9)$$

Substituting back (8.6), and (8.7) into (8.4) gives an indirect utility as a function of h_s

$$V(h_s) = \left((b(X)wh_s^\delta + y)^\rho + 2^{1-\rho}(T - h_s)^\rho \right)^{\frac{1}{\rho}}, \quad (8.10)$$

here $w = (P_1 + P_2)^{1-\delta}$ determines the marginal return to an hour worked when that hour is optimally allocated across services.

The first-order condition for h_s is

$$b(X)w\delta h_s^{\delta-1}(b(X)wh_s^\delta + y)^{\rho-1} - 2^{1-\rho}(T - h_s)^{\rho-1} = 0 \quad (8.11)$$

8.3 Data and Descriptive Statistics

I use panel data on specialist physicians practicing in Quebec between 1996 and 2002, that I described in Chapter 2. The final sample contains 1,231 physicians performing 221 services. I dropped the cohort of physician aged over 70 years old, because the retirement age for specialists in Quebec is in average 71 years.¹ This eliminated 16 physicians and the final sample contains 1,215 physicians performing 221 different services.

8.3.1 Descriptive Statistics

The matched sample consists of 3,123 observations on 1,215 specialists performing 221 services² between 1996 and 2002.

Physician experience is measured in years. It is calculated as the total number of years worked since obtaining a regular permit to practice medicine from the College of Physicians of

1. Source : *Le Médecin du Québec*, volume 46, numéro 5, mai 2011

2. Note the number of services is different from Table 4.1. Because a service code or price can change with the speciality, for example, consultation price and code are not the same within the specialities.

Quebec. There are 10 groups of age ranked from 1 to 10. The value 1 implies 30 years old and less and the value 10 means 70 years old and more. The age interval among each group is five years.

The physicians in Quebec was quite experienced. The average age in the sample is 5.09 meaning that the average age is between 45 and 49 years old, the median age is also between 45 and 49 years old. Similarly, average experience in the sample is 20 years, and the median level of experience is 21. Table 8.1 presents average and median values for age and experience.

TABLE 8.1 – Mean experience profiles

	Mean	Median
Age	5.09	5
Experience	20.47	21

Table 8.2 gives the sample means of earnings and clinical hours worked according to years of experience. These results are consistent with human capital theory, since physicians learn through direct experience (learning by doing). Namely, they produce more services when they gain more experience. A physician with zero-experience produces 90.23 CAD dollars of services. Then his or her productivity increases with the number of years he or she has been practicing. At 25 years of experience, the physician reach his or her highest value of productivity (here 129,26 CAD dollars of services). After 25 years of experience, his or her productivity starts decreasing until retirement.

TABLE 8.2 – Mean experience profiles

Experience (Years)	Mean Earnings (Thousands CAD \$)	Mean Hours	Observations
0	90.23	47.93	42
5	108.39	47.36	246
10	110.50	44.24	351
15	106.73	44.18	557
20	120.91	44.24	576
25	129.26	45.01	621
30	119.88	44.01	435
35	117.68	44.05	212
40	103.46	36.15	76
45	58.65	27.00	7
Average	116.55	44.40	3123

8.4 Empirical Model

I consider an empirical version of the model developed in Section 8.2. Production of service j is assumed to be a function of hours devoted to it h_j , a function of physician personal characteristics $b(X)$ and a multiplicative production shock ϵ_j . The production shock captures random events which could affect physicians behaviour and how complex the task can be. The output of a physician in service j is now

$$A_j = b(X)h_j^\delta \epsilon_j. \quad (8.12)$$

Data indicates that sampled physicians can provide 2 services, 3 services or 4 services. Let

$$D_k = \begin{cases} 1 & \text{if physician performs } k(= 2, 3, 4) \text{ services} \\ 0 & \text{otherwise.} \end{cases} \quad (8.13)$$

Note that there is heterogeneity between physicians providing the same number of services. Among physicians providing 2 services there are two types of physicians. The first type consists of physicians who provide services 1 and 2. The second type of physicians is those who provide services 1 and 3. I denote by d_{12} and d_{13} the dummies that indicate that a physician performs, respectively, services 1 and 2, and services 1 and 3. For physicians providing 3 services, there is 3 separated sets of physicians. Let $d_{12j} = 1$ if a physician performs services 1, 2 and $j = 3, 5, 6$ and zero otherwise. For physicians providing 4 services, there is 2 separated sets of physicians. Let d_{124j} the dummy variable capturing whether the physician is providing services 1, 2, 4 and $j = 3, 5$ or not. That is, the utility function is

$$U = ([D_2(\alpha_1 A_1 + d_{12}\alpha_2 A_2 + d_{13}\alpha_3 A_3) + D_3(\alpha_1 A_1 + \alpha_2 A_2 + d_{123}\alpha_3 A_3 + d_{125}\alpha_5 A_5 + d_{126}\alpha_6 A_6) + D_4(\alpha_1 A_1 + \alpha_2 A_2 + \alpha_4 A_4 + d_{1243}\alpha_3 A_3 + d_{1245}\alpha_5 A_5) + y]^\rho + [h_t - h_s]^\rho + [T - h_t]^\rho)^{\frac{1}{\rho}}. \quad (8.14)$$

Taking into account the hours constraint $D_2(h_1 + d_{12}h_2 + d_{13}h_3) + D_3(h_1 + h_2 + d_{123}h_3 + d_{125}h_5 + d_{126}h_6) + D_4(h_1 + h_2 + h_4 + d_{1243}h_3 + d_{1245}h_5) = h_s$ and maximizing utility with respect to h_j , $j = 1, 2, 3, 4, 5, 6$ and h_t conditional to h_s gives

$$h_1(h_s) = \frac{\tilde{P}_1}{\tilde{P}} h_s; \quad (8.15)$$

$$h_2(h_s) = \frac{D_2 d_{12} \tilde{P}_2 + D_3 \tilde{P}_2 + D_4 \tilde{P}_2}{\tilde{P}} h_s; \quad (8.16)$$

$$h_3(h_s) = \frac{D_2 d_{13} \tilde{P}_3 + D_3 d_{123} \tilde{P}_3 + D_4 d_{1234} \tilde{P}_3}{\tilde{P}} h_s; \quad (8.17)$$

$$h_4(h_s) = \frac{D_4 \tilde{P}_4}{\tilde{P}} h_s; \quad (8.18)$$

$$h_5(h_s) = \frac{D_3 d_{125} \tilde{P}_5 + D_4 d_{1245} \tilde{P}_5}{\tilde{P}} h_s; \quad (8.19)$$

$$h_6(h_s) = \frac{D_3 d_{126} \tilde{P}_6}{\tilde{P}} h_s; \quad (8.20)$$

$$h_t(h_s) = \frac{T + h_s}{2}; \quad (8.21)$$

where $\tilde{P}_j = (\alpha_j \epsilon_j)^{1/(1-\delta)}$; and

$$\tilde{P} = \tilde{P}_1 + D_2(d_{12}\tilde{P}_2 + d_{13}\tilde{P}_3) + D_3(\tilde{P}_2 + d_{123}\tilde{P}_3 + d_{125}\tilde{P}_5 + d_{126}\tilde{P}_6) + D_4(\tilde{P}_2 + \tilde{P}_4 + d_{1243}\tilde{P}_3 + d_{1245}\tilde{P}_5).$$

8.4.1 Earnings equation

I assume common shocks to simplify the analysis.; i.e, $\epsilon_j = \epsilon$; $j = 1, 2, \dots, 6$. That means, the productivity of each physician is affected in the same way by the complexity of the medical services, new technologies or new care procedures. Substituting the ϵ 's back into physician's optimal choices, the predicted earnings in period t can be written

$$\text{Earnings} = b(X) w h_s^\delta \epsilon, \quad (8.22)$$

where $P_j = (\alpha_j)^{1/(1-\delta)}$ and $w = (D_2 w_2 + D_3 w_3 + D_4 w_4)^{1-\delta}$. Where $w_2 = P_1 + d_{12} P_2 + d_{13} P_3$; $w_3 = P_1 + P_2 + d_{123} P_3 + d_{125} P_5 + d_{126} P_6$; $w_4 = P_1 + P_2 + P_4 + d_{1243} P_3 + d_{1245} P_5$. Note that w can be interpreted as a price index of an hour spend seeing patients. The indirect utility can also be written as a function of w and h_s

$$V(h_s) = (b(X) w h_s^\delta \epsilon + y)^\rho + 2^{1-\rho} (T - h_s)^\rho. \quad (8.23)$$

The first-order condition for indirect utility maximization in the choice of h_s is

$$b(X) w \delta h_s^{\delta-1} \epsilon (b(X) w h_s^\delta \epsilon + y)^{\rho-1} - 2^{1-\rho} (T - h_s)^{\rho-1} = 0, \quad (8.24)$$

suggesting that clinical hours, h_s , is endogenous since h_s depends on ϵ .

8.4.2 Estimation strategy

The log earnings equation for the i th physicians at time t is given by

$$\ln(\text{Earnings}_{it}) = \ln b(X_{it}) + \ln w_{it} + \delta \ln h_{s,it} + e_{it1}, \quad (8.25)$$

where $e_{it1} = \ln \epsilon_{it}$ is an idiosyncratic error. To specify $\ln b(X_{it})$ let

$$\ln b(X_{it}) = x_{it}\beta + c_{i1}; \quad (8.26)$$

where x_{it} is a 1x2 vector containing physician potential experience and its square, β is a 2x1 vector of parameters, and c_{i1} is a time-constant unobserved effect. Note that variables in x_{it} are assume to be exogenous. Substituting $\ln b(X_{it})$ back into (8.25) gives

$$\ln(\text{Earnings}_{it}) = x_{it}\beta + \ln w_{it} + \delta \ln h_{s,it} + c_{i1} + e_{it1}. \quad (8.27)$$

Recall that the final earnings sample consists of 588 specialists, or 3,123 observations over the 7-year period (1996-2002) instead of 4,116 for this period. Thus about 24% of earnings data are missing due to non-participation.¹ Give this, the estimation strategy should take into account the unbalanced panel issue, in addition to the endogeneity of clinical hours as suggested by (8.24). The partial observability of earnings is linked to the fact that one physician (paid by FFS scheme) for a certain year, t , did not spend a time seeing patients. This implies that for this year t , the percentage of his working time devoted to clinical activities is zero. This leads to incidental truncation (Gronau, 1974) which I model by specifying a selection rule

$$s_{it} = 1[h_{s,it}^* > 0] = 1[x_{it}\mu + \theta'\alpha_{it} + z_t\zeta + c_{i2} + e_{it2} > 0], \quad (8.28)$$

where $s_{it} = 1$ is a selection indicator that equals one if earnings is observed and is zero otherwise, $h_{s,it}^*$ is the latent variable for clinical hours, z_t a vector of exogenous variables varying only across time t , including marginal tax rate, childcare expenses and market return rate. The term c_{i2} accounts for unobserved time-invariant individual-specific effects and e_{it2} is an idiosyncratic error. α_{it} the column vector of the interaction variables between dummies indicating the services provided by the physician i and the services prices. α_{it} is given by $\alpha_{it} = \text{diag}(\alpha_{1t}, \alpha_{2t}, \dots, \alpha_{6t})K_i D_i$ where $\text{diag}()$ represents a diagonal matrix,

$$K_i = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & d_{12}^i & 1 & 1 \\ 0 & d_{13}^i & d_{123}^i & d_{1234}^i \\ 0 & 0 & 0 & 1 \\ 0 & 0 & d_{125}^i & d_{1245}^i \\ 0 & 0 & d_{126}^i & 0 \end{pmatrix}; \quad D_i = \begin{pmatrix} 1 \\ D_{2i} \\ D_{3i} \\ D_{4i} \end{pmatrix}; \quad \theta = \begin{pmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \\ \theta_4 \\ \theta_5 \\ \theta_6 \end{pmatrix}.$$

1. Note that non-participants physicians include those who spent 100% of their time in teaching, research or administrative duties.

Where d_{1j}^i , $j = 2, 3$ is the dummy variable capturing whether the physician i provides services 1 and j ; d_{12j}^i , $j = 3, 5, 6$ is the dummy variable capturing whether the physician i provides services 1, 2 and j ; d_{124j}^i , $j = 3, 5$ is the dummy variable capturing whether the physician i provides services 1, 2, 4 and j . D_{ki} is the dummy variable indicating that the number of services provides by the physician i is $k = 2, 3, 4$.

In what follows, I use Mundlak's (1978) device to model the unobserved effects as

$$c_{i1} = \bar{x}_i\eta_1 + \psi_1'\bar{\alpha}_i + a_{i1}, \quad E(a_{i1}|\bar{x}_i, \bar{\alpha}_i) = 0; \quad (8.29)$$

$$c_{i2} = \bar{x}_i\eta_2 + \psi_2'\bar{\alpha}_i + a_{i2}; \quad (8.30)$$

where $\bar{Z}_i = \frac{1}{T} \sum_{t=1}^T Z_{it}$ with $Z = x, \alpha$.

Substituting (8.29) into (8.27) gives

$$\ln(\text{Earnings}_{it}) = x_{it}\beta + \ln w_{it} + \delta \ln h_{s,it} + \bar{x}_i\eta_1 + \psi_1'\bar{\alpha}_i + u_{it1}; \quad (8.31)$$

where $u_{it1} = a_{i1} + e_{it1}$ and $E(u_{it1}|\bar{x}_i, \bar{\alpha}_i) = 0$. The augmented selection equation can be written, using (8.30), as

$$s_{it} = 1[x_{it}\mu + \theta'\alpha_{it} + z_t\zeta + \bar{x}_i\eta_2 + \psi_2'\bar{\alpha}_i + u_{it2} > 0], \quad (8.32)$$

where $a_{i2} + e_{it2} = u_{it2} \sim \text{Normal}(0, 1)$. The normality assumption is not crucial for estimating the selection equation. I relax this assumption later and use a semiparametric estimator to check robustness of the normality assumption.

To consistently estimate the model, I have to deal with both selection bias and endogeneity of h_s as suggested by (8.24). I follow Semykina and Wooldridge [2013], who propose a correction procedure to estimate selection models in the presence of endogenous variables, using panel data. Their method generalizes procedures developed by Nijman and Verbeek [1992] and Chen and Liu [2008] in which all explanatory variables are exogenous. Because clinical hours worked is endogenous, I follow Semykina and Woodridge [2010] correction procedure to estimate equation (8.31) and test for the selection bias. Semykina and Woodridge [2010] describe the following procedure :

- (i) For each t , use probit to estimate the augmented selection equation $P(s_{it} = 1) = \Phi[x_{it}\mu + \theta'\alpha_{it} + z_t\zeta + \bar{x}_i\eta_2 + \psi_2'\bar{\alpha}_i]$. Here $\Phi(\cdot)$ denotes the cumulative distribution function of the standard normal distribution. Use the resulting estimates to obtain the inverse Mills ratio $\hat{\lambda}_{it} = \lambda[x_{it}\hat{\mu} + \hat{\theta}'\alpha_{it} + z_t\hat{\zeta} + \bar{x}_i\hat{\eta}_2 + \hat{\psi}_2'\bar{\alpha}_i]$.
- (ii) For $s_{it} = 1$, use GMM to estimate the nonlinear equation : $\ln(\text{Earnings}_{it}) = x_{it}\beta + \ln w_{it} + \delta \ln h_{s,it} + \bar{x}_i\eta_1 + \psi_1'\bar{\alpha}_i + \sigma\hat{\lambda}_{it} + v_{it1}$.¹ The GMM weight matrix contains exoge-

1. In an unbalanced panel, equation (8.31) can be write as

$$\ln(\text{Earnings}_{it}) = x_{it}\beta + \ln w_{it} + \delta \ln h_{s,it} + \bar{x}_i\eta_1 + \psi_1'\bar{\alpha}_i + E(u_{it1}|s_{it}) + v_{it1};$$

nous variables including the price index, w_{it} , x_{it} , \bar{x}_i , $\hat{\lambda}_{it}$ and instruments for clinical hours worked marginal tax rate, childcare expenses and market return rate.

(iii) Use the t-statistic to test $H_0 : \sigma = 0$. This is a test for the selection bias.

A necessary condition to perform this procedure and get consistency, is to have a sufficient number of instruments. If this condition is not met, the estimated inverse Mills ration, $\hat{\lambda}_{it}$, can be close to linear, causing multicollinearity. However, I have enough instruments (3 instruments for a single endogenous variables) to perform this procedure and test for the exogeneity of these instruments. Moreover, I will estimate the parameters jointly using a GMM estimator, similar to [Meijer and Wansbeek \[2007\]](#) to gain efficiency.

8.5 Results

8.5.1 Specification

Econometric analysis focuses on the specification and estimation of $\ln b(X_{it})$. The data suggests three subsamples of physicians, those who provide 2 services, those who provide 3 services and those who provide 4 services. Within each same subsample there is heterogeneity among physicians. To take this into account, I allow the constant term to be physician specific according to the services he or she provides. That is, let

$$\ln b(X_{it}) = c_{i1} + D_{2i}(\beta_{01}d_{12}^i + \beta_{02}d_{13}^i) + D_{3i}(\beta_{03}d_{123}^i + \beta_{04}d_{125}^i + \beta_{05}d_{126}^i) + D_{4i}(\beta_{06}d_{1234}^i + \beta_{07}d_{1245}^i) + \beta_1 \text{Expr}_{it} + \beta_2 \text{Expr}_{it}^2, \quad (8.33)$$

where Expr_{it} is the experience (number of year of practice) of physician i in year t . c_{i1} represents the unobserved heterogeneity of the physician. Using Mundlak procedure to model fixed effects, $c_{i1} = b_1 \overline{\text{Expr}_i} + b_2 \overline{\text{Expr}_i^2}$, and substituting into (8.33), log earnings can be written, for $s_{it} = 1$,

$$\begin{aligned} \ln(\text{Earnings}_{it}) = & D_{2i}(\beta_{01}d_{12}^i + \beta_{02}d_{13}^i) + D_{3i}(\beta_{03}d_{123}^i + \beta_{04}d_{125}^i + \beta_{05}d_{126}^i) \\ & + D_{4i}(\beta_{06}d_{1234}^i + \beta_{07}d_{1245}^i) + \beta_1 \text{Expr}_{it} + \beta_2 \text{Expr}_{it}^2 \\ & + \ln w_{it} + \delta \ln h_{s,it} + b_1 \overline{\text{Expr}_i} + b_2 \overline{\text{Expr}_i^2} + \sigma \hat{\lambda}_{it} + v_{it1}. \end{aligned} \quad (8.34)$$

This specification captures both the personal characteristics of the physicians and the effect of incentives, through the price index (w) and hour worked. Note that all physicians in the sample are paid FFS.

where $E(v_{it1}|s_{it}) = 0$, by construction. Assuming $E(u_{it1}|s_{it}) = E(u_{it1}|u_{it2}) = \sigma u_{it2}$ gives

$$\ln(\text{Earnings}_{it}) = x_{it}\beta + \ln w_{it} + \delta \ln h_{s,it} + \bar{x}_i\eta_1 + \psi'_1 \bar{\alpha}_i + \sigma E(u_{it2}|s_{it}) + v_{it1}.$$

For $s_{it} = 1$, and using the normality of u_{it2} , $E(u_{it2}|s_{it} = 1) = \frac{\phi(\cdot)}{\Phi(\cdot)} = \lambda_{it}(\cdot)$. Thus, the structural equation in interest can be write as $\ln(\text{Earnings}_{it}) = x_{it}\beta + \ln w_{it} + \delta \ln h_{s,it} + \bar{x}_i\eta_1 + \psi'_1 \bar{\alpha}_i + \sigma \lambda_{it} + v_{it1}$

TABLE 8.3 – GMM estimates with corrections for selectivity

	Coefficient	(Std. err.)
Experience	0.02***	(0.0002)
Experience squared	-0.0004***	(8.23e-06)
Mean Experience	0.006***	(0.0003)
Mean Experience squared	2.35e-05***	(7.73e-06)
Inverse Mills Ratio	0.017***	(0.004)
δ	0.84***	(0.0009)
d_{12}	0.91***	(0.003)
d_{13}	0.01***	(0.003)
d_{123}	1.45***	(0.003)
d_{125}	1.46***	(0.002)
d_{126}	0.88***	(0.002)
d_{1234}	0.42***	(0.003)
d_{1245}	0.61***	(0.002)
J-test statistic	5.251	[0.154]
RMSE	0.62021	-
Observations	3,123	-

*** p<0.01, ** p<0.05, * p<0.1

The results for this specification appear in Table 8.3. Note that the coefficients on experience and Experience squared are both significant at the 1% level, with positive and negative signs respectively. Revealing a usual concave experience profile. The significance of the inverse Mills ratio coefficient at 1% level indicates that selection bias is present. The null hypothesis of no selection is rejected at the 1% significance level.

The marginal return to time spent by the physician to produce a service, δ , is estimated at 0.84, significant at 1% level and between 0 and 1. This is important for the validity of the structural specification. Based on Hansen's J-test of overidentifying restriction, the null hypothesis that the instruments (marginal tax rate, childcare expenses and market return rate) are exogenous or valid cannot be rejected. The p-value of the J-test is 0.154.

The coefficients on the experience (0.02) and experience squared (-0.0004) suggest that productivity profile is increasing concave function of experience.

8.5.2 Productivity Profiles

Productivity profiles are derived by substituting the estimate of $\ln b(X_{it})$ into the log earnings equation (8.34). Differentiating (8.34) with respect to experience gives

$$\frac{\partial E(\text{Earnings}_{it})|_{s_{it}=1}}{\partial \text{Expr}_{it}} = [\beta_1 + 2\beta_2 \text{Expr}_{it}] \times [1 - \sigma \lambda \{\text{Index}_{it}\} (\text{Index}_{it} + \lambda \{\text{Index}_{it}\})] \quad (8.35)$$

where $\text{Index}_{it} = x_{it}\hat{\mu} + \hat{\theta}'\alpha_{it} + z_t\hat{\zeta} + \bar{x}_i\hat{\eta}_2 + \hat{\psi}'_2\bar{\alpha}_i$ is obtained from the augmented selection equation.

Estimates of this expression, evaluated at the sample means for experience and index, are given for each period in the first column of Table 8.4. These estimates suggest that a one-year increase in experience increased productivity by 0.003 percent. This implies an increase of the service production, in average, by $\exp(0.003) = 1.003$ thousands CAN dollar. Moreover, the marginal effect of experience on productivity is positive for all seven years. This is consistent with the learning-by-doing process. Time spent seeing patients in a given year increases his/her productivity in future years. The effect is concave.¹

TABLE 8.4 – The Marginal Effect of Experience on Productivity

1996	0.006
1997	0.005
1998	0.004
1999	0.004
2000	0.003
2001	0.002
2002	0.001
Average	0.003

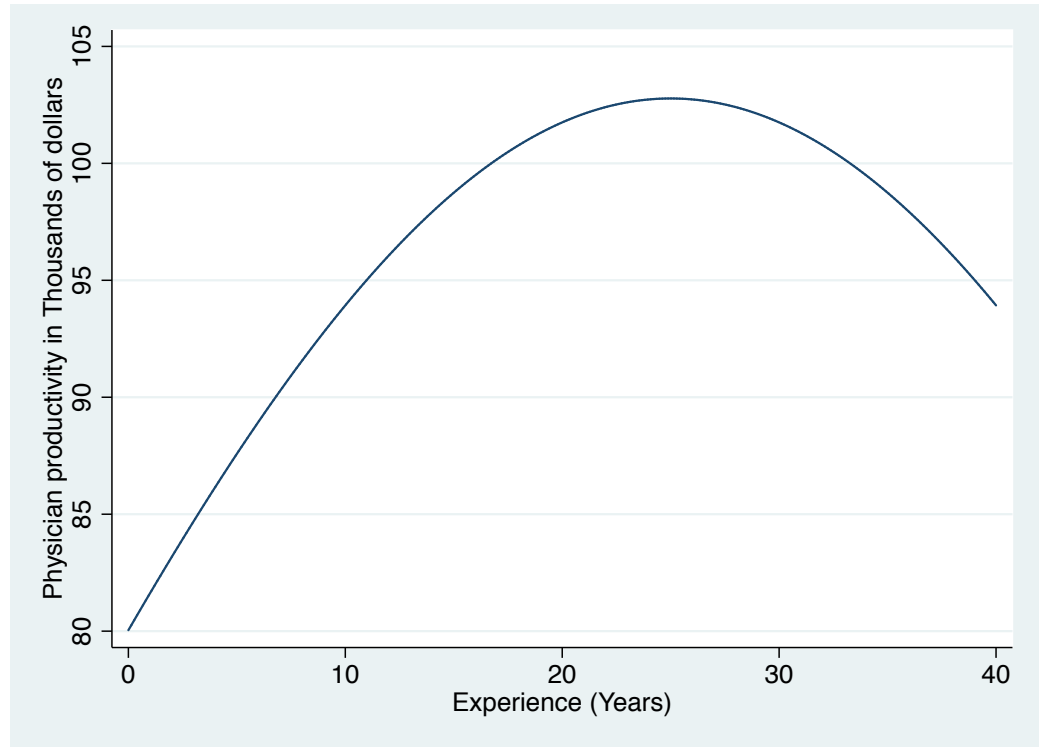
Productivity profiles can also be graphed for each period.² One such profile, for year 1996, is shown in Figure 8.1. The graph shows that a physician is most productive when he or she reach 25 years of experience. The data report that the most productive physician in 1996, earned 330.52 thousand CAD dollars and had 23 years of experience.

These results has revealed that the experience earning profiles of physicians share many of the attributes of Mincer's "human capital earnings function" [Mincer, 1974]. Physician earnings rise, but at a decreasing rate, reaching a peak at 25 years of experience. Their earnings decline slightly toward the end of their career. Similar results was found by Fjeldvig [2009] using data on Norwegian physicians. These results support two conclusions. First, younger physicians (inexperienced) are working more hours per week (see Table 8.2) but are less productive (in term of number of services provided) than the more experienced counterparts. However, at the margin, physician with less than 25 years of experience is more productive that one with more than 25 years of experience. Second, after 25 years of experience older physicians shorten their hours worked (see Table 8.2) becomes less productive, perhaps because they don't have debt and they do have retirement money.

1. Because experience stands for potential experience, I will check for robustness later by controlling for past quantity of services provide by a physician.

2. The difference between graphs in each period will be the starting point, because the coefficients of experience and experience squared are the same for each year.

FIGURE 8.1 – Productivity Profile



8.5.3 Robustness checks

The results of the model presented in the previous section were estimated under the parametric assumption of normally distributed errors in the selection equation. Moreover, I did not control for the actual experience i.e the quantity of services provided by a physician in the past. These can lead to misspecification to the model.

Here, as a robustness check, I re-estimated the earnings equation : firstly, by controlling for the actual experience captured by the lagged values of log earnings.¹ Secondly, I relax the assumption of normally distributed errors in the selection equation and propose a semiparametric estimator that is robust to a wide variety of actual error distributions.

1. This specification gives a dynamic panel data model with selection techniques, well documented by [Semykina and Wooldridge \[2013\]](#).

Controlling for actual experience

Adding the lagged values of earnings gives

$$\ln(\text{Earnings}_{it}) = \gamma \ln(\text{Earnings}_{i,t-1}) + x_{it}\beta + \ln w_{it} + \delta \ln h_{s,it} + c_{i1} + e_{it1}. \quad (8.36)$$

Recall that x_{it} is a vector of physician's experience and its squared. The parameters of interest are the β 's and c_{i1} represents unobserved heterogeneity. To estimate this dynamic panel data model with selection, I follow Semykina and Wooldridge [2013] parametric procedure, and rewrite (8.36) as

$$\begin{aligned} \ln(\text{Earnings}_{it}) = & \gamma^t \ln(\text{Earnings}_{i0}) + \left(\sum_{j=0}^{t-1} \gamma^j x_{i,t-j} \right) \beta + \left(\sum_{j=0}^{t-1} \gamma^j \ln w_{i,t-j} \right) \\ & + \left(\sum_{j=0}^{t-1} \gamma^j \ln h_{s,i,t-j} \right) \delta + \frac{1 - \gamma^t}{1 - \gamma} (\eta_1 + \bar{x}_i \chi_1 + \psi_1 \ln(\text{Earnings}_{i0})) + v_{it1}; \end{aligned} \quad (8.37)$$

where Earnings_{i0} is the initial value of physician's earning (earnings value in 1996) and the selection equation

$$s_{it} = 1[\eta_2 + \left(\sum_{j=0}^{t-1} x_{i,t-j} \kappa_j \right) + \theta'_2 \alpha_{it} + z_t \zeta_2 + \bar{x}_i \chi_2 + \psi_2 \ln(\text{Earnings}_{i0}) + v_{it2} > 0]. \quad (8.38)$$

Results from dynamic log earnings model are presented in Table 8.5.¹

The estimate of γ is 0.04 and is statistically significant at the 1% level. This represents a weak, but highly significant correlation between past and current values of earnings. The coefficient γ permits me to test the presence of the observed dynamics. If only the unobserved dynamics are present γ would be zero (see Semykina and Wooldridge [2013]). Again, the t-test of the coefficient of inverse Mills ratio show that selection bias may be present. The initial earnings coefficient is significantly positive, its value is 0.91. The estimates of the

1. The results presented is for the model containing only the first lag of variables. Due to the fact that I have a panel of only 7 year and also due to the data aggregation strategy. The augmented learnings equation, corrected for selectivity is ,

$$\begin{aligned} \ln(\text{Earnings}_{it}) = & \gamma^t \ln(\text{Earnings}_{i0}) + \beta_0 \text{Expr}_{it} + \beta_0 \gamma \text{Expr}_{i,t-1} + \beta_1 \text{Expr}2_{it} + \beta_1 \gamma \text{Expr}2_{i,t-1} + \ln w_{i,t} + \gamma \ln w_{i,t-1} \\ & + \delta \ln h_{s,it} + \delta \gamma \ln h_{s,i,t-1} + \frac{1 - \gamma^t}{1 - \gamma} (\eta_1 + \chi_{21} \overline{\text{Expr}}_i + \chi_{22} \overline{\text{Expr}2}_i + \psi_1 \ln(\text{Earnings}_{i0})) + \phi_2 \hat{\lambda}_{it} + \text{err}_{it1}. \end{aligned}$$

At the final estimates, 2148 observations over 3123 are includes in estimation. Because, I consider physicians whose earnings can be observed in 1996 (the first period of the sample) and lagging variables dropped 588 observations. I use simulated GMM the instruments included marginal tax rate, childcare expenses, market return rate, inverse Mills ratio, price index for an hours worked and its lagged.

coefficient of experience (0.016) and experience squared (-0.00036) are significant and similar to that arrived at using the model without controlling for past earnings. The J-test does not reject the validity of the instruments, its p-value is 0.81. While controlling for past earnings gives a better fit (RMSE is about 0.25), it does not change the productivity profiles of physician.

TABLE 8.5 – Estimates for the dynamic log(earnings) equation

	Coefficient	(Std. err.)
Lagged log of earnings	0.04***	(0.002)
Experience	0.016***	(0.0002)
Experience squared	-0.00036***	(5.37e-06)
Mean Experience	-0.024***	(0.0002)
Mean Experience squared	0.0004***	(5.08e-06)
$\ln(\text{Earnings}_{i0})$	0.91***	(0.002)
Inverse Mills Ratio	0.006***	(0.002)
δ	0.02***	(0.0005)
d_{12}	-0.44***	(0.002)
d_{13}	-0.52***	(0.002)
d_{123}	-0.87***	(0.002)
d_{125}	-0.81***	(0.002)
d_{126}	-0.91***	(0.002)
d_{1234}	-1.10***	(0.002)
d_{1245}	-1.17***	(0.002)
J-test statistic	0.940	[0.816]
RMSE	0.249	-
Observations	2148	-

*** p<0.01, ** p<0.05, * p<0.1

Semiparametric specification

Next, I relax the assumption of normally distributed errors in the selection equation. A general way in which to deal with possible inconsistency due to nonnormality is to use semiparametric approach. I follow Gallant and Nychka [1987].¹

The basic idea of Gallant and Nychka [1987] is to approximate the unknown joint density function of (e_{it1}, e_{it2}) by Hermite polynomial expansions and use the approximations to derive a pseudo-ML estimator for the model parameters. The unknown joint density, f , of errors is given by

1. There are other semiparametric approaches that can be used to fit a binary-choice model (see, for example, Klein and Spady [1993]; Ichimura and Thompson [1993].

$$f(e_1, e_2) = \frac{1}{\psi_R} \tau_R(e_1, e_2)^2 \phi(e_1) \phi(e_2) \quad (8.39)$$

where $\phi(\cdot)$ is the standardized normal density, $\tau_R(e_1, e_2) = \sum_{h=0}^{R_1} \sum_{k=0}^{R_2} \tau_{hk} e_1^h e_2^k$ is a polynomial in e_1 and e_2 of order $R = (R_1, R_2)$. The function

$$\psi_R = \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} \tau_R(e_1, e_2) \psi(e_1) \psi(e_2) de_1 de_2$$

is a normalization factor that ensures f is a proper density.

The estimators can be obtained by maximizing the pseudo log-likelihood function

$$L(\Theta) = \sum_i \sum_t (s_{it} \ln F_{it}(\Theta) + (1 - s_{it}) \ln \{1 - F_{it}(\Theta)\}) \quad (8.40)$$

where F_{it} is a cumulative distribution function derived from the density f and Θ is a vector of unknown parameters. Gallant and Nychka [1987] provide consistency results for the semiparametric estimators. These estimates can be used to construct the selection index $\text{Index}_{it} = x_{it}\hat{\mu} + \hat{\theta}'\alpha_{it} + z_t\hat{\zeta} + \bar{x}_i\hat{\eta}_2 + \hat{\psi}'_2\bar{\alpha}_i$. Now, the model can be written for $s_{it} = 1$,

$$\begin{aligned} \ln(\text{Earnings}_{it}) = & D_{2i}(\beta_{01}d_{12}^i + \beta_{02}d_{13}^i) + D_{3i}(\beta_{03}d_{123}^i + \beta_{04}d_{125}^i + \beta_{05}d_{126}^i) \\ & + D_{4i}(\beta_{06}d_{1234}^i + \beta_{07}d_{1245}^i) + \beta_1 \text{Expr}_{it} + \beta_2 \text{Expr}_{it}^2 \\ & + \ln w_{it} + \delta \ln h_{s,it} + b_1 \overline{\text{Expr}_i} + b_2 \overline{\text{Expr}_i^2} + h(\text{Index}_{it}) + v_{it1} \end{aligned} \quad (8.41)$$

where $h(\cdot)$ is an unknown function. To estimate Equation (8.41), I follow Newey [2009] and employ series estimators to approximate $h(\cdot)$. In particular, I use the power series which approximate $h(\cdot)$ by a polynomial function of the selection index.¹

To limit the size of the selection index on the estimates, I follow Newey use the inverse Mills ratio transformation.² Thus, Equation (8.41) is estimated using simulated GMM.

The estimates obtained using these methods are reported in the Table 8.6. Note that the value of experience and its squared coefficients are 0.016 and -0.00045 respectively, similar to the experience (0.02) and experience squared (-0.0004) coefficients in Table 8.3, derived from parametric estimation. The value of the RMSE decreases very slightly, from 0.62 in the parametric case to 0.61 in the semiparametric case. The productivity profile based on these estimates is similar to the one derived from parametric estimation.

1. I choose a second order polynomial, $h(\text{Index}_{it}) = c_1 \text{Index}_{it} + c_2 \text{Index}_{it}^2$.

2. This simply means that I replace Index_{it} by $\phi(\text{Index}_{it})/\Phi(\text{Index}_{it})$ where $\phi(\cdot)$ and $\Phi(\cdot)$ are the PDF and CDF of standard normal respectively. Note that several possibilities had been proposed by Newey [2009] including logit transformation $1 + \exp(\text{Index}_{it})$ and standard normal transformation $\Phi(\text{Index}_{it})$

TABLE 8.6 – Semiparametric GMM estimates with corrections for selectivity

	Coefficient	(Std. err.)
Experience	0.016***	(0.0003)
Experience squared	-0.00045***	(6.76e-06)
Mean Experience	0.006***	(0.0003)
Mean Experience squared	-8.11e-06***	(6.7746e-06)
$\frac{\phi(\text{Index}_{it})}{\Phi(\text{Index}_{it})}$	0.04***	(0.008)
$\left(\frac{\phi(\text{Index}_{it})}{\Phi(\text{Index}_{it})}\right)^2$	0.001***	(0.0005)
δ	0.68***	(0.01)
d_{12}	0.90***	(0.006)
d_{13}	0.002	(0.006)
d_{123}	1.37***	(0.009)
d_{125}	1.41***	(0.01)
d_{126}	0.80***	(0.01)
d_{1234}	0.28***	(0.011)
d_{1245}	0.53***	(0.011)
J-test statistic	5.602	[0.133]
RMSE	0.611	-
Observations	3,123	

*** p<0.01, ** p<0.05, * p<0.1

8.6 Policy Implications

I use the model estimates in Table 8.3 to simulate the effect of replacing experienced physicians with inexperienced physicians. I calculate the replacement ratio – the number of inexperienced physicians needed to replace an experienced physician. To calculate the replacement ratio, I first separate the sample in two groups, unexperienced physicians (years of practice less than 25) and experienced physicians (years of practice greater or equal to 25). Then, I compute the total amount of services produced by experienced physicians, A_{exp} . The replacement ratio is obtained by dividing the number of unexperienced physicians needed to produce, exactly A_{exp} by the number of experience counterparts.

The results show that 1.2 inexperienced physicians) would be needed to replace one experienced physician. This could explain why the increasing number of physicians has not reduced waiting times over the past nine years. Inexperienced (and unproductive) physicians are replacing experience (and productive) physicians.

8.7 Conclusion

This Chapter has estimated productivity profiles from fee-for-service compensated physicians. Data were collected from the Quebec College of Physicians and the Health Insurance

Organization of Quebec administrative files. I have developed and estimated a structural labour supply model that incorporates the fact that physicians provide more than one services. This generates a price index giving the marginal return to an hour worked when that hour is optimally distributed across services. The earnings equation is directly related to fee-for-service physician productivity as these physicians are paid per service provided. I have captured these effects by modelling the relationship between experience productivity and earnings. I have derived and estimated physician's log earnings equation using simulated GMM method with correction for selectivity bias.

I have used the estimates to derive the productivity profiles of physicians. The increasing concave productivity profiles are consistent with those derived from studies which use wages as a proxy for productivity, see [Hutchens \[1989\]](#) for a review of this literature. These results are also similar to [Shearer \[1996\]](#). In this respect the results are supportive of the human capital and learning-by-doing interpretation of earnings profiles, namely, that the increasing concave earnings profiles reflect changes in physician productivity over the course of years of providing services in health sector. The productivity profile in the health sector in Quebec is very flat. A one-year increase in experience increased productivity by 0.003 percent, this represents an increase of service production by approximately 1,003 CAN dollar. Also, my findings suggest that a physician with 25 years of experience, has the highest productivity.

I use the model estimates to simulate the effect of replacing experienced physicians with unexperienced physicians. The result suggests that the replacement ratio is 1.2, when physicians with less than 25 years of experience is considered as unexperienced. These ratio could explain why the increasing number of physicians has not reduce the wait times because the new physicians replacing the older one are experienced.

The paper also raises some modelling issues for physician labour supply. I modelled physician behaviour using a static labour supply model. It would be interesting to take into account human capital accumulation (or learning by doing) when physician make labor supply decisions. Extending the model to account for learning-by-doing process would allow for more applications, in particular, it will allow the analysis of the full effect of policy to induce participation among young physicians. Including learning-by-doing process requires a dynamic labour supply model (see, for example, [Shaw \[1989\]](#) ; [Hotz and Miller \[1988\]](#) ; [Eckstein and Wolpin \[1989\]](#)). I leave this for future work.

General conclusions to thesis

Although the waiting times for health care in Canada are still among the longest among OECD countries, little research exists about physicians labour supply and their productivity. This dissertation develops and applies methods to measure the reaction of physicians to monetary incentives and to estimate how their productivity varies with experience throughout a physician's career. Our approach is model based. We have developed and estimated a structural labour supply model that incorporates the technology of medical services production and the allocation of hours across services into the standard consumption/leisure trade-off. We also examine the policy implications arising from our modelling approach.

We have use a unique data set on Quebec physicians to make three contributions to the literature on physician's labour supply, as well as, on physician productivity. First, using limited information methods we show that lower bounds to the global substitution elasticity for the own-price elasticities are significantly positive, suggesting that physicians do react to incentives. Second, we estimate the full model (unconditionally on clinical hours worked) allowing us to identifying the full response of physicians to changes in relative prices, including both income and substitution effects. The results show that the own-price elasticities of substitution of hours (volume) are positive, while the cross-price elasticities of substitution of hours (volume) are negative. We also provide a direct evidence on the size of income effects. Moreover, fee changes affect very slightly weekly total hours and clinical hours (extensive margin).

We use the structural model to simulate the effect of recently observed price increases in physician contracts, by increasing simultaneously the prices of services by 32%. The results show that when physician are paid FFS, a policy increasing the price of services will reduce the total hours worked and clinical hours worked. This leads physicians to reduce volume of services provided. Therefore, increasing services fees when physician are paid FFS creates a disincentive for physicians to work and provide service.

Finally, I modify our model to take into account the relationship between the productivity of physicians and their experience. I estimate a selection model to correct for non-randomly missing observations. Results suggest that productivity profiles are increasing concave functions of experience and the shape of the profile is robust to controlling for actual experience

and to parametric assumption.

Annexe A

Comparative Statics

Recalling that $F(\hat{h}_s, \alpha_1, \alpha_2, y) = \omega \delta \hat{h}_s^{\delta-1} (\omega \hat{h}_s^\delta + y)^{\rho-1} - 2^{1-\rho} (T - \hat{h}_s)^{\rho-1}$ and let F_k be the partial derivative of F with respect to k . We have, the following results

$$F_{\hat{h}_s} = \omega \delta (\delta - 1) \hat{h}_s^{\delta-2} (\omega \hat{h}_s^\delta + y)^{\rho-1} + (\rho - 1) (\omega \delta \hat{h}_s^{\delta-1})^2 (\omega \hat{h}_s^\delta + y)^{\rho-2} + 2^{1-\rho} (\rho - 1) (T - \hat{h}_s)^{\rho-2} < 0 \quad ;$$

$$F_y = (\rho - 1) \omega \delta \hat{h}_s^{\delta-1} M^{\rho-2} < 0 \quad ;$$

$$\begin{aligned} F_{\alpha_1} &= \frac{\partial \omega}{\partial \alpha_1} \delta \hat{h}_s^{\delta-1} M^{\rho-1} + \frac{\partial \omega}{\partial \alpha_1} \hat{h}_s^\delta (\rho - 1) M^{\rho-2} \omega \delta \hat{h}_s^{\delta-1} \quad , \\ &= \frac{\partial \omega}{\partial \alpha_1} \hat{h}_s^{\delta-1} \left[\delta M^{\rho-1} + \hat{h}_s (\rho - 1) \omega \delta \hat{h}_s^{\delta-1} M^{\rho-2} \right] = \frac{\partial \omega}{\partial \alpha_1} \hat{h}_s^{\delta-1} \delta M^{\rho-2} (\rho \omega \hat{h}_s^\delta + y) \quad \begin{matrix} > \\ < \end{matrix} \quad 0 \quad , \\ &= \frac{\partial \omega}{\partial \alpha_1} \hat{h}_s^{\delta-1} \left[\delta M^{\rho-1} + \hat{h}_s F_y \right] \quad ; \end{aligned}$$

$$\begin{aligned} F_{\alpha_2} &= \frac{\partial \omega}{\partial \alpha_2} \hat{h}_s^{\delta-1} \delta M^{\rho-2} (\rho \omega \hat{h}_s^\delta + y) \quad \begin{matrix} > \\ < \end{matrix} \quad 0 \quad , \\ &= \frac{\partial \omega}{\partial \alpha_2} \hat{h}_s^{\delta-1} \left[\delta M^{\rho-1} + \hat{h}_s F_y \right] \quad ; \end{aligned}$$

where $M = \omega \hat{h}_s^\delta + y$ and

$$\frac{\partial \omega}{\partial \alpha_i} = \left(\frac{P_i}{P_i + P_j} \right)^\delta > 0 \quad i \neq j \quad ; \quad i, j \in \{1, 2\}$$

As $\rho \in (\infty, 1)$ then $\text{sign}(F_{\alpha_i})$ is unknown. $F_{\hat{h}_s} = W_{h_s h_s} = \frac{\partial^2 W(.)}{\partial h_s^2} < 0$ by the second order condition.

A.0.1 Income elasticity, \hat{h}_s

$$\begin{aligned}\frac{d\hat{h}_s}{dy} &= -\frac{F_y}{F_{\hat{h}_s}} = \frac{(1-\rho)\omega\delta\hat{h}_s^{\delta-1}M^{\rho-2}}{F_{\hat{h}_s}} < 0 \\ \frac{y}{\hat{h}_s} \frac{d\hat{h}_s}{dy} &= \frac{y}{\hat{h}_s} \frac{(1-\rho)\omega\delta\hat{h}_s^{\delta-1}M^{\rho-2}}{F_{\hat{h}_s}} \\ \zeta_{\hat{h}_s/y} &= \frac{(1-\rho)\delta\omega y\hat{h}_s^{\delta-2}M^{\rho-2}}{W_{h_s h_s}}\end{aligned}$$

A.0.2 Income elasticity, \hat{h}_t

$$\begin{aligned}\frac{d\hat{h}_t}{dy} &= \frac{1}{2} \frac{d\hat{h}_s}{dy} \\ \frac{d\hat{h}_t}{dy} &= \frac{y}{2h_s} \frac{d\hat{h}_s}{dy} \frac{h_s}{y} \\ \frac{d\hat{h}_t}{dy} &= \frac{h_s}{2y} \zeta_{\hat{h}_s/y} \\ \frac{y}{\hat{h}_t} \frac{d\hat{h}_t}{dy} &= \frac{y}{\hat{h}_t} \frac{h_s}{2y} \zeta_{\hat{h}_s/y} \\ \zeta_{\hat{h}_s/y} &= \frac{y}{\frac{T+h_s}{2}} \frac{h_s}{2y} \zeta_{\hat{h}_s/y} \\ \zeta_{\hat{h}_t/y} &= \frac{\hat{h}_s}{T+\hat{h}_s} \zeta_{\hat{h}_s/y} < 0\end{aligned}$$

A.0.3 Income elasticity, \hat{h}_i

$$\frac{d\hat{h}_i}{dy} = \frac{P_j}{P_i + P_j} \frac{d\hat{h}_s}{dy} < 0 \quad i \neq j \quad ; \quad i, j \in \{1, 2\}$$

This equation can be write in terms of elasticities, by using the fact that $\frac{\hat{h}_i}{\hat{h}_s} = \frac{P_j}{P_i + P_j}$. We have,

$$\zeta_{\hat{h}_i/y} = \zeta_{\hat{h}_s/y}$$

A.0.4 Income elasticity, \hat{A}_i

$$\frac{d\hat{A}_i}{dy} = \delta\hat{h}_i^{\delta-1} \frac{d\hat{h}_i}{dy} < 0 \quad i \neq j \quad ; \quad i, j \in \{1, 2\}$$

This equation can be write in terms of elasticities, by using the fact that $A_i = h_i^\delta$. We have,

$$\zeta_{\hat{A}_i/y} = \delta\zeta_{\hat{h}_s/y}$$

A.0.5 Price elasticity, \hat{h}_s

$$\begin{aligned}
\frac{d\hat{h}_s}{d\alpha_i} &= -\frac{F_{\alpha_i}}{F_{\hat{h}_s}} \\
&= -\frac{\frac{\partial \omega}{\partial \alpha_i} \hat{h}_s^{\delta-1} [\delta M^{\rho-1} + \hat{h}_s F_y]}{F_{\hat{h}_s}} \\
&= \frac{\partial \omega}{\partial \alpha_i} \hat{h}_s^{\delta-1} \left[-\frac{\delta M^{\rho-1}}{F_{\hat{h}_s}} - \hat{h}_s \frac{F_y}{F_{\hat{h}_s}} \right] \\
&= \frac{\partial \omega}{\partial \alpha_i} \hat{h}_s^{\delta-1} \left[-\frac{\delta M^{\rho-1}}{F_{\hat{h}_s}} + \hat{h}_s \frac{d\hat{h}_s}{dy} \right] \\
&= -\frac{\partial \omega}{\partial \alpha_i} \frac{\delta \hat{h}_s^{\delta-1} M^{\rho-1}}{F_{\hat{h}_s}} + \hat{h}_s^\delta \frac{\partial \omega}{\partial \alpha_i} \frac{d\hat{h}_s}{dy} \\
&= -\left(\frac{P_j \hat{h}_s}{P_i + P_j} \right)^\delta \frac{\hat{h}_s^{-1} \delta M^{\rho-1}}{F_{\hat{h}_s}} + \left(\frac{P_j \hat{h}}{P_i + P_j} \right)^\delta \frac{d\hat{h}_s}{dy} \\
&= -\hat{h}_i^\delta \frac{\delta M^{\rho-1}}{\hat{h}_s F_{\hat{h}_s}} + \hat{h}_i^\delta \frac{d\hat{h}_s}{dy}
\end{aligned}$$

Finally,

$$\frac{d\hat{h}_s}{d\alpha_i} = -\hat{h}_i^\delta \frac{\delta M^{\rho-1}}{\hat{h}_s F_{\hat{h}_s}} + \hat{h}_i^\delta \frac{d\hat{h}_s}{dy}$$

The equation can be converted to elasticity terms by multiplying by α_i/\hat{h}_s . After adjusting the income effect, we get

$$\zeta_{\hat{h}_s/\alpha_i} = -\frac{\delta \alpha_i \hat{A}_i M^{\rho-1}}{\hat{h}_s^2 W_{h_s h_s}} + \frac{\alpha_i \hat{A}_i}{y} \zeta_{\hat{h}_s/y}$$

A.0.6 Price elasticity, \hat{h}_t

$$\begin{aligned}
\frac{d\hat{h}_t}{d\alpha_i} &= \frac{1}{2} \frac{d\hat{h}_s}{d\alpha_i} \\
\frac{d\hat{h}_t}{d\alpha_i} &= \frac{\alpha_i}{2h_s} \frac{d\hat{h}_s}{d\alpha_i} \frac{h_s}{\alpha_i} \\
\frac{d\hat{h}_t}{d\alpha_i} &= \frac{h_s}{2\alpha_i} \zeta_{\hat{h}_s/\alpha_i} \\
\frac{\alpha_i}{\hat{h}_t} \frac{d\hat{h}_t}{d\alpha_i} &= \frac{\alpha_i}{\hat{h}_t} \frac{h_s}{2\alpha_i} \zeta_{\hat{h}_s/\alpha_i} \\
\zeta_{\hat{h}_s/\alpha_i} &= \frac{\alpha_i}{\frac{T+h_s}{2}} \frac{h_s}{2\alpha_i} \zeta_{\hat{h}_s/\alpha_i} \\
\zeta_{\hat{h}_t/\alpha_i} &= \frac{\hat{h}_s}{T + \hat{h}_s} \zeta_{\hat{h}_s/\alpha_i}
\end{aligned}$$

A.0.7 Own-price elasticity, \hat{h}_i

$$\begin{aligned}
\frac{d\hat{h}_i}{d\alpha_i} &= \frac{P_j}{P_i + P_j} \frac{d\hat{h}_s}{d\alpha_i} + \frac{d}{d\alpha_i} \left[\frac{P_j}{P_i + P_j} \right] \hat{h}_s \\
&= \frac{P_j}{P_i + P_j} \frac{d\hat{h}_s}{d\alpha_i} + \frac{P_j P_i \alpha_i^{-1}}{(1 - \delta)(P_i + P_j)^2} \hat{h}_s \\
&= \frac{P_j}{P_i + P_j} \left[-\frac{\partial \omega}{\partial \alpha_i} \frac{\delta \hat{h}_s^{\delta-1} M^{\rho-1}}{F_{\hat{h}_s}} + \hat{h}_s^\delta \frac{\partial \omega}{\partial \alpha_i} \frac{d\hat{h}_s}{dy} \right] + \frac{P_j P_i \alpha_i^{-1}}{(1 - \delta)(P_i + P_j)^2} \hat{h}_s \\
&= \frac{P_j}{P_i + P_j} \left[-\frac{\partial \omega}{\partial \alpha_i} \frac{\delta \hat{h}_s^{\delta-1} M^{\rho-1}}{F_{\hat{h}_s}} + \hat{h}_s^\delta \frac{\partial \omega}{\partial \alpha_i} \frac{d\hat{h}}{dy} \right] + \frac{P_j P_i \alpha_i^{-1}}{(1 - \delta)(P_i + P_j)^2} \hat{h}_s \\
&= \frac{P_j}{P_i + P_j} \left[-\frac{\partial \omega}{\partial \alpha_i} \frac{\delta \hat{h}_s^{\delta-1} M^{\rho-1}}{F_{\hat{h}_s}} + \hat{h}_s^\delta \frac{\partial \omega}{\partial \alpha_i} \frac{d\hat{h}_s}{dy} \right] + \frac{P_j P_i \alpha_i^{-1}}{(1 - \delta)(P_i + P_j)^2} \hat{h}_s \\
&= \frac{P_j}{P_i + P_j} \left[-\left(\frac{P_j \hat{h}_s}{P_i + P_j} \right)^\delta \frac{\hat{h}_s^{-1} \delta M^{\rho-1}}{F_{\hat{h}_s}} + \left(\frac{P_j \hat{h}_s}{P_i + P_j} \right)^\delta \frac{d\hat{h}_s}{dy} \right] + \frac{P_j P_i \alpha_i^{-1}}{(1 - \delta)(P_i + P_j)^2} \hat{h}_s \\
&= \frac{P_j}{P_i + P_j} \left[-\hat{h}_i^\delta \frac{\hat{h}_s^{-1} \delta M^{\rho-1}}{F_{\hat{h}_s}} + \hat{h}_i^\delta \frac{d\hat{h}_s}{dy} \right] + \frac{P_j P_i \alpha_i^{-1}}{(1 - \delta)(P_i + P_j)^2} \hat{h}_s \\
&= -\frac{P_j}{P_i + P_j} \hat{h}_i^\delta \frac{\delta M^{\rho-1}}{\hat{h}_s F_{\hat{h}_s}} + \hat{h}_i^\delta \frac{d\hat{h}_i}{dy} + \frac{P_j P_i \alpha_i^{-1}}{(1 - \delta)(P_i + P_j)^2} \hat{h}_s \\
&= -\frac{P_j}{P_i + P_j} \hat{h}_i^\delta \frac{\delta M^{\rho-1}}{\hat{h}_s F_{\hat{h}_s}} + \hat{h}_i^\delta \frac{d\hat{h}_i}{dy} + \frac{P_i \alpha_i^{-1}}{(1 - \delta)(P_i + P_j)} \hat{h}_i \\
&= \frac{\hat{h}_i}{\alpha_i} \left[\frac{\hat{h}_j}{\hat{h}_s} \frac{1}{(1 - \delta)} - \delta \alpha_i \hat{h}_i^\delta \frac{M^{\rho-1}}{\hat{h}_s^2 F_{\hat{h}_s}} \right] + \hat{h}_i^\delta \frac{d\hat{h}_i}{dy}
\end{aligned}$$

Finally we have,

$$\frac{d\hat{h}_i}{d\alpha_i} = \frac{\hat{h}_i}{\alpha_i} \left[\frac{\hat{h}_j}{\hat{h}_s} \frac{1}{(1 - \delta)} - \delta \alpha_i \hat{h}_i^\delta \frac{M^{\rho-1}}{\hat{h}_s^2 F_{\hat{h}_s}} \right] + \hat{h}_i^\delta \frac{d\hat{h}_i}{dy}$$

The equation can be converted to elasticity terms by multiplying by α_i / \hat{h}_i and recalling that $\frac{\hat{h}_j}{\hat{h}_s} = \frac{P_j}{P_i + P_j}$. After adjusting the income effect, we have

$$\zeta_{h_i/\alpha_i} = \left[\frac{1}{(1 - \delta)} \frac{P_j}{P_i + P_j} - \frac{\delta \alpha_i \hat{A}_i M^{\rho-1}}{\hat{h}_s^2 W_{h_s h_s}} \right] + \frac{\alpha_i \hat{A}_i}{y} \zeta_{h_i/y}$$

A.0.8 Own-price elasticity, \hat{A}_i

$$\begin{aligned}\frac{d\hat{A}_i}{d\alpha_i} &= b_i h_i^{\delta-1} \delta \frac{d\hat{h}_i}{d\alpha_i} \\ \frac{d\hat{A}_i}{d\alpha_i} &= \frac{\hat{A}_i}{\hat{h}_i} \delta \frac{d\hat{h}_i}{d\alpha_i} \\ \frac{\alpha_i}{A_i} \frac{d\hat{A}_i}{d\alpha_i} &= \delta \frac{\alpha_i}{\hat{h}_i} \frac{d\hat{h}_i}{d\alpha_i} \\ \zeta_{A_i/\alpha_i} &= \delta \zeta_{h_i/\alpha_i}\end{aligned}$$

A.0.9 Cross-price elasticity, \hat{h}_i

$$\begin{aligned}\frac{d\hat{h}_i}{d\alpha_j} &= \frac{P_j}{P_i + P_j} \frac{d\hat{h}_s}{d\alpha_j} + \frac{\partial}{\partial \alpha_j} \left[\frac{P_j}{P_i + P_j} \right] \hat{h}_s \\ &= \frac{P_j}{P_i + P_j} \frac{d\hat{h}_s}{d\alpha_j} - \frac{P_j P_i \alpha_j^{-1}}{(1 - \delta)(P_i + P_j)^2} \hat{h}_s \\ &= \frac{P_j}{P_i + P_j} \left[-\frac{\partial \omega}{\partial \alpha_j} \frac{\delta \hat{h}_s^{\delta-1} M^{\rho-1}}{F_{\hat{h}_s}} + \hat{h}_s^\delta \frac{\partial \omega}{\partial \alpha_j} \frac{d\hat{h}_s}{dy} \right] - \frac{P_j P_i \alpha_j^{-1}}{(1 - \delta)(P_i + P_j)^2} \hat{h}_s \\ &= \frac{P_j}{P_i + P_j} \left[-\left(\frac{P_i \hat{h}_s}{P_i + P_j} \right)^\delta \frac{\hat{h}_s^{-1} \delta M^{\rho-1}}{F_{\hat{h}_s}} + \left(\frac{P_i \hat{h}_s}{P_i + P_j} \right)^\delta \frac{d\hat{h}_s}{dy} \right] - \frac{P_j P_i \alpha_j^{-1}}{(1 - \delta)(P_i + P_j)^2} \hat{h}_s \\ &= \frac{P_j}{P_i + P_j} \left[-\hat{h}_j^\delta \frac{\hat{h}_s^{-1} \delta M^{\rho-1}}{F_{\hat{h}_s}} + \hat{h}_j^\delta \frac{d\hat{h}_s}{dy} \right] - \frac{P_j P_i \alpha_j^{-1}}{(1 - \delta)(P_i + P_j)^2} \hat{h}_s \\ &= -\frac{P_j}{P_i + P_j} \hat{h}_j^\delta \frac{\delta M^{\rho-1}}{\hat{h}_s F_{\hat{h}_s}} + \hat{h}_j^\delta \frac{d\hat{h}_i}{dy} - \frac{P_j P_i \alpha_j^{-1}}{(1 - \delta)(P_i + P_j)^2} \hat{h}_s \\ &= -\frac{P_j}{P_i + P_j} \hat{h}_j^\delta \frac{\delta M^{\rho-1}}{\hat{h}_s F_{\hat{h}_s}} + \hat{h}_j^\delta \frac{d\hat{h}_i}{dy} - \frac{P_j \alpha_j^{-1}}{(1 - \delta)(P_i + P_j)} \hat{h}_j \\ &= -\frac{\hat{h}_i}{\alpha_j} \left[\frac{\hat{h}_j}{\hat{h}_s} \frac{1}{(1 - \delta)} + \delta \alpha_j \hat{h}_j^\delta \frac{M^{\rho-1}}{\hat{h}_s^2 F_{\hat{h}_s}} \right] + \hat{h}_j^\delta \frac{d\hat{h}_i}{dy} \\ \frac{d\hat{h}_i}{d\alpha_j} &= -\frac{\hat{h}_i}{\alpha_j} \left[\frac{\hat{h}_j}{\hat{h}_s} \frac{1}{(1 - \delta)} + \delta \alpha_j \hat{h}_j^\delta \frac{M^{\rho-1}}{\hat{h}_s^2 F_{\hat{h}_s}} \right] + \hat{h}_j^\delta \frac{d\hat{h}_i}{dy}\end{aligned}$$

Dividing by \hat{h}_i and multiplying by α_j , we get elasticity

$$\zeta_{\hat{h}_i/\alpha_j} = - \left[\frac{1}{(1-\delta)} \frac{P_j}{P_i + P_j} + \delta \alpha_j \hat{A}_j \frac{M^{\rho-1}}{\hat{h}_s^2 F_{\hat{h}_s}} \right] + \frac{\alpha_j \hat{A}_j}{y} \zeta_{\hat{h}_i/y}$$

A.0.10 Cross-price elasticity, \hat{A}_i

$$\begin{aligned} \frac{d\hat{A}_i}{d\alpha_j} &= b_i h_i^{\delta-1} \delta \frac{d\hat{h}_i}{d\alpha_j} \\ \frac{d\hat{A}_i}{d\alpha_j} &= \frac{\hat{A}_i}{\hat{h}_i} \delta \frac{d\hat{h}_i}{d\alpha_j} \\ \frac{\alpha_i}{A_i} \frac{d\hat{A}_i}{d\alpha_i} &= \delta \frac{\alpha_i}{\hat{h}_i} \frac{d\hat{h}_i}{d\alpha_j} \\ \zeta_{A_i/\alpha_j} &= \delta \zeta_{h_i/\alpha_j} \end{aligned}$$

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