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# Primary Care Access and Emergency Department Utilization: Theory and Evidence from Canada

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## Abstract

We develop a theoretical model to study how after-hours incentives affect emergency department (ED) utilization via changing physician behavior. The model reveals that reductions in ED utilization can only come from patients with conditions severe enough to warrant visiting the ED, yet mild enough to be treatable by their primary care physician. While these incentives induce physicians to work more after hours, they also reduce regular-hours services. Thus, incentivizing physicians to provide after-hours services ambiguously affects ED utilization. Model predictions are tested using administrative data from the province of Ontario, Canada. The data cover visits to physicians' offices and ED visits from 2004 to 2013, a period with exogenous changes in after-hours incentives. Our findings are consistent with model predictions. We also find that after-hours incentives reduce ED visits, suggesting that our proposed framework may be useful for understanding and even designing after-hours incentives.

JEL Classification: I11; I12; I18; H51

Keywords: primary care; physician incentives

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# 1 Introduction

In developed countries, avoidable, or nonurgent, emergency department (ED) visits are undertaken by a large proportion of the population (Carret et al., 2009). Survey data suggest that about 39% of Canadians who visited an ED considered their visits avoidable if primary care were more accessible (Schoen et al., 2005). Aside from contributing to overcrowding, which may delay care for patients in urgent need, the utilization of EDs for nonurgent health problems may be associated with higher health care costs (Campbell et al., 2005; Mehrotra et al., 2009; Thygeson et al., 2008) and lower continuity of care, adversely affecting health outcomes—especially for patients with chronic conditions (Dunnion and Kelly, 2005; Stiell et al., 2003; Vinker et al., 2004).

Because access to primary health care services outside regular working hours may reduce costly ED visits, encouraging after-hours care has attracted considerable policy attention. In 2003, explicit financial incentives were implemented in the province of Ontario, Canada, where physicians practicing in certain primary care delivery models became eligible for an after-hours premium, which started at 10% higher than regular-hours prices and increased in stages to 30% by 2012. Our main objective is to understand and quantify how and whether after-hours incentives can reduce ED utilization and costs.

Some studies have examined the association between improved after-hours access to primary care initiatives and ED visits, with mixed findings. These initiatives include the implementation of an after-hours clinic or cooperative (Buckley et al., 2010; Pickin et al., 2004), extension of primary care practice opening hours (Dolton and Pathania, 2016; Harris et al., 2011; Lippi Bruni et al., 2016; Lowe et al., 2005), reorganization of after-hours care (van Uden and Crebolder, 2004; van Uden et al., 2005), and after-hours financial incentives (Franco et al., 1997; Piehl et al., 2000).

With the exception of Dolton and Pathania (2016) and Lippi Bruni et al. (2016), previous studies may report biased results as they do not control for potentially unobserved confounders. Our study addresses several methodological limitations of the previous literature. Specifically, we develop a theoretical model to understand how the interaction between physician behavior and patient characteristics determines the effect of after-hours incentives. We then use this model to guide our empirical analysis, using rich administrative data covering the population of Ontario, the most populous province in Canada.

The motivation behind increasing access to physicians is to reduce costs to the health care system. Despite its policy importance and conflicting empirical findings, no theoretical work has studied the interaction between patient and physician behavior in the context of reducing ED utilization, until now. Our first contribution is to develop a model that incorporates several features of the institutional environment: (i) physicians' skill levels determine the most severe conditions they can treat, (ii) patients prefer to be treated by their own physician rather than at the ED, and (iii) physicians choose how to allocate time between leisure, services provided during regular hours, and services provided after hours.

The model reveals two reasons underlying the documented difficulty in finding a substantial reduction in ED utilization: First, reductions in ED utilization can only come about if patients have conditions that are treatable by physicians: even if incentives shift physicians to increase after-hours access, this will not necessarily translate to substantial reductions in ED utilization. Second, even if after-hours ED visits are reduced, our model predicts that physicians will substitute away from regular-hour services in response to the higher after-hours premium, possibly leading to increased ED utilization during regular hours.

The model also shows that, even if ED utilization decreases and physicians have lower average costs of treating patients than EDs, the effect of increasing after-hours services would still have an ambiguous effect on net costs to the health care system. This is because what matters is the physician-ED cost differential for inframarginal patients (i.e., patients with condition severities high enough to warrant visiting the ED but low enough to be treated by their primary care physician). Cost-savings, then, crucially depend on how both physician and ED treatment costs depend on patient condition severity. To date, there is no direct evidence about this cost differential for the relevant population of inframarginal patients.

The model generates testable implications of key elements of our story, which we then bring to the data. To the best of our knowledge, this paper is the first to examine the impact of after-hours incentives on ED visits using a large-scale, longitudinal, dataset. There are two main benefits of our dataset: First, the longitudinal nature of our data allows us to control for unobserved heterogeneity. Access to multiple years of data allows us to exploit temporal variation in the strength of after-hours incentives, by using them as shifters in an instrumental variables approach—intuitively, after-hours incentives should only affect ED utilization via how they affect physician behavior. Second, the large number of physicians allows us to break down estimated effects of after-hours services on ED utilization by different subgroups, such as physicians with relatively-healthy or relatively-sick patients.

Our empirical findings are strikingly consistent with the theoretical model. For example, we document that regular- and after-hours services move in opposite directions in response to stronger after-hours incentives. We find that after-hours services reduce nonurgent ED visits, and have little to no impact on urgent ED visits. Most nonurgent ED reductions come from patients in practices with below-median patient morbidity. These findings are not only interesting in themselves; they also support the view that the reduction in ED utilization due to increased after-hours incentives is driven by physician behavior. We estimate that primary care physicians can, on average, treat patients at lower cost than the ED. These cost reductions are increasing in patients' disease severities. Our results show that considering physician skills and patient costs are more than a theoretical exercise; rather, the guidance provided by the model pointed us towards these empirically relevant factors.

## 2 Theoretical Framework

We develop a model to understand how physician behavior and ED utilization are related by analyzing the behavior of patients and physicians during a 24-hour interval, or day. Each day is split into two periods $\tau$: regular hours ($\tau = r$) and after-hours ($\tau = a$).[1] Patients draw disease severities and choose where to seek treatment. Physicians choose how many patients to treat during regular and after hours.

**Patient problem:** In each period $\tau$, patients choose a treatment destination to maximize their utility from health gain, net cost of obtaining treatment. At the beginning of each period, each patient draws a period-specific disease severity $\theta \overset{i.i.d.}{\sim} \text{Unif}[0, 1]$. The random variable $\theta$ represents their utility gain from receiving treatment; sicker patients have bigger health gains, and therefore, utility gains, from treatment. A patient can choose to visit their physician at no cost or can visit the hospital's emergency department at non-pecuniary cost $k_\tau > 0$, which captures disutility of waiting in the ED, anxiety associated with visiting medial services from someone other than the physician you know, etc. A physician can treat patients with severity $\theta \leq \theta_d$, where $\theta_d$ is a public signal representing the physician's skill level. Hospital behavior is fixed: The hospital assigns patients with severity $\theta \leq \theta_h$ to the nonurgent ED and all other patients to the urgent ED, where $\theta_h > k_\tau$ is fixed. A patient has the same health benefit from treatment rendered by either their physician or the hospital's ED, which is natural given that physicians treat patients with conditions treatable at their skill level.

**Physician problem:** The model of physician behavior builds on that of Kantarevic et al. (2011). We normalize each physician to have measure 1 of patients. Let $\mu_\tau$ denote the (endogenous) measure of the physician's patients who seek treatment at the physician's office in period $\tau$.

The physician chooses the level of services to provide during regular hours ($x_r$) and after hours ($x_a$) to maximize utility, subject to budget and time constraints. For simplicity, services $x_\tau$ can be viewed as the probability a patient seeking treatment at the physician during period $\tau$ will be treated.[2] Formally, the physician

[1] To simplify exposition, we assume these periods are of equal length. This assumption is not necessary and does not qualitatively affect the theoretical results.

[2] This assumption is only made to simplify the exposition; the theoretical results also hold in the more general case where the probability of being seen by the physician is an increasing in physician services $x_\tau$.

solves

$$\max_{x_r, x_a, l} u(c, l, x_a) \tag{1}$$

$$\text{s.t.} \quad c = \mu_r x_r + (1+\pi)\mu_a x_a \tag{2}$$

$$l = H - x_r - x_a \tag{3}$$

$$x_r \geq 0; \quad x_a \geq x_{\min} > 0. \tag{4}$$

Equation (1) specifies that the physician derives utility from consumption goods $c$ and leisure $l$, and that their utility also depends on the total level of after-hours services; utility is assumed to be separable in these arguments. We assume that marginal utilities of consumption and leisure are positive ($u_c, u_l > 0$) and decreasing ($u_{cc}, u_{ll} < 0$). We also assume that the marginal utility of working after hours is negative and decreasing ($u_a, u_{aa} < 0$). The budget constraint, equation (2), states that the physician spends their total income on consumption goods. Total income comes from services provided during regular hours ($\mu_r x_r$) and after hours ($(1+\pi)\mu_a x_a$), where the price of medical services has been set to 1 and $\pi > 0$ is the after-hours premium. Equation (3) says that the physician allocates $H$ units of time between services provided during regular hours, services provided during after-hours $x_a$ and leisure activities ($l$). Because $x_\tau$ represents the physician's availability, the measure of patients $\mu_\tau$ does not enter equation (3)—i.e., the physician does not consume leisure time at their office, even if no patients arrive. We obtain similar results so long as the physician enjoys leisure during non-work hours more than leisure during work hours. Finally, the equations (4) state that medical services during regular hours must be nonnegative and that after hours services must be above some minimal level $x_{\min}$.

**Equilibrium:** Because visiting their physician is costless, the optimal patient action is independent of physician treatment probabilities $x_\tau$. Therefore, we solve the patient problem first.

**Patient solution:** Define a threshold disease severity $\theta_\tau \equiv k_\tau$. Patients' optimal actions map their disease severity to a treatment destination according to the following:

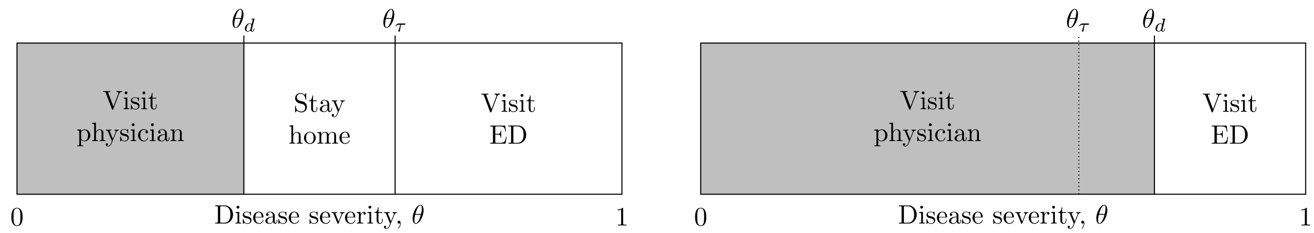
- if $\theta \leq \theta_d$ they seek treatment at the physician (because they receive expected benefit $x_\tau \theta$, which is larger than their cost of visiting the physician, which is 0);
- if $\theta > \theta_d$ and $\theta < \theta_\tau$ they stay at home (because the physician cannot treat them and their benefit from visiting the ED does not warrant their cost of going there, $k_\tau$);
- and if $\theta > \theta_d$ and $\theta \geq \theta_\tau$ they seek treatment at the ED.

Patients' optimal actions are shown in Figure 1. Figure 1(a) shows the solution for patients whose physician has a skill level below their cutoff for visiting the ED, i.e., $\theta_d < \theta_\tau$. Figure 1(b) shows the solution for patients who have a relatively high-skill physician, i.e., $\theta_d > \theta_\tau$. In each figure, the patients with disease states $\theta$ such that they would visit their physician are shaded gray. Note there is no need to take a stand about whether the relationship between physician skill and patient costs is like that in Figure 1(a) or Figure 1(b); rather, the data will indicate whether physician skills are high enough to reduce ED visits. Also note that a model in which patients did not know their disease severity would have the same patient solution: Because visiting their physician is costless, patients would always seek treatment at the physician, who if they see the patient, would treat them if $\theta \leq \theta_d$; if seen by their physician, a patient would only be referred to the ED if $\theta > \theta_d$ and would find it worth the non-pecuniary cost of doing so only if $\theta > \theta_\tau$.

**Physician solution:** Given patients' optimal strategies, in equilibrium it must be the that $\mu_\tau = \theta_d$ for $\tau = r, a$. That is, patients who can be treated by the physician are the measure of patients seeking treatment by the physician in either the regular- or after-hours period.

Figure 1: How patient solution depends on disease severity $\theta$, physician skill $\theta_d$, and cost of visiting ED $\theta_\tau$

(a) Patient solution when $\theta_d < \theta_\tau$ (b) Patient solution when $\theta_d > \theta_\tau$




The physician's optimal strategy maximizes their utility, equation (1), having set $\mu_\tau = \theta_d$. We consider interior solutions, i.e., positive levels of regular- and after-hour services and leisure.[3] Substituting the budget and time constraints, the first order conditions with respect to $x_r$ and $x_a$ are, respectively,

$$\theta_d u_c(\theta_d(x_r + (1+\pi)\, x_a)) - u_l(H - x_r - x_a) = G_r(x_r, x_a, \pi) = 0 \tag{5}$$

and

$$(1+\pi)\, \theta_d u_c(\theta_d(x_r + (1+\pi)\, x_a)) - u_l(H - x_r - x_a) + u_a(x_a) = G_a(x_r, x_a, \pi) = 0. \tag{6}$$

An interior solution is a pair $(x_r^*, x_a^*)$ such that $G_r(x_r^*, x_a^*, \pi) = 0$ and $G_a(x_r^*, x_a^*, \pi) = 0$.

**Comparative statics:** We now characterize how the above equilibrium would change in response to an increase in the after-hours incentive. Let $\phi_r(x_a; \pi)$ characterize the level of regular-hours services satisfying equation (5), given after-hours services $x_a$ and premium level $\pi$. By the Implicit Function Theorem

$$\frac{\partial \phi_r(x_a;\pi)}{\partial x_a} = \frac{\partial x_r}{\partial x_a}|_{G_r(x_r,x_a;\pi)=0} = -\frac{\frac{\partial G_r}{\partial x_a}}{\frac{\partial G_r}{\partial x_r}} = -\frac{(1+\pi)\,\theta_d^2 u_{cc} + u_{ll}}{\theta_d^2 u_{cc} + u_{ll}} < -1, \tag{7}$$

because both $u_{cc}$ and $u_{ll}$ are negative, both the numerator and denominator are negative, and then $\pi > 0$ implies the numerator is larger than the denominator. The slope becomes more negative as $\pi$ increases, corresponding to a downward shift of $\phi_r(x_a; \pi)$. Intuitively, increases in $x_a$ increase consumption, causing a decrease in $x_r$—or increase in leisure—to maintain equation (5). The decrease in $x_r$ will be larger when $\pi$ is larger.

Let $\phi_a(x_r; \pi)$ characterize the level of after-hours services satisfying equation (6), given regular-hours services $x_r$ and a premium level $\pi$. Again, by the Implicit Function Theorem

$$\frac{\partial \phi_a(x_r;\pi)}{\partial x_r} = \frac{\partial x_a}{\partial x_r}|_{G_a(x_r,x_a;\pi)=0} = -\frac{\frac{\partial G_a}{\partial x_r}}{\frac{\partial G_a}{\partial x_a}} = -\frac{(1+\pi)\,\theta_d^2 u_{cc} + u_{ll}}{(1+\pi)^2\,\theta_d^2 u_{cc} + u_{ll} + u_{aa}} \in (-1, 0), \tag{8}$$

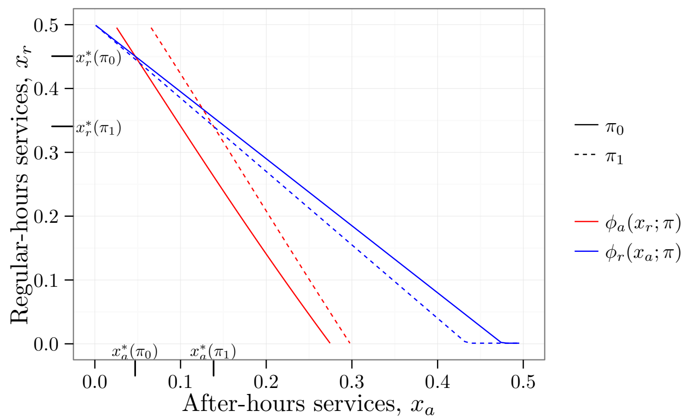
because $u_{aa}$ is also negative, which combined with $\pi > 0$, implies the denominator is larger than the numerator. Here, an increase in $\pi$ increases the denominator more than the numerator, meaning the slope becomes shallower, or less negative, when the premium increases. This corresponds to an upward shift of $\phi_a(x_r; \pi)$ when $\pi$ increases; which is intuitive given that $\pi$ reflects the consumption gain from providing after-hours services.

Instead of solving the model for a specific parameterization, we sign comparative statics using a graphical technique for our fairly general specification of the physician's problem. Figure 2 depicts the optimal solution to the physician's problem, where $H = 1$, the x-axis indicates after-hours services, and the y-axis indicates regular-hours services. The solid blue line shows how the physician's optimal choice of regular-hours services

[3] If at corner solution where $x_a^* = 0$ then $\frac{\partial x_a^*}{\partial \pi} = \frac{\partial x_r^*}{\partial \pi} = 0$. This result differs from that in Kantarevic et al. (2011) because, in our context, there is no income effect if the physician does not exploit the higher after-hours premium; the results in our paper do not assume that income effects are zero. That paper also had changes in physician remuneration during regular hours because it compared FHG and FFS.

$x_r$ depend on after-hours services, $x_a$, given an initial after-hours premium $\pi = \pi_0$. As after-hours services increase, regular-hours services decrease by a greater amount, as the income effect from the premium has the physician consuming more leisure.

Figure 2: Comparative statics of services with respect to after-hours premium




The solid red line shows the optimal level of after-hours services, given regular-hours services and $\pi = \pi_0$. This function is lower than that for regular hours, due to the disutility of providing after-hours services. Like $\phi_r$, it is also decreasing due to the marginal utility from leisure; however, because income effects would now work in the opposite direction, the decline is shallower than that for regular-hours services.[4] The solution to the physician's problem is then the fixed-point $(x_r^*, x_a^*; \pi)$ solving $x_r^* = \phi_r(x_a^*; \pi)$ and $x_a^* = \phi_a(x_r^*, \pi)$, i.e., the intersection of the solid red and blue lines.

The dotted blue line shows how $\phi_r$ rotates when the premium increases to $\pi_1$. Intuitively, the income effect is now even larger, meaning the decrease in regular-hours services would be even larger given a change in after-hours services. The dotted red line shows how $\phi_a$ shifts when the premium increases. A higher premium increases $(1+\pi)u_c(c(x_r, x_a; \pi))$, requiring higher after-hours services (which lowers $u_c(\cdot)$) to satisfy the first-order condition; this is why the dotted red line lies to the right of the solid red line. Therefore, $\phi_a(x_r; \pi)$ increases in $\pi$. The fact that both dotted lines shift to reduce regular-hours services results in the first model implication.

**Implication 1.** *An increase in the after-hours premium unambiguously reduces regular-hours services $x_r^*$.*

If $\phi_a(x_r; \pi)$ was increasing in $x_r$, then the effect of increasing the after-hours premium would be ambiguous. However, we showed in equation (8) that $\phi_a$ is decreasing in $x_r$, which leads to the second implication.

**Implication 2.** *After-hours services $x_a^*$ will unambiguously increase in response to an increase in the after-hours premium.*

Implication 1 is intuitive: substitution and income effects both decrease regular-hours services $x_r^*$. In contrast, Implication 2 may be surprising because it may have seemed that the effect on $x_a^*$ should be ambiguous. The perfect substitutability between $x_r$ and $x_a$ implied by the budget and time constraints underlies the unambiguous result. There are two substitution effects, from $x_r$ and $l$ into $x_a$, as $\pi$ increases. The income effect, however, should in the opposite direction, causing the physician to decrease services and consume more leisure. Indeed, a physician's total services, $(x_r^* + x_a^*)$, may increase or decrease in response to an increase in $\pi$; if $x_r^*$ were fixed at zero then the effect of increasing $\pi$ on $x_a^*$ would indeed be ambiguous. Put another way, if the (unambiguous) reduction in $x_r^*$ is primarily re-allocated to $x_a^*$, then leisure will decrease. The opposite occurs if it is instead primarily re-allocated to leisure.

[4]To see this graphically, rotate Figure 2 counter-clockwise.

Note that service responses to increases in the premium $\pi$ (i.e., reduction in $x_r$ and increase in $x_a$) will be larger, the higher is a physician's skill level, $\theta_d$. This is because both $\phi_a$ and $\phi_r$ shift by larger amounts when a physician's skill level $\theta_d$ is larger. Intuitively, the marginal benefit associated with changing one's service level in response to an increase in the premium increases in the measure of patients (i.e., increase in income and, therefore, consumption) the physician can treat.

## 2.1 Effect of After-Hours Incentives on Emergency Department Utilization

Now that we have characterized how physicians will respond to increases in the after-hours premium, we examine how increases in the premium will affect ED utilization. We first consider the effect on ED visits and then the effect on net health system costs.

### 2.1.1 Effect of After-Hours Incentives on Emergency Department Visits

Consider period $\tau$. Let $T$ denote the event that a patient is treated by the physician, $ED$ denote the patient being treated at the ED, $N$ denote being treated at the nonurgent ED, and $U$ denote being treated at the urgent ED. Table 1 presents the measures of patients treated at the nonurgent ED ($N$) and urgent ED ($U$) and by their physician ($T$), which are derived in Appendix A. In the "Low" physician's skill level scenario the physician's skill level is below the minimum disease severity that would have patients visit the ED. Therefore, changes in physician services $x_\tau$ have no effect on the measures of patients at either nonurgent $\mu_{N,\tau}$ or urgent EDs $\mu_{U,\tau}$. Note however, that the measure of patients treated by the physician $x_\tau \theta_d$ is increasing in both service level and physician skill level. In the "Moderate" scenario the physician is skilled enough to treat some, but perhaps not all, disease severities high enough to warrant seeking (and receiving) treatment at the nonurgent ED, but not skilled enough to treat diseases severe enough to warrant treatment at the urgent ED. Corresponding to this, $\mu_{N,\tau}$ is decreasing in physician services, as $\theta_d > \theta_\tau$ in this scenario, but $\mu_{U,\tau}$ is unaffected by physician services. Finally, in the "High" scenario the physician is skilled enough to treat even urgent-ED-level disease severities, meaning that increases in physician services reduce patients at the nonurgent ED (as $\theta_h > \theta_\tau$) and the urgent ED (as $\theta_d > \theta_h$ in this scenario). Examination of Table 1 leads to the next model implication.

Table 1: Measure of patients at each treatment destination in period $\tau$, by physician skill $\theta_d$ scenario

| | | Physician skill scenario | | |
|---|---|---|---|---|
| | | Low | Moderate | High |
| Measure of patients treated at: | | $\theta_d \leq \theta_\tau$ | $\theta_d \in (\theta_\tau, \theta_h]$ | $\theta_d > \theta_h$ |
| Nonurgent ED | $\mu_{N,\tau}(= \Pr\{\text{N}\|\tau\})$ | $\theta_h - \theta_\tau$ | $(\theta_h - \theta_\tau) - x_\tau(\theta_d - \theta_\tau)$ | $(\theta_h - \theta_\tau) - x_\tau(\theta_h - \theta_\tau)$ |
| Urgent ED | $\mu_{U,\tau}(= \Pr\{\text{U}\|\tau\})$ | $1 - \theta_h$ | $1 - \theta_h$ | $(1 - \theta_h) - x_\tau(\theta_d - \theta_h)$ |
| Physician | $\mu_{T,\tau}(= \Pr\{T\|\tau\})$ | $x_\tau \theta_d$ | $x_\tau \theta_d$ | $x_\tau \theta_d$ |

**Implication 3.** *Increases in period-$\tau$ services do not necessarily result in commensurate decreases in ED visits; rather the reduction in ED visits depends on the relationship between physician skill $\theta_d$ and patient costs of visiting the ED, $k_\tau$.*

To see why Implication 3 is true, again consider the "Moderate" physician skill scenario and hold physician skill and patient costs constant. The change in after-hours ED visits due to an increase in premium is $-\frac{\partial x_a}{\partial \pi}(\theta_d - \theta_a)$, while the change in patients treated by the physician after-hours is $\frac{\partial x_a}{\partial \pi}\theta_d$. The higher is the patients' non-pecuniary cost of visiting the ED after hours, $\theta_a$, the smaller reduction in nonurgent ED visits after hours corresponding to a given increase in after-hours premium. In the extreme, as $\theta_a \to \theta_d$ we have $\frac{\partial \mu_{N,a}}{\partial \pi} \to 0$, i.e., there would be no reduction in after-hours visits to the nonurgent ED.

The measure of ED visits in the data is the sum of regular- and after-hours visits. Given how regular and after hours partition each day (recall that, for simplicity, we assume an equal split, i.e., $\Pr\{r\} = \Pr\{a\} = 1/2$, which is not necessary for our theoretical results), we can write the total measure of patients at the nonurgent ED during a period as $\Pr\{N\} = \Pr\{N|a\}\Pr\{a\} + \Pr\{N|r\}\Pr\{r\}$ which, as shown in Table 1, depends on physician skill level and services provided. Total measures of patients at each treatment location are shown in Table A.1 in Appendix A.

For the "Moderate" physician skill scenario, fixing physician skill $\theta_d$ and patient costs $(\theta_r, \theta_a)$, we can compute how increasing access to after-hours care by increasing the after-hours premium affects the measure of patients visiting the nonurgent ED

$$\frac{\partial \mu_N}{\partial \pi} = -\frac{1}{2}\left(\frac{\partial x_r^*}{\partial \pi}(\theta_d - \theta_r) + \frac{\partial x_a^*}{\partial \pi}(\theta_d - \theta_a)\right). \tag{9}$$

We have previously argued that $\frac{\partial x_a^*}{\partial \pi} > 0$ and $\frac{\partial x_r^*}{\partial \pi} < 0$. In the likely case that leisure decreases, i.e., $\frac{\partial l^*}{\partial \pi} < 0$, it must then also be the case that $|\frac{\partial x_a^*}{\partial \pi}| > |\frac{\partial x_r^*}{\partial \pi}|$. However, $\theta_\tau$ is likely lower during regular hours, i.e., $\theta_r < \theta_a$, because patients' cost $k_r$ is likely lower than $k_a$, as waiting in the ED in the night may take quite a long time, and is much costlier than simply showing up at one's physician's office in the night. Indeed, that leisure time is more expensive at night is why after-hours incentives were required in the first place; all else equal, physicians (and other people) would rather not work at night time. Therefore, this means $(\theta_d - \theta_r) > (\theta_d - \theta_a)$, which, by equation (9), implies that the net effect of increasing the premium on nonurgent ED visits is then ambiguous. Note that the same reasoning applies to nonurgent ED visits in the "High" physician skill scenario.

**Implication 4.** *Increasing physician incentives to provide after-hours access may have an ambiguous effect on ED visits.*[5]

The model shows that physician responses and the ceteris paribus effects of those responses on ED visits both depend on the physician skill level. We have observed that behavioral responses of physicians are larger, the higher is the physician's skill level. The next implication examines this source of potential heterogeneity.

**Implication 5.** *Conditional on physician services, the effects of increasing the after-hours premium on ED visits will be larger for physicians with higher skill levels. Because physicians with higher skill levels will respond more to increases in the after-hours premium, this also implies the effects of increasing the after-hours premium on ED visits will be larger for higher-skilled physicians even when not conditioning on their service levels.*

The intuition for the first part of Implication 5 is that a given service level will have a larger effect on ED visits when the physician can treat more patients who are likely to have conditions severe enough to warrant their visiting the ED.

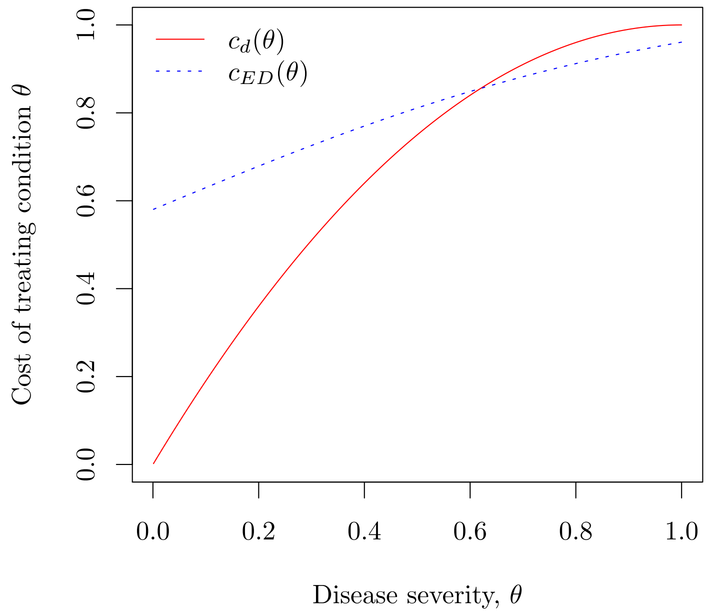
#### 2.1.2 Effect of After-hours Incentives on Net Costs

The model can also be used to analyze how increasing the after-hours premium would affect costs. Let $c_{ED}(\theta)$ and $c_d(\theta)$ respectively denote costs to the ED and physician of treating a patient with disease severity $\theta$. Because physicians are primarily paid according to fee-for-service, one would expect $c_d(\cdot)$ to be constant across physicians, i.e., independent of $\theta_d$.

For simplicity, first assume that $\theta_r = \theta_a = 0$, which implies that any increase in physician services would result in a commensurate decrease in ED visits. The change in cost resulting from the physician with service level $x_\tau$ for patients with severities $\theta \in [\theta_1, \theta_2]$ would then be (recall that $\theta$ is uniformly distributed on the unit

[5] In reality, patients could also visit physicians at walk-in clinics, who are not their regular primary care provider. The model can capture this via an increase in $\theta_a$; if there is another treatment option available this would increase the non-pecuniary cost of visiting the ED. Note then that this further dampen the measured effect of increased after-hours access on ED visits.

Figure 3: Illustration of physician and ED cost functions, $c_d(\theta)$ and $c_{ED}(\theta)$




interval)

$$x_\tau \int_{\theta_1}^{\theta_2} (c_d(\theta) - c_{ED}(\theta))\, d\theta. \tag{10}$$

It is natural (but not necessary for our analysis) to assume that both cost functions are nondecreasing in disease severity. Even if we suppose further that, on average, physicians could treat conditions within their skill level at a lower cost than the ED, i.e., $\frac{\int_0^{\theta_d}(c_d(\theta)-c_{ED}(\theta))d\theta}{\theta_d} < 0$, we obtain another implication.

**Implication 6.** *Even if i) the increased after-hours premium decreases ED visits via increasing physician services and ii) on average, physicians can treat patients at lower cost than can the ED for the entire population of patients, the effect of increasing the after-hours premium has an ambiguous effect on total costs for inframarginal patients, i.e., patients with disease severities $\theta \in [\theta_\tau, \theta_d]$.*

This implication follows because what matters for cost-savings is *the empirical distribution of disease severities*, i.e., whether $c_d(\theta) < c_{ED}(\theta)$, on average, for the relevant range of disease severities low enough to be treatable by physicians, yet high enough to warrant patients' visiting the ED in case they were not able to receive treatment from their physician. This theoretical ambiguity is illustrated in Figure 3, where the physician (solid red curve) has a lower average cost of treating patients, primarily due to a very low cost of treating relatively low-disease severity patients, i.e., those with conditions $\theta < 0.6$. However, the ED (dotted blue curve) has a lower cost of treating patients with high disease severities, i.e., those with severities $\theta > 0.6$. If $\theta_d > \theta_\tau > 0.6$ then an increase in physician services $x_\tau$ will *increase costs to the health system, despite the reduction in ED visits.* It is important to note that this ambiguity arises even without taking into account the mechanical increases in the cost of physician services due to the higher premium.

Section 4.1 shows how the above theoretical results are mapped to the data.

# 3 Background, Data, and Variables

## 3.1 Institutional Background

Primary care reforms were introduced in the early 2000s across various jurisdictions in Canada (Health Canada, 2007; Sweetman and Buckley, 2014). Common across these reforms was a move from the traditional fee-for-service (FFS) remuneration scheme towards non-FFS payment models with varying degrees of financial incentives for after-hours access, preventive care bonuses, and chronic disease management incentives (Glazier et al., 2008; Hutchison et al., 2011; Ricketts, 2011; Sarma et al., 2011). Several new types of non-FFS primary care delivery models featuring these financial incentives have been introduced since 2004 (Hutchison et al., 2011).

Before 2004, virtually all family physicians in Ontario were paid on a FFS basis; by 2010, more than two-thirds of Ontario family physicians had joined one of the new models, with Family Health Organizations (FHO) and Family Health Groups (FHG) being the two most popular choices (Henry et al., 2012). The FHG is an enhanced FFS model where the majority of payments are based on FFS but it includes explicit financial incentives for patient enrollment, health promotion and disease management activities. The Comprehensive Care Model (CCM) model is very similar to FHG except that physicians are solo practitioners. Family Health Networks (FHN) and FHO models have a very similar incentive structure to FHGs except that physicians are predominantly paid on a capitation basis for enrolled patients, adjusted for age and gender ((OAGO), 2011; Glazier et al., 2012).

Each physician practicing in the new models is required to provide a minimum of a three-hour session per week during either weeknights after 5 pm or weekends. These physicians receive an after-hours premium for services provided outside regular working hours. Initially, the premium was 10% when it was introduced in 2003 but increased to 15% in April 2005, 20% in April 2006 and then to 30% in September 2011 (Sweetman and Buckley, 2014).

## 3.2 Data and Variables

The data for this study come from several administrative databases held at the Institute for Clinical Evaluative Sciences (ICES). Primary care physicians and their characteristics were obtained from the ICES Physician Database. The Corporate Provider Database (CPDB) is used to obtain the physician's model type, effective date of eligibility for billing under the Ontario Health Insurance Plan (OHIP) and physician group size (based on the unique group affiliation number in the CPDB). Our data span the years 2004-2013, with 7,320 unique physicians and 44,470 physician-year observations.

The Client Agency Program Enrollment Database (CAPE) is used to obtain the physician's model type and their enrolled patients' information in each year. If a physician was affiliated with more than one practice type in a given year, then the most recent one joined was selected. The CAPE database is used to assign patients to physicians in all patient enrollment models. Patient demographic information (age and sex) was obtained from the Registered Persons Database (RPDB), which is Ontario's health registry database. Patient postal codes from the RPDB were used to obtain dissemination-area level deprivation indices and rurality index. The deprivation index is organized into quintiles, where 1 is least marginalized and 5 is most marginalized, and individuals with a rurality index of 40 or higher are considered to reside in rural areas. (Kralj, 2000; Matheson et al., 2012).

Information regarding after-hour visits was obtained from OHIP. We identified all claims submitted to the Ministry of Health and Long-term care by physicians with the after-hour premium code Q012 for physicians in capitation (FHN/FHO) and FFS (FHG), and Q016 for those in CCM together with a list of fee codes (A001, A003, A004, A007, A008, A888, K005, K013, K017, K033, k030, Q050 for the claims prior to Jan 1, 2013; after Jan 1, 2013, three more codes K130A, K131A and K132A were added). Because certain physicians were exempted from providing after-hours service as per the FHG and FHO contracts, we restricted our analysis to those physicians who claimed at least one Q012 or Q016 incentive in OHIP in a given year (as discussed previously, this is consistent with our focus on interior solutions in the theoretical model). We excluded part-time physicians, defined as having fewer than 500 patients or 500 visits in any given year. Information regarding emergency department visits was obtained from the National Ambulatory Care Reporting System (NACRS), which captures information on patient visits to hospital and community based ambulatory care, day surgeries, outpatient clinics and emergency departments.

A patient visit to a physician was identified through the OHIP billing and shadow billing claims. For each physician, total annual office visits were derived as the sum of patient visits to his/her office. The total number of annual office visits minus the corresponding total number of annual after-hour visits defines regular hours visits for each physician. Group size was calculated by summing up the number of primary care physicians with the same group number.

ED visits were classified into urgent and nonurgent based on the Canadian Triage and Acuity Scale (Beveridge et al., 1999) recorded in NACRS. If the triage level was 1 (resuscitation), 2 (emergent), or 3 (urgent), then the ED visit was defined as urgent; if the triage level was 4 (less-urgent/semi-urgent) or 5 ( nonurgent), then it is defined as nonurgent in our empirical analysis.

We derived ADGs for each patient based on their diagnosis codes from the hospital Discharge Abstract Database (DAD) and OHIP, using the Johns Hopkins Adjusted Clinical Group case-mix adjustment system, a well-known measure of patients' comorbidity status in the health services literature. As the ADGs comprise 32 diagnosis groups, each patient has 32 indicator variables. We summed up ADGs for each patient, yielding an ADG score up to 32. The average ADG score was defined as the average of ADG scores of the physician' patients.

# 4 Empirical Framework

## 4.1 Mapping the Theoretical Model to the Data

### 4.1.1 Testable Implications

Our theoretical analysis focused on physician behavior as the driver of changes in ED utilization and also proposed determinants of physician behavior: relative compensation of after-hours services $\pi$ and physician skill level $\theta_d$. There are several theoretical predictions concerning the effects of after-hours premium increases on physician behavior and ED visits, which can be tested empirically. Testing these implications not only lends credence to our theoretical framework, in which physicians choose how to allocate their time to maximize their utility, but also provides evidence that physician services may indeed underlie changes in ED visits due to stronger incentives.

**Implications 1-2:** Services during regular hours will decrease while those provided after-hours will increase in response to an increase in the after-hours premium.

**Operationalization:** To analyze the relationship between incentivizing access and services provided, we estimate the following regression equation:

$$\ln(x_{it}) = Z'_{it}\beta_{x,\pi} + \rho_{x,\pi}\pi_t + \epsilon_{it,x,\pi}, \tag{11}$$

where $x_{it}$ can be either regular- or after-hours services, measured by either visits per 1,000 patients or (deflated) cost per 1,000 patients; $Z_{it}$ includes a time trend, physician's age, physician's age squared, proportion of female physicians and foreign graduates in the physician's practice, group size, average age of patients, average ADG score of patients, proportion of patients living in deprived neighborhoods, and proportion of patients living in rural areas; $\pi_t$ is the premium level in year $t$; and $\epsilon_{it,x,\pi}$ represents the error term, which may include a fixed-effect component for the physician. Implication 1 would predict that $\rho_{x,\pi} < 0$; Implication 2 would predict the opposite.

Data on after-hours services are not relevant for FFS physicians, leading us to focus our analysis on physicians who have switched into a scheme that incentivizes after-hours services via a positive premium, instead of studying physicians pre- and post-introduction of after-hours incentives. That is, we start with $\pi > 0$ and consider interior solutions $(x_\tau > 0, \tau = a, r)$. Not only does this use the time periods for which we have the best measures, but also avoids potential corner solutions in after-hours services.

**Implication 3:** The within-period percentage reduction in ED visits will be smaller than the percentage increase in physician services, i.e., $\frac{\partial \mu_{ED,\tau}}{\partial x_\tau}$ may be small.

**Operationalization:** Recall that ED-utilization data are available at the aggregated (i.e., sum of regular- and after-hours periods) level, meaning that Implication 3 cannot be directly tested. To see how our empirical analysis can still have a bearing on Implication 3, consider the effect of a change in after-hours visits, caused by the increase in premium, on nonurgent ED visits in the "Moderate" skill scenario, if we did not condition on regular-hours services $x_r$:

$$\frac{\partial \mu_N}{\partial x_a} = -(\theta_d - \theta_a) - \frac{\partial x_r}{\partial x_a}(\theta_d - \theta_r), \tag{12}$$

where the first term is the direct effect, i.e., $\frac{\partial \mu_{N,a}}{\partial x_a}$, and is negative, in theory, and the second term is positive, in theory, as $\frac{\partial x_r}{\partial x_a}$ move in opposite directions according to Implications 1-2. Note, however, that if $\theta_r < \theta_a$, as we argued previously was likely the case, then by estimating $\frac{\partial \mu_N}{\partial x_a}$ we obtain a measure of $\frac{\partial \mu_{N,a}}{\partial x_a}$ that is biased upwards towards zero. The larger is $\mid \frac{\partial x_r}{\partial x_a} \mid$, i.e., the smaller is the decrease (or the bigger is the increase) in leisure, the more attenuated this measure will be.

Therefore, we directly analyze the relationship between after-hours services and ED services, as well as provide some evidence about Implication 3—that changes in services will not result in commensurate decreases in ED visits—by estimating the elasticity of ED visits with respect to after-hours services using the following regression model:

$$\ln(\mu_{it}) = Z_{it}'\beta_{\mu,x} + \rho_{\mu,x}\ln(x_{it}) + \epsilon_{it,\mu,x}, \tag{13}$$

where $\mu_{it}$ can be total, nonurgent, or urgent ED visits per 1,000 patients for physician $i$ in year $t$; $x_{it}$ represents after-hours services; $Z_{it}$ contains the variables from equation (11); and $\epsilon_{it,\mu,x}$ represents the error term, which may include a fixed-effect component for the physician. Based on equation (12), when interpreting estimates of equation (13) we keep in mind the caveat that the estimate of $\rho_{\mu,x}$ likely understates the extent to which after-hours services reduce ED visits.

**Implication 5:** The effect of increasing the after-hours premium on ED visits will be larger for higher-skilled physicians.

**Operationalization:** Consider again the effect of after-hours services on nonurgent visits for the "Moderate" skill scenario. As with Implication 3, we can only study the effect on the sum of regular- and after-hours ED visits[6]

$$\frac{\partial^2 \mu_N}{\partial x_a \partial \theta_d} = -1 - \frac{\partial^2 x_r}{\partial x_a \partial \theta_d}(\theta_d - \theta_r) - \frac{\partial x_r}{\partial x_a}. \tag{14}$$

The middle term represents how the leisure response of physicians varies with respect to physician skill, and is arguably not very large. The last term will be smaller than one in absolute value in the likely case that physicians decrease leisure time in response to the increased after-hours premium, which is likely the case given

[6]This is derived by first computing $\frac{\partial \mu_N}{\partial x_a} = -(\theta_d - \theta_a) - \frac{\partial x_r}{\partial x_a}(\theta_d - \theta_r)$, which we then differentiate with respect to $\theta_d$.

that after-hours visits comprise a relatively small share of total office visits. So long as these latter two terms are not large, the sign of the expression in equation (14) will be informative about the extent to which more highly skilled physicians have larger effects on ED utilization.

A second issue is that physician skills are not directly observed in the data; indeed the assessment of physician human capital would constitute a research project in itself. However, consider two physicians, one with relatively healthy patients and one with relatively sick patients. If variation in physician quality is smaller than variation in patient health distributions, then the physician with the sicker patients has higher skill, relative to their patient health distribution, because they can treat a larger measure of patients' health conditions. Then, we can examine Implication 5 by estimating equation (13) on subsamples of physicians, split by the distribution of patient health.

#### 4.1.2 Theoretically Ambiguous Effects

The model also shows that the effects of after-hours incentives on ED visits and costs are theoretically ambiguous. Therefore, we must estimate the following relationships using our detailed micro-data on physician services, ED visits, and costs:

**Implication 4:** The net effect of increasing the after-hours premium on nonurgent ED visits may be ambiguous.

**Operationalization:** We estimate the following regression equation:

$$\ln(\mu_{it}) = Z_{it}'\beta_{\mu,\pi} + \rho_{\mu,\pi}\pi_t + \epsilon_{it,\mu,\pi}, \tag{15}$$

where $\mu_{it}$ can be total, nonurgent, or urgent ED visits per 1,000 patients for physician $i$ in year $t$; $\pi_t$ is the after-hours premium in year $t$; $Z_{it}$ contains the variables from equation (11); and $\epsilon_{it,\mu,\pi}$ represents the error term, which may include a fixed-effect component for the physician.

**Implication 6:** The net effect of increasing the after-hours premium on the sum of nonurgent ED and after-hours costs may be ambiguous, even if nonurgent ED visits decrease due to the after-hours premium increase.

**Operationalization:** Similar to that for Implication 4.

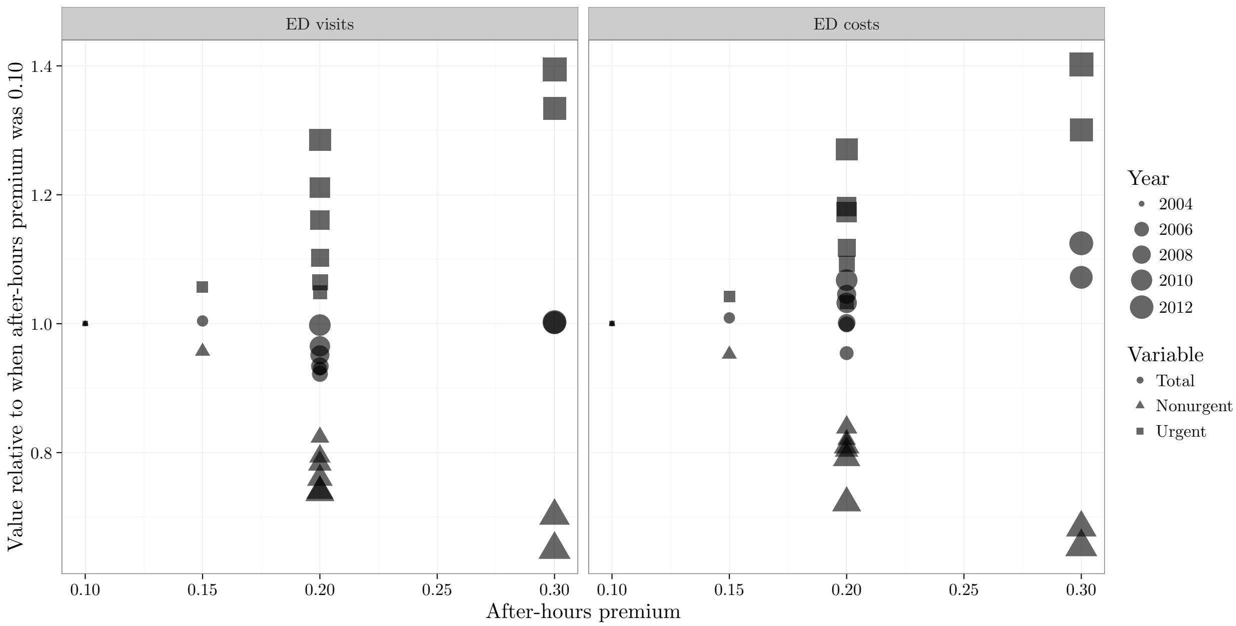
### 4.2 Descriptive Statistics

Descriptive statistics by year are in Table B.1, in Appendix B. Between 2004 and 2013, the number of regular- and after-hours visits per 1,000 patients of physicians decreased. However, the value of after-hours fees (deflated by the premium level), a measure of physician services provided after hours, more than doubled.[7] During the same period, the number of urgent ED visits increased while the number of nonurgent ED visits decreased. The average age of physicians, the proportion of female physicians, and proportion of foreign graduates increased over time while group and roster sizes decreased. The average age of patients increased while the proportions of patients from deprived and rural areas decreased. Table B.2, also in Appendix B, presents statistics pooled over the sample period and shows that after-hours visits comprise about 11% of physicians' total visits, on average.

Figure 4 shows how mean ED visits per 1,000 patients (left panel) and mean ED costs per 1,000 patients (right panel) change as a function of the after-hours premium $\pi$, which ranges from 10% (in 2004) to 30% (for 2012 and 2013). In each panel, the point at the far left is the value for that variable when the after-hours premium was 10%, which has been normalized to 1. The shape of the point indicates the variable being

[7] Note that by "after-hours fees" we refer to the bonus paid to the physician; we refer to the base amount plus bonus as the "total payment".

Figure 4: ED visits and costs by after-hours premium




measured; for example, total ED visits are circles, nonurgent ED visits are triangles, and urgent ED visits are squares. To show time variation, point size is increasing in year. This is indicated in both panels, where point sizes increase as the premium, plotted on the x-axis, increases.

Looking at after-hours visits (left panel), we can see that total ED visits (circles) initially decrease as the after-hours premium increases from around 10%-15% to 20%, but then increase over time as the premium is fixed at 20% and stay constant when the premium again increases to 30%. However, this pattern obscures heterogeneity by type of ED visit. Nonurgent ED visits (triangles) decrease sharply when the after-hours premium increases, and then they decrease further as the premium stays constant at 20% and 30%. In contrast, urgent ED visits (squares) tend to increase when the after-hours premium increases, though such increases are approximately the same as increases that occur over time when the premium is fixed. The pattern for ED costs (right panel) is almost identical in shape and magnitude, indicating that cost per ED visit type remain more-or-less constant. Total ED costs are higher at the end of the sample period than at the beginning, in contrast to total ED visits, which stay more or less constant because urgent ED visits have above-median costs per visit.

## 4.3 Empirical Findings

We start our empirical analysis by bringing the data to bear on Implication 4. We then test model predictions to see whether our proposed mechanism involving patient health and costs and physician skill levels is broadly consistent with the data (Implications 1-3). We end by examining Implication 5, leaving Implication 6 for the discussion (Section 5). Standard errors are clustered at the physician level for all specifications.

**Effect of after-hours incentives on ED utilization:** Implication 4 is that the effect of after-hours incentives is ambiguous. The left side of Table 2 presents coefficients from OLS regressions of the logarithm of ED visits $\mu$ on the after-hours premium and physician/practice characteristics, for total ED visits, nonurgent ED visits, and urgent ED visits (eq. 15). The partial correlation coefficient on the premium is negative overall (specification (1)), and for both nonurgent and urgent ED visits (specifications (2)-(3), respectively). Female physicians tend to have fewer ED visits, as do foreign medical graduates (IMG) and physicians in larger practices (group size). Physicians with younger patients (avg. age), fewer deprived patients (avg. deprived), and fewer rural patients (avg. rural) also have fewer ED visits. Physicians with higher mean patient ADGs (avg. ADG) have more ED visits, which is driven by more urgent ED visits. The right side of Table 2 presents the (physician) fixed-effects results. We can see that the effect of $\pi$ is now half as large for total ED visits (specification (4)) and is driven by both nonurgent and urgent ED visits (specifications (5) and (6), respectively). The qualitative results from the OLS and fixed-effects models are the same: ED visits decrease as physicians are exposed to higher premium levels.

Comparing OLS and fixed-effects specification highlights the potential importance of empirically addressing physician and practice heterogeneity. The OLS results indicate that higher practice-level mean ADG scores (avg. ADG) have a negative partial correlation with nonurgent ED visits and a positive partial correlation with urgent ED visits. In contrast, the fixed-effects results indicate that within-physician increases in mean ADG scores have positive partial correlations with both nonurgent and urgent ED visits. The model helps to explain this apparent inconsistency. If more-skilled physicians—in the model represented by higher $\theta_d$—serve less-healthy patients—in the data, higher avg. ADG—then by increasing mean ADG scores we may also increase physician skill levels as we move through the cross section, which would, according to Implication 5, correspond to reductions in nonurgent ED visits.[8] The fixed-effects results only use variation coming from changes within a physician, which likely restrict variation in physician skill to a fraction of that in the cross-section. Here, increases in mean ADG score, which we could model as an increase in the lower-bound of the distribution of $\theta$, would increase both nonurgent and urgent ED visits by increasing the density of patient disease severities at risk of visiting the ED.

[8]Note that if physician choices are determined by the premium, by conditioning on the premium we are effectively controlling for changes in these inputs.

Table 2: Change in emergency department visits, as function of after-hours premium and other covariates

| | OLS | | | | | | FE | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ln total visits | | Ln nonurgent visits | | Ln urgent visits | | Ln total visits | | Ln nonurgent visits | | Ln urgent visits | |
| | (1) | | (2) | | (3) | | (4) | | (5) | | (6) | |
| | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. |
| Premium | −0.285 | 0.031 | −0.254 | 0.044 | −0.264 | 0.030 | −0.130 | 0.016 | −0.104 | 0.025 | −0.155 | 0.020 |
| Year | −6.935 | 0.745 | 4.561 | 1.111 | −8.612 | 0.715 | −3.843 | 0.394 | 7.895 | 0.610 | −7.130 | 0.460 |
| Year sq. | 0.002 | 0.000 | −0.001 | 0.000 | 0.002 | 0.000 | 0.001 | 9.820e−5 | −0.002 | 0.000 | 0.002 | 0.000 |
| Age | −0.011 | 0.003 | −0.007 | 0.004 | −0.013 | 0.002 | | | | | | |
| Age sq. | 7.460e−5 | 2.440e−5 | 2.510e−5 | 3.500e−5 | 9.790e−5 | 2.140e−5 | 0.000 | 1.840e−5 | 6.460e−5 | 3.040e−5 | 0.000 | 2.230e−5 |
| Female | −0.025 | 0.008 | 0.021 | 0.011 | −0.056 | 0.007 | | | | | | |
| IMG | −0.080 | 0.011 | −0.123 | 0.015 | −0.054 | 0.010 | | | | | | |
| Group size | −0.001 | 5.750e−5 | −0.001 | 7.320e−5 | −0.001 | 5.180e−5 | −9.460e−5 | 1.960e−5 | 1.460e−6 | 2.830e−5 | −0.000 | 2.340e−5 |
| Avg. age | 0.014 | 0.001 | 0.012 | 0.001 | 0.015 | 0.001 | 0.009 | 0.001 | 0.000 | 0.002 | 0.014 | 0.001 |
| Avg. ADG | 0.021 | 0.008 | −0.104 | 0.011 | 0.086 | 0.007 | 0.078 | 0.005 | 0.057 | 0.007 | 0.076 | 0.006 |
| Avg. deprived | 0.008 | 0.000 | 0.008 | 0.000 | 0.008 | 0.000 | 0.005 | 0.001 | 0.006 | 0.001 | 0.005 | 0.001 |
| Avg. rural | 0.009 | 0.000 | 0.015 | 0.000 | 0.002 | 0.000 | 0.008 | 0.001 | 0.013 | 0.001 | 0.001 | 0.001 |
| Constant | 6953 | 749.6 | -4556 | 1114 | 8610 | 716.7 | 3868 | 395.8 | -7901 | 612.9 | 7145 | 462.1 |
| Obs. | 44470 | | 44470 | | 44470 | | 44470 | | 44470 | | 44470 | |

Note: Fixed-effects are at physician level. Standard errors are clustered at physician level; 7320 clusters.

Table 3: Fixed-effects regressions of regular- and after-hours services on after-hours premium and other characteristics

| | Ln after-hrs visits | | Ln after-hrs fees | | Ln reg. visits | |
|---|---|---|---|---|---|---|
| | (1) | | (2) | | (3) | |
| | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. |
| Premium | −0.479 | 0.117 | 0.522 | 0.134 | −0.363 | 0.040 |
| Year | −19.960 | 2.887 | −3.086 | 3.230 | 5.709 | 0.891 |
| Year sq. | 0.005 | 0.001 | 0.001 | 0.001 | −0.001 | 0.000 |
| Age sq. | −0.000 | 0.000 | −0.000 | 0.000 | 0.000 | 4.600e−5 |
| Group size | −2.150e−5 | 0.000 | −0.000 | 0.000 | 0.000 | 4.360e−5 |
| Avg. age | −0.003 | 0.006 | −0.006 | 0.007 | −0.006 | 0.003 |
| Avg. ADG | 0.260 | 0.034 | 0.344 | 0.037 | 0.272 | 0.014 |
| Avg. deprived | −0.000 | 0.003 | −0.003 | 0.004 | 0.003 | 0.001 |
| Avg. rural | −0.007 | 0.003 | −0.008 | 0.003 | 0.001 | 0.001 |
| Constant | 20 067 | 2898 | 3034 | 3242 | −5673 | 894.3 |
| Obs. | 44 470 | | 44 470 | | 44 470 | |

Note: Fixed-effects are at physician level. Standard errors are clustered at physician level; 7320 clusters.

**Effect of after-hours incentives on services:** If increasing the after-hours premium reduces ED utilization by changing physician behavior, this should show up in the data. As discussed in Section 4.1, Implications 1-2 can be examined using our data on physician services. It is not clear what the ideal measure of physician services would be. One possibility would be to use office visits; however, this is not ideal because the amount of services provided per visit may change if the after-hours premium changed. The rich data we obtained for this study enable us to use two measures of physician services rendered by physicians after hours: visits and cost of services administered, deflated for inflation and the size of the premium. The latter measure is a particularly good measure of services rendered if service prices capture input amounts. Visits data were available for regular hours; given that the regular-hours "premium" stays constant at zero, visits and regular-hours costs will co-vary at the same rate over our sample period.[9]

Table 3 presents the fixed-effects results from regressing measures of services on the after-hours premium (eq. (11)).[10] Specification (1) regresses after-hours visits (ln after-hrs visits) on the premium, and finds a negative significant partial correlation coefficient; that is, a higher premium results in lower numbers of after-hours visits. Specification (2) uses the cost of after-hours services—adjusted for the change in premium—as the measure of services rendered (ln after-hrs fees), and finds a strong *positive* relationship between the premium amount (i.e., increase in physician price of labor) and services rendered. Specification (3) examines how the premium affects regular visits (ln reg. visits), and reveals a negative effect, as predicted by the theoretical model. Note the results are larger for after-hours services (visits and fees), consistent with their having a smaller base than regular hours visits. It may be natural for after-hours visits to decrease if physicians can, say, provide more services per visit to take advantage of the higher premium, an effect that would not be present for regular-hours visits. Therefore, though the results in Table 3 are consistent with Implications 1-2, we primarily focus on the deflated cost of after-hours services as the measure of after-hours services in our analysis.[11]

[9]Assuming that the service mix chosen by physicians remains constant.

[10]OLS estimates are similar for these results and those for our other empirical findings. Results are available upon request.

[11]Unless otherwise stated, after-hours fees are deflated to take into account their mechanical increase due to the rise in after-hours premium over time, as opposed to increases in after-hours service levels.

**Effect of after-hours services on ED utilization:** Tables 2 and 3 show that, within-physician, increases in the after-hours premium result in both lower ED usage and higher levels of after-hours services. We can more directly examine Implication 3 by estimating the elasticity of ED visits with respect to service measures using equation (13). Table 4 summarizes the relationship between after-hours fees and ED utilization, using OLS (first row) and fixed-effects (second row) estimates. The qualitative findings from both OLS and fixed-effects models are the same. Increases in after-hours services, measured by after-hours fees, reduce overall ED visits (specification (1)), primarily through reducing nonurgent ED visits (specification (2)). Though, as shown in equation (12) in Section 4.1, because the model shows that regular-hours services will move in the opposite direction as after-hours services, our estimates of how after-hours services affect ED utilization should be interpreted as net of this reduction in regular-hours services. The effect of increasing after-hours services has a smaller (and indistinguishable from zero), effect on urgent ED visits. These results confirm that primary care physicians typically have lower skills than those found in an ED (i.e., have $\theta_d < \theta_h$—the "Moderate" skill scenario). This is consistent with what one would expect physician skill levels to be; if, on average, physicians could treat high-severity conditions there would be little need for specialized practitioners like ED physicians. The fixed-effects estimates are smaller than those from OLS. In either case note that the relatively small effects presented in Table 4 are consistent with Implication 3, that changes in services will not result in commensurate changes in ED visits.

Table 4: Elasticities of emergency department visits with respect to after-hours services

| | Ln total visits (1) | | Ln nonurgent visits (2) | | Ln urgent visits (3) | |
|---|---|---|---|---|---|---|
| | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. |
| OLS estimate | −0.0418 | 0.0024 | −0.0541 | 0.0033 | −0.0281 | 0.0021 |
| FE estimate | −0.0034 | 0.0010 | −0.0041 | 0.0015 | −0.0021 | 0.0012 |

Note: All regressions include the full set of control variables, $Z_{it}$. After-hours services are measured using deflated after-hours fees. Fixed-effects are at physician level. Standard errors are clustered at physician level; 7320 clusters.

The fixed-effects models control for time-invariant physician heterogeneity and provide evidence that increases in after-hours services reduce ED visits, but do they truly represent the impact of physician services on ED visits? Suppose a physician received new patients from another practice and, because the physician did not know these patients, a fast diagnosis was difficult. This would increase physician services and, possibly, increase ED visits too, dampening the estimated effect of physician services on ED utilization. More generally, because fixed-effects models remove cross-sectional variation, one might expect such shocks to play a non-trivial role in associated estimates. The direction of potential bias underlying fixed-effects models, if any, is not obvious a priori.

Motivated by these potential concerns about OLS and fixed-effects estimates, we provide even stronger evidence supporting the link between after-hours services and ED visits by exploiting variation in the after-hours premium over time. We do this by using a two-stage-least-squares approach.

The left side of Table 5 presents regression results showing that the after-hours premium (premium) indeed does strongly relate to the (deflated) value of after-hours services per 1,000 patients (after-hrs fees); this corresponds to the first stage of the two-stage-least-squares estimator, and is consistent with specification (2) in Table 3. The middle side of Table 5 presents second-stage results. The key takeaway from this panel is that total ED visits (specification (1)) decrease as the after-hours premium increases, and this decrease is driven by a decrease in nonurgent ED visits (specification (2)). The results regarding nonurgent ED visits are consistent with those in specifications (2) and (5) in Table 2. However, unlike the OLS and fixed-effects estimates there is no estimated impact of premium increases on urgent ED visits.

Specification (1) of the right side of Table 5 is the estimated impact of after-hours services on total ED visits.

We can see a significant reduction in total ED visits when after-hours services increase; increasing after-hours services by 10% of a standard deviation (sd) would reduce total ED visits by 7.7% sd. Specifications (2)-(3) show that this reduction in ED visits is driven by reductions in nonurgent ED visits, not urgent ED visits. Thus, the instrumental variables estimates are broadly consistent with those estimated from the fixed-effects models: increasing the after-hours premium increases physicians' provision of after-hours services, which in turn decrease ED visits via reducing nonurgent ED visits. The advantage of the instrumental variables estimates is that they isolate the channel of physician behavior as a determinant of ED utilization.

Table 5: Regressions of after-hours services and ED visits on after-hours premium and other characteristics

| | First stage | | Second stage | | | | | | | 2SLS | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | After-hours fees | | Total visits | | Nonurgent visits | | Urgent visits | | | Total visits | | Nonurgent visits | | Urgent visits | |
| | (1) | | (1) | | (2) | | (3) | | | (1) | | (2) | | (3) | |
| | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. | | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. |
| Premium | 699.817 | 291.182 | −52.239 | 12.233 | −52.050 | 9.487 | 4.746 | 6.334 | After-hrs fees | −0.075 | 0.024 | −0.074 | 0.022 | 0.007 | 0.009 |
| Year | 100.510 | 5.626 | 5.418 | 0.364 | −3.558 | 0.281 | 8.815 | 0.189 | Year | 12.921 | 2.745 | 3.917 | 2.510 | 8.133 | 1.075 |
| Age | 21.064 | 6.791 | −3.668 | 1.095 | −0.615 | 0.751 | −3.060 | 0.534 | Age | −2.096 | 1.459 | 0.952 | 1.267 | −3.203 | 0.592 |
| Age sq. | −0.121 | 0.066 | 0.020 | 0.011 | −0.002 | 0.007 | 0.022 | 0.005 | Age sq. | 0.011 | 0.014 | −0.011 | 0.012 | 0.023 | 0.006 |
| Female | −635.013 | 18.523 | −8.212 | 3.136 | 3.258 | 2.107 | −11.562 | 1.545 | Female | −55.614 | 15.612 | −43.972 | 14.238 | −7.256 | 6.107 |
| IMG | 388.078 | 26.052 | −22.792 | 3.891 | −12.580 | 2.437 | −10.221 | 1.967 | IMG | 6.177 | 10.512 | 16.283 | 9.575 | −12.853 | 4.138 |
| Group size | 1.273 | 0.126 | −0.206 | 0.020 | −0.073 | 0.014 | −0.134 | 0.010 | Group size | −0.111 | 0.039 | 0.022 | 0.035 | −0.142 | 0.016 |
| Avg. age | −83.734 | 2.086 | 5.274 | 0.303 | 1.668 | 0.210 | 3.604 | 0.145 | Avg. age | −0.977 | 2.037 | −4.559 | 1.864 | 4.172 | 0.799 |
| Avg. ADG | 1220.436 | 28.292 | 11.681 | 3.252 | −7.425 | 2.193 | 19.031 | 1.651 | Avg. ADG | 102.783 | 29.942 | 83.347 | 27.420 | 10.754 | 11.633 |
| Avg. deprived | 2.613 | 0.632 | 3.773 | 0.129 | 1.855 | 0.094 | 1.906 | 0.058 | Avg. deprived | 3.968 | 0.159 | 2.049 | 0.143 | 1.889 | 0.067 |
| Avg. rural | −4.336 | 0.282 | 4.577 | 0.137 | 3.970 | 0.124 | 0.579 | 0.042 | Avg. rural | 4.253 | 0.165 | 3.648 | 0.151 | 0.608 | 0.059 |
| Constant | -201885.5 | 11267.26 | -10731.73 | 732.543 | 7232.632 | 564.552 | -17639.3 | 381.121 | Constant | -25801.88 | 5512.023 | -7782.95 | 5040.931 | -16270.1 | 2159.597 |
| Obs. | 44 470 | | 44 470 | | 44 470 | | 44 470 | | Obs. | 44 470 | | 44 470 | | 44 470 | |
| F-Statistic | 493.260 | | | | | | | | | | | | | | |

Note: After-hours services are measured using deflated after-hours fees. Standard errors are clustered at physician level; 7320 clusters.

### 4.3.1 Emergency Department Costs

Table 6: Elasticities of ED costs with respect to after-hours services

| | Ln total cost | | Ln nonurgent cost | | Ln urgent cost | |
|---|---|---|---|---|---|---|
| | (1) | | (2) | | (3) | |
| | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. |
| Ln after-hours fees | −0.0037 | 0.0010 | −0.0083 | 0.0016 | −0.0014 | 0.0011 |

Note: All regressions include the full set of control variables, $Z_{it}$. After-hours services are measured using deflated after-hours fees. Fixed-effects are at physician level. Standard errors are clustered at physician level; 7320 clusters.

We have presented evidence that increasing the after-hours premium reduces ED visits, by way of increasing physicians' after-hours services. However, health system cost savings crucially depend on the empirical distribution of disease severities substituted from the ED to physicians. We begin our cost analysis by verifying that the results for ED costs are consistent with those for ED visits. We then take advantage of the variation in strength of after-hours premium to estimate the mean ED cost for inframarginal patients, which the model shows may not be the same as the unconditional ED cost. We examine the potential scope for the after-hours premium reducing net costs in Section 5.

Using values for ED visits (2002 dollars) from the Ministry of Health, we estimate the following regression:

$$\ln(\$\mu_{it}) = Z'_{it}\beta_{\$\mu,x} + \rho_{\$\mu,x}\ln(\$x_{it}) + \epsilon_{it,\$\mu,x}, \tag{16}$$

where $\ln(\$\mu_{it})$ is the natural logarithm of the cost of ED visits per 1,000 patients and $\$x_{it}$ is the cost of after-hours incentive per 1,000 patients. Note the cost of the after-hours incentive used in this section includes the increase in premium. Here, we are primarily interested in the estimated coefficient $\rho_{\$\mu,x}$, the elasticity of ED costs with respect to after-hours fees. Positive ED costs imply the resulting estimates should be qualitatively similar to those for ED visits, in Table 4.

Table 6 summarizes elasticities of ED costs with respect to after-hours costs, estimated using fixed-effects models. For urgent ED, the elasticity of ED costs (-0.00138) is insignificant and indistinguishable from the elasticities of ED visits reported in Table 4 (-0.00205). However, the elasticity of nonurgent ED costs with respect to after-hours fees (-0.00828) is twice the elasticity of nonurgent ED visits with respect to after-hours fees (-0.00414), consistent with ED reductions coming from more severe, costlier to treat, conditions.[12]

We can directly exploit time-variation in the after-hours premium to estimate how after-hours services affect ED costs. Table 7 presents two-stage-least-squares estimates of after-hours services on ED costs. Consistent with the results for ED visits, the increase in after-hours services (due to the higher after-hours premium) results in reductions in ED costs. Also consistent with our earlier results, these results are driven by cost reductions for nonurgent ED visits. Dividing the estimated reduction on ED costs by the estimated reduction in ED visits, we calculate that the average cost of nonurgent ED visits reduced by increased after-hours services is $\frac{-\$20.50811 \text{ per 1,000 patients per physician per year}}{-0.0743767 \text{ visits per 1,000 patients per physician per year}} = \$275.73$ per visit reduced. This calculation is useful because it exploits changes in costs and visits induced by variation in the after-hours premium, and as such represents mean costs of treating inframarginal patients at the nonurgent ED.

To get a sense of how heterogeneity in the cost of treating patients varies by condition severity, we can compare this estimate to the unweighted sample mean, computed by dividing pooled ED visits by ED costs, by type of ED visit; these numbers are in Table B.2. The overall mean of ED visits was $215.55, for total ED visits, and $144.58 for nonurgent ED visits. Our estimated savings of $275.73 per nonurgent ED visit implies that it was indeed patients with more expensive conditions, presumably those with severities high enough to

[12] This difference is significant with a p-value of 0.053.

Table 7: 2SLS estimates of effect of after-hours services on ED costs

| | Total cost | | Nonurgent cost | | Urgent cost | |
|---|---|---|---|---|---|---|
| | (1) | | (2) | | (3) | |
| | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. |
| After-hours fees | −17.078 | 4.989 | −20.508 | 5.250 | 4.608 | 2.633 |
| Year | 3229.962 | 573.179 | 1567.270 | 605.595 | 1518.635 | 301.652 |
| Age | −558.671 | 300.591 | 322.857 | 304.144 | −907.318 | 166.876 |
| Age sq. | 3.925 | 2.849 | −2.558 | 2.856 | 6.635 | 1.576 |
| Female | −14 395.600 | 3267.165 | −12 518.340 | 3440.580 | −1141.175 | 1730.764 |
| IMG | 2349.723 | 2205.705 | 6264.209 | 2360.400 | −4372.859 | 1181.939 |
| Group size | −20.376 | 7.977 | 17.272 | 8.497 | −39.255 | 4.584 |
| Avg. age | 673.787 | 427.333 | −1366.286 | 451.745 | 2137.512 | 226.326 |
| Avg. ADG | 25 254.850 | 6277.684 | 24 105.600 | 6645.951 | −301.681 | 3292.797 |
| Avg. deprived | 783.495 | 31.297 | 316.761 | 33.284 | 461.852 | 18.823 |
| Avg. rural | 538.985 | 28.471 | 452.352 | 28.676 | 87.564 | 15.472 |
| Constant | −6 491 291 | 1 151 199 | −3 138 252 | 1 216 511 | −3 063 706 | 605 785 |
| Obs. | 44 470 | | 44 470 | | 44 470 | |

Note: After-hours services are measured using deflated after-hours fees. Standard errors are clustered at physician level; 7320 clusters.

warrant treatment at the ED, who were treated after hours because of the premium. Had we simply used mean cost data for the total (non-inframarginal) set of patients, the reduction in ED costs would have been understated by over 50%. This calculation in itself comprises a useful contribution of this paper, as it estimates cost of ED treatment, using the empirical distribution of services and patients substituted from nonurgent ED to physicians.

Table 8: FE estimates: ED visits and after-hours services as a function of premium, by average ADG at practice

| | Ln total visits | | | | Ln nonurgent visits | | | | Ln urgent visits | | | | Ln after-hrs fees | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Avg. ADG low | | Avg. ADG high | | Avg. ADG low | | Avg. ADG high | | Avg. ADG low | | Avg. ADG high | | Avg. ADG low | | Avg. ADG high | |
| | (1) | | (2) | | (3) | | (4) | | (5) | | (6) | | (7) | | (8) | |
| | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. |
| Premium | -0.1591 | 0.0230 | -0.1034 | 0.0239 | -0.2200 | 0.0350 | -0.0117 | 0.0374 | -0.1522 | 0.0286 | -0.1683 | 0.0283 | 0.4805 | 0.1911 | 0.2738 | 0.1916 |

Note: “Avg. ADG low” and “high” respectively refer to practices where mean patient ADG is below and above the sample median mean practice ADG. All regressions include the full set of control variables, $Z_{it}$. After-hours services are measured using deflated after-hours fees. Fixed-effects are at physician level. Standard errors are clustered at physician level.

#### 4.3.2 Variation in Patient Health Distributions

Our final set of analyses investigates in more detail where reductions in after-hours services come from. Implication 5 suggests that physicians may differ in their responses to after-hours premiums, because of their patient disease severities, resulting in differential changes in ED visits. Therefore, we re-run our prior fixed-effects regressions separately for two subsamples of observations: those where a physician's practice had below-median average patient ADG (avg. ADG low) and those where a physician's practice had above-median average patient ADG (avg. ADG high).

Table 8 summarizes percentage changes of ED usage (left panel) and service measures (right panel) with respect to the premium, split by mean ADG at the physician-level. The left panel shows that though practices with more- and less-sick patients reduce patients sent to the ED when the after-hours premium increases, less-sick practices experience larger declines (specification (1) vs. specification (2)). This decline is largest for nonurgent ED visits at practices with below-median mean ADGs (specification (3)); there is no such decline for patients at practices with above-median mean ADGs (specification (4)). The effect of increasing the after-hours premium on urgent ED visits is similar for physicians with lower- and higher-morbidity patients (specifications (5) and (6)). The right panel shows that increases in the premium have a larger positive effect on after-hours services, as measured by fees, for physicians with below-median mean ADGs (specifications (7) vs. (8)).

To help think about why there might be a larger reduction in ED visits at practices with low mean ADG, consider the change in nonurgent ED visits in $\tau$, in the "Moderate" skill scenario: $\frac{\partial \mu_{N,\tau}}{\partial \pi} = -\frac{\partial x_\tau}{\partial \pi}(\theta_d - \theta_\tau)$. If we can think of a low ADG practice as one where the physician has a relatively high skill level, this could be loosely thought of as an increase in $\theta_d$ (or decrease in the lower bound of $\theta$), which in turn would increase the effect of an increase in services provided, $x_\tau$. That is, healthier practices may have more patients treatable by the physician, which we may be able to loosely think of as their having higher $\theta_d$ (relative to their patients' health distribution). Similarly, physicians with high-morbidity patients may not be able to treat many of their patients with conditions severe enough to warrant nonurgent ED, resulting in a null effect. As such, we would expect larger reductions in ED visits in such practices, and these reductions to be driven by the nonurgent ED visits that physicians could themselves likely obviate. We can see this in the first row of Table 9, which reports the elasticity of ED visits with respect to after-hours services (measured by after-hours fees), split by whether practices have low and high mean ADGs. The results from the middle two specifications, corresponding to nonurgent ED visits, indicate a significant negative elasticity with respect to value of after-hours services (first row) for only low-mean-ADG practices. A similar result holds for ED costs, presented in the second row, which shows that the elasticity of nonurgent ED costs with respect to after-hours services is -0.01304 for practices with below-median mean ADG. The results from Tables 8 and 9 are consistent with the model prediction that increases in after-hours services will be larger, the larger a physician's skill level (or lower the lower bound of a physician's patients' disease severity distribution).

The model shows that cost reduction per ED visit reduction will be increasing if $c_{ED}(\theta) - c_d(\theta)$ is increasing in $\theta$. That is, if physicians have lower marginal increases in treatment costs than does the nonurgent ED, when averaged over the set of patients who no longer would attend the ED because they were treated by their physician. We could model this by increasing $\theta_1$ and $\theta_2$ in equation (10) for practices with above-median mean ADG. This is what we find in the data: increases in after-hours services at practices with above-median mean ADG also correspond to significant reductions in nonurgent ED costs (elasticity of -0.00423), in spite of the negligible impact on nonurgent ED visits. Not only are physicians able to treat patients more at lower cost than the ED, but these cost savings also increase in patient severity.

Table 9: Elasticities of ED visits and costs, with respect to after-hours services

| | Ln total | | | | Ln nonurgent | | | | Ln urgent | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Avg. ADG low | | Avg. ADG high | | Avg. ADG low | | Avg. ADG high | | Avg. ADG low | | Avg. ADG high | |
| | (1) | | (2) | | (3) | | (4) | | (5) | | (6) | |
| Elasticity of: | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. |
| ED visits | -0.00448 | 0.00130 | -0.00222 | 0.0014 | -0.00836 | 0.00204 | -0.0002 | 0.00208 | -0.00162 | 0.00165 | -0.00295 | 0.00168 |
| ED costs | -0.00459 | 0.00129 | -0.00299 | 0.0015 | -0.01304 | 0.00216 | -0.00423 | 0.00230 | -0.00138 | 0.00156 | -0.00219 | 0.00173 |

Note: All regressions include the full set of control variables, $Z_{it}$. After-hours services are measured using deflated after-hours fees. Fixed-effects are at physician level. Standard errors are clustered at physician level; 7320 clusters.

## 5 Discussion

This paper develops a theoretical model and uses micro-data to examine how increasing an after-hours premium, a natural policy instrument to increase access to physicians, affects ED utilization. The model shows that increases in the after-hours premium have an ambiguous effect on ED visits. This ambiguity stems from the model's prediction that patient costs attenuate in-period ED reductions and that utility-maximizing physicians will substitute after-hours for regular-hours services when incentivized to due so by the higher premium.

We use exogenous variation in the after-hours premium to confirm the model prediction that after- and regular-hours services indeed do move in opposite directions in response to increases in the after-hours premium. We then further exploit this variation to estimate the theoretically ambiguous net impact of premium increases on ED visits, which we estimate to be negative, and reduced-form response of ED visits to changes in after-hours services, which is also estimated to be negative. The latter relationship is estimated using fixed-effects and 2SLS models, giving credence to the proposed mechanism of physician behavioral responses to after-hours premium increases via changes in service provision. Also consistent with the model prediction that the interaction between patient costs and physician behavior affecting the extent to which premium increases reduce ED utilization, the reduction is driven by a decline in nonurgent ED visits.

We find evidence of a small, but significant, effect of increasing after-hours services on ED utilization, which is consistent with our theoretical model. Our service measures allow us to interpret this as a *small net effect*, distinct from an *inherently small/null effect* due to a lack of physician responses to stronger after-hours incentives. Physicians may also take time to learn about after-hours incentives, which is another factor potentially diminishing the estimated effect of after-hours incentives.[13]

Consistent with our findings about ED visits, we find that ED costs decrease with increases in the after-hours premium. We estimate that the mean cost to the nonurgent ED of patients now treated by their physicians due to stronger after-hours incentives is substantially higher than the unconditional mean cost of nonurgent ED patients. This is also consistent with the model prediction that patients with low-severity conditions, which presumably are less expensive to treat, are less likely to visit the ED. Also consistent with the model's prediction, we find larger service responses and ED reductions for physicians with sicker patients, who are likely more highly skilled.

**Does Increasing the After-hours Premium Reduce Net Costs?** The model shows that, even if average ED costs are higher than physicians' costs and conditional on a reduction in ED visits, increases in the after-hours premium have an ambiguous effect on net costs. This ambiguity arises because what matters for net effects on costs is the cost of ED relative to that of physician services for the *inframarginal* distribution of patient conditions, which we find to be above the (unconditional) sample mean.

It is inherently quite difficult to discern how increasing the after-hours premium affects net costs to the health care system. However, we can use the policy variation in the after-hours premium to obtain a back-of-the-envelope estimate of the net effect. Our approach is to directly use the variation in the after-hours premium to estimate how both after-hours and nonurgent ED costs respond, i.e., $\frac{\partial \$x_a}{\partial \pi}$ and $\frac{\partial \$\mu_N}{\partial \pi}$, respectively. This variation allows us to separate the effect of after-hours incentives from other, aggregate, trends. Then we compute how changes in the premium affected *total* after-hours payments (i.e., the bonus plus the base amount) and nonurgent ED costs for each change in premium, and then aggregate these sums over the sample period. Because our cost estimates are regression-adjusted and computed using policy variation in the after-hours premium, they are a relatively clean picture of how the cost of physician services and nonurgent ED visits change over the sample period, as a function of the after-hours premium.[14]

We estimate that total physician after-hours payments increase by $33,014,816 in response to increases in

[13]See the 2011 Annual Report of the Office of the Auditor General of Ontario ( `http://www.auditor.on.ca/en/content/annualreports/arreports/en11/2011ar_en.pdf`, page 164).

[14]See Appendix C for details.

the premium, over the sample period. This figure accords with our estimated increase of after-hours fees (i.e., bonuses) due to increases in the premium and amounts to $742 per physician per year, a reasonable number. In contrast, we compute a total nonurgent ED cost reduction of $126,518,106, or an average of $2,845.02 per physician per year. Again, this is qualitatively consistent with our prior estimates where increasing the after-hours premium reduced both nonurgent ED visits and costs.

Overall, we conclude that increasing the after-hours premium reduced *net* costs, meaning that physicians could treat inframarginal conditions at a lower cost than the nonurgent ED. We also find that the countervailing increase in physician treatment cost represents about one quarter of the savings from fewer nonurgent ED visits.

Our results show that the after-hours incentive in Ontario's primary care setting largely improves access to care for patients and results in a reduction in ED visits. The net-cost analysis is only a very rough estimate for how after-hours incentives may have affected outcomes. There is reason to believe that improved access to primary care services during after-hours can positively impact population health and overall satisfaction with the primary health care system, suggesting that our cost-savings calculation is more of a lower-bound on the potential gain.

Our empirical approach exploited rich panel data on physicians and exogenous variation in the strength of after-hours incentives. Nevertheless, like any other study, ours has limitations. For example, it may have been the case that the extensive margin of incentive strength (i.e., the introduction of after-hours incentives) had a larger effect on physician behavior and ED visits than our study, which exploited variation in the intensive margin (e.g., increasing the premium from 10% to 15%). While our empirical work was guided by a theoretical model, estimating structural parameters governing physician behavior, patient costs, and ED utilization would allow one to study how we should design incentives. Therefore, we view this as an important avenue for future research. Another implication of our work relates to the change in net cost as disease severity increases. The fact that savings differ with respect to disease severity suggests that a constant after-hours premium may not be most cost-effective—one that differs with disease severity may lead to further health-system savings. This bolsters our belief that optimal design of the after-hours premium is a potentially fruitful area for future research.

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# Appendix A Derivation of Measures of Patients at Nonurgent and Urgent ED

Consider period $\tau$. Let $S$ denote the event that a patient is *seen* by the physician (which depends on the level of services the physician provides, $x_\tau$), $T$ denote the patient being *treated* by the physician, $ED$ denote the patient being treated at the ED, $N$ denote being treated at the nonurgent ED, and $U$ denote being treated at the urgent ED.

Because there is a measure 1 of patients, the measure of patients in any condition equals the probability of being in that condition. Hence, taking into account patients' optimal behavior, which depends on their disease severity $\theta$ and non-pecuniary ED cost $k_\tau$ (resulting in cutoff $\theta_\tau$), the measure of patients at the nonurgent ED during period $\tau$ for the "Moderate" skill scenario is

$$\Pr\{N|\tau\} = \underbrace{(1 - x_\tau)}_{\substack{\text{not seen}\\\text{by phys.}}} \underbrace{(\theta_h - \theta_\tau)}_{\substack{\text{would visit ED}\\\text{if not seen}}} + \underbrace{x_\tau}_{\substack{\text{seen by}\\\text{phys.}}} \underbrace{(\theta_h - \theta_d)}_{\substack{\text{too severe}\\\text{for phys.}}} = (\theta_h - \theta_\tau) - x_\tau (\theta_d - \theta_\tau). \tag{17}$$

The measure of patients at the urgent ED during $\tau$ is derived using analogous reasoning, as are measures of patients at different treatment sites (physician, nonurgent ED, and urgent ED) under the other physician skill scenarios.

Table A.1 computes total measures of patients at the nonurgent and urgent ED, as well as those treated by physicians, by combing the period-specific measures with our simplifying assumption that regular- and after-hours periods are of the same length.

Table A.1: Total measure of patients at nonurgent and urgent ED, by physician skill $\theta_d$ scenario

| | Physician skill scenario | | |
|---|---|---|---|
| | Low | Moderate | High |
| Measure of patients | $\theta_d \le \theta_\tau$ | $\theta_d \in (\theta_\tau, \theta_h]$ | $\theta_d > \theta_h$ |
| $\mu_N (= \Pr\{\text{N}\})$ | $\frac{\theta_h - \theta_r}{2} + \frac{\theta_h - \theta_a}{2}$ | $\frac{(\theta_h - \theta_r) - x_r(\theta_d - \theta_r)}{2} + \frac{(\theta_h - \theta_a) - x_a(\theta_d - \theta_a)}{2}$ | $\frac{(\theta_h - \theta_r) - x_r(\theta_h - \theta_r)}{2} + \frac{(\theta_h - \theta_a) - x_a(\theta_h - \theta_a)}{2}$ |
| $\mu_U (= \Pr\{\text{U}\})$ | $1 - \theta_h$ | $1 - \theta_h$ | $(1 - \theta_h) - \frac{x_r(\theta_d - \theta_h)}{2} - \frac{x_a(\theta_d - \theta_h)}{2}$ |
| $\mu_T (= \Pr\{T\})$ | $\left(\frac{x_r}{2} + \frac{x_a}{2}\right)\theta_d$ | $\left(\frac{x_r}{2} + \frac{x_a}{2}\right)\theta_d$ | $\left(\frac{x_r}{2} + \frac{x_a}{2}\right)\theta_d$ |

Note: Physicians are assumed to have measure one of patients. These calculations assume regular- and after-hours periods are of equal length; theoretical results do not depend on this assumption.

# Appendix B Descriptive Statistics

Table B.1: Sample means and standard deviations, by year

| | 2004 | | 2005 | | 2006 | | 2007 | | 2008 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. |
| Age | 48.17 | 9.17 | 49.03 | 9.39 | 50.14 | 9.49 | 50.78 | 9.63 | 50.69 | 9.89 |
| Female | 0.32 | 0.47 | 0.33 | 0.47 | 0.35 | 0.48 | 0.36 | 0.48 | 0.37 | 0.48 |
| IMG | 0.07 | 0.25 | 0.08 | 0.28 | 0.14 | 0.35 | 0.16 | 0.37 | 0.17 | 0.38 |
| Group size | 22.87 | 21.96 | 25.95 | 25.75 | 60.34 | 93.37 | 60.32 | 95.19 | 61.00 | 93.39 |
| Roster size | 1744.50 | 689.91 | 1752.98 | 746.49 | 1763.89 | 756.61 | 1764.58 | 777.40 | 1724.20 | 773.17 |
| Avg. Age | 38.04 | 5.49 | 38.80 | 5.84 | 38.95 | 5.94 | 39.20 | 6.04 | 39.43 | 5.97 |
| Avg. ADG | 3.12 | 0.39 | 3.20 | 0.42 | 3.27 | 0.47 | 3.25 | 0.47 | 3.18 | 0.47 |
| Avg. Deprived | 26.62 | 13.84 | 27.58 | 14.80 | 28.57 | 15.45 | 28.06 | 15.39 | 27.72 | 15.21 |
| Avg. Rural | 15.61 | 26.07 | 13.44 | 24.08 | 9.67 | 19.66 | 9.26 | 19.24 | 9.39 | 19.51 |
| Premium | 0.10 | 0 | 0.15 | 0 | 0.20 | 0 | 0.20 | 0 | 0.20 | 0 |
| Below variables are per 1,000 patients | | | | | | | | | | |
| Total office visits | 3464.56 | 1252.40 | 3518.23 | 1363.80 | 3653.17 | 1644.80 | 3536.40 | 1716.48 | 3576.38 | 1958.03 |
| Ln total office visits | 8.09 | 0.34 | 8.11 | 0.34 | 8.13 | 0.38 | 8.09 | 0.39 | 8.09 | 0.41 |
| Regular-hours office visits | 3107.84 | 1139.57 | 3143.02 | 1241.74 | 3241.50 | 1482.23 | 3135.53 | 1579.49 | 3180.58 | 1800.16 |
| Ln regular-hours office visits | 7.98 | 0.35 | 7.99 | 0.36 | 8.01 | 0.39 | 7.96 | 0.40 | 7.97 | 0.41 |
| After-hours office visits | 356.73 | 353.43 | 375.21 | 393.45 | 411.67 | 475.92 | 400.87 | 452.69 | 395.80 | 462.13 |
| Ln after-hours office visits | 5.31 | 1.32 | 5.31 | 1.38 | 5.37 | 1.38 | 5.37 | 1.33 | 5.33 | 1.35 |
| After-hours fees (not deflated) | 766.53 | 731.05 | 1218.43 | 1232.73 | 1620.76 | 1765.52 | 1612.20 | 1776.68 | 1714.10 | 1942.59 |
| Ln after-hours fees (not deflated) | 6.04 | 1.39 | 6.46 | 1.45 | 6.70 | 1.48 | 6.71 | 1.45 | 6.75 | 1.47 |
| After-hours fees (deflated) | 696.85 | 664.59 | 1059.51 | 1071.94 | 1350.64 | 1471.27 | 1343.50 | 1480.57 | 1428.42 | 1618.83 |
| Ln after-hours fees (deflated) | 5.95 | 1.39 | 6.32 | 1.45 | 6.51 | 1.48 | 6.52 | 1.45 | 6.56 | 1.47 |
| Total ED visits | 400.89 | 197.99 | 402.59 | 199.22 | 372.97 | 174.87 | 369.66 | 169.74 | 374.45 | 177.84 |
| Ln total ED visits | 5.90 | 0.40 | 5.91 | 0.41 | 5.83 | 0.42 | 5.83 | 0.41 | 5.84 | 0.41 |
| Urgent ED visits | 189.44 | 58.57 | 200.22 | 67.22 | 198.72 | 70.82 | 201.61 | 69.07 | 208.83 | 71.43 |
| Ln urgent ED visits | 5.20 | 0.29 | 5.25 | 0.31 | 5.23 | 0.35 | 5.25 | 0.34 | 5.29 | 0.34 |
| Nonurgent ED visits | 211.33 | 180.02 | 202.26 | 174.84 | 174.11 | 137.56 | 167.84 | 127.89 | 165.39 | 134.66 |
| Ln nonurgent ED visits | 5.14 | 0.59 | 5.09 | 0.60 | 4.96 | 0.59 | 4.94 | 0.56 | 4.92 | 0.58 |
| Total ED costs | 80 694.15 | 31 287.34 | 81 422.01 | 32 338.94 | 77 008.51 | 30 192.23 | 80 603.21 | 31 489.43 | 80 806.52 | 32 418.04 |
| Ln total ED costs | 11.23 | 0.35 | 11.24 | 0.36 | 11.18 | 0.39 | 11.23 | 0.38 | 11.23 | 0.39 |
| Urgent ED costs | 50 675.19 | 16 327.12 | 52 827.71 | 17 855.01 | 52 376.65 | 19 198.48 | 55 400.66 | 20 039.48 | 56 653.33 | 20 567.02 |
| Ln urgent ED costs | 10.78 | 0.31 | 10.82 | 0.33 | 10.80 | 0.37 | 10.86 | 0.36 | 10.88 | 0.36 |
| Nonurgent ED costs | 30 007.57 | 24 694.10 | 28 583.44 | 24 033.34 | 24 616.09 | 18 240.33 | 25 181.13 | 18 068.18 | 24 131.08 | 18 657.82 |
| Ln nonurgent ED costs | 10.11 | 0.58 | 10.05 | 0.59 | 9.93 | 0.57 | 9.97 | 0.55 | 9.91 | 0.57 |
| Obs. | 1693 | | 2683 | | 3969 | | 4093 | | 4844 | |

| | 2009 | | 2010 | | 2011 | | 2012 | | 2013 | |
|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. |
| Age | 51.07 | 10.06 | 51.36 | 10.20 | 51.63 | 10.35 | 51.82 | 10.58 | 52.03 | 10.73 |
| Female | 0.39 | 0.49 | 0.40 | 0.49 | 0.41 | 0.49 | 0.42 | 0.49 | 0.43 | 0.50 |
| IMG | 0.18 | 0.39 | 0.19 | 0.40 | 0.21 | 0.41 | 0.22 | 0.42 | 0.23 | 0.42 |
| Group size | 60.20 | 94.53 | 54.48 | 86.13 | 48.24 | 79.66 | 44.24 | 73.24 | 43.19 | 72.45 |
| Roster size | 1702.08 | 773.05 | 1676.41 | 755.84 | 1655.38 | 750.46 | 1626.29 | 742.08 | 1605.14 | 724.17 |
| Avg. Age | 39.68 | 6.05 | 39.83 | 6.08 | 40.10 | 6.09 | 40.40 | 6.12 | 40.74 | 6.14 |
| Avg. ADG | 3.23 | 0.48 | 3.23 | 0.49 | 3.21 | 0.48 | 3.24 | 0.49 | 3.16 | 0.47 |
| Avg. Deprived | 27.47 | 15.23 | 27.32 | 15.16 | 27.27 | 15.12 | 27.02 | 15.10 | 26.85 | 14.97 |
| Avg. Rural | 9.15 | 19.25 | 9.22 | 19.38 | 9.12 | 19.13 | 8.87 | 18.68 | 8.71 | 18.33 |
| Premium | 0.20 | 0 | 0.20 | 0 | 0.20 | 0 | 0.30 | 0 | 0.30 | 0 |
| Below variables are per 1,000 patients | | | | | | | | | | |
| Total office visits | 3520.47 | 2170.26 | 3403.49 | 2077.24 | 3325.25 | 2071.55 | 3134.86 | 1822.41 | 3029.00 | 1696.03 |
| Ln total office visits | 8.06 | 0.43 | 8.03 | 0.43 | 8.00 | 0.44 | 7.94 | 0.45 | 7.91 | 0.46 |
| Regular-hours office visits | 3132.76 | 2019.77 | 3036.49 | 1924.58 | 2961.70 | 1923.47 | 2781.48 | 1624.20 | 2674.21 | 1528.51 |
| Ln regular-hours office visits | 7.94 | 0.43 | 7.91 | 0.43 | 7.88 | 0.45 | 7.82 | 0.46 | 7.78 | 0.46 |
| After-hours office visits | 387.71 | 468.85 | 367.00 | 453.47 | 363.55 | 451.89 | 353.39 | 451.85 | 354.78 | 442.01 |
| Ln after-hours office visits | 5.31 | 1.34 | 5.24 | 1.35 | 5.25 | 1.31 | 5.22 | 1.30 | 5.25 | 1.26 |
| After-hours fees (not deflated) | 1681.81 | 1910.84 | 1622.59 | 1891.80 | 2159.11 | 2602.80 | 2304.05 | 2845.16 | 2279.56 | 2734.80 |
| Ln after-hours fees (not deflated) | 6.74 | 1.44 | 6.68 | 1.46 | 6.97 | 1.45 | 7.03 | 1.42 | 7.06 | 1.38 |
| After-hours fees (deflated) | 1401.50 | 1592.37 | 1352.15 | 1576.50 | 1799.26 | 2169.00 | 1772.35 | 2188.58 | 1753.51 | 2103.69 |
| Ln after-hours fees (deflated) | 6.55 | 1.44 | 6.50 | 1.46 | 6.78 | 1.45 | 6.77 | 1.42 | 6.80 | 1.38 |
| Total ED visits | 381.51 | 167.63 | 386.83 | 168.80 | 400.02 | 169.95 | 401.57 | 165.11 | 401.88 | 155.61 |
| Ln total ED visits | 5.87 | 0.39 | 5.88 | 0.39 | 5.92 | 0.38 | 5.92 | 0.37 | 5.93 | 0.36 |
| Urgent ED visits | 219.96 | 73.13 | 229.49 | 75.98 | 243.41 | 78.24 | 252.68 | 82.82 | 264.09 | 83.77 |
| Ln urgent ED visits | 5.34 | 0.32 | 5.38 | 0.32 | 5.45 | 0.32 | 5.48 | 0.32 | 5.53 | 0.31 |
| Nonurgent ED visits | 160.61 | 120.36 | 156.49 | 115.40 | 155.91 | 113.71 | 148.32 | 103.79 | 137.26 | 92.31 |
| Ln nonurgent ED visits | 4.91 | 0.55 | 4.88 | 0.55 | 4.88 | 0.55 | 4.84 | 0.54 | 4.77 | 0.53 |
| Total ED costs | 84 371.92 | 32 344.26 | 83 300.89 | 31 941.64 | 86 143.92 | 32 451.23 | 86 497.73 | 32 373.74 | 90 758.83 | 32 509.38 |
| Ln total ED costs | 11.27 | 0.37 | 11.26 | 0.37 | 11.30 | 0.37 | 11.30 | 0.37 | 11.36 | 0.35 |
| Urgent ED costs | 59 893.61 | 21 215.61 | 59 433.03 | 20 849.21 | 64 381.82 | 22 480.05 | 65 903.65 | 23 304.54 | 71 073.27 | 24 370.68 |
| Ln urgent ED costs | 10.94 | 0.35 | 10.93 | 0.34 | 11.01 | 0.35 | 11.04 | 0.35 | 11.12 | 0.34 |
| Nonurgent ED costs | 24 311.07 | 17 558.09 | 23 746.59 | 16 856.88 | 21 661.80 | 15 501.78 | 20 513.98 | 14 127.78 | 19 613.94 | 12 978.56 |
| Ln nonurgent ED costs | 9.93 | 0.54 | 9.91 | 0.54 | 9.82 | 0.55 | 9.77 | 0.54 | 9.73 | 0.53 |
| Obs. | 5059 | | 5301 | | 5486 | | 5609 | | 5733 | |

Table B.2: Sample means and standard deviations, pooled over all years

| Variable | Mean | Std. Dev. |
|---|---|---|
| Age | 51.01 | 10.09 |
| Female | 0.39 | 0.49 |
| IMG | 0.18 | 0.38 |
| Group size | 50.46 | 81.59 |
| Roster size | 1689.57 | 752.46 |
| Avg. Age | 39.72 | 6.03 |
| Avg. ADG | 3.21 | 0.47 |
| Avg. Deprived | 27.44 | 15.12 |
| Avg. Rural | 9.65 | 19.75 |
| Premium | 0.22 | 0 |
| | | |
| Below variables are per 1,000 patients | | |
| Total office visits | 3387.58 | 1863.20 |
| Ln total office visits | 8.03 | 0.42 |
| Regular-hours office visits | 3011.60 | 1707.97 |
| Ln regular-hours office visits | 7.91 | 0.43 |
| After-hours office visits | 375.98 | 449.54 |
| Ln after-hours office visits | 5.29 | 1.33 |
| After-hours fees (not deflated) | 1818.04 | 2180.57 |
| Ln after-hours fees (not deflated) | 6.79 | 1.44 |
| After-hours fees (deflated) | 1482.44 | 1762.50 |
| Ln after-hours fees (deflated) | 6.59 | 1.44 |
| Total ED visits | 388.97 | 171.55 |
| Ln total ED visits | 5.88 | 0.39 |
| Urgent ED visits | 226.65 | 75.28 |
| Ln urgent ED visits | 5.37 | 0.32 |
| Nonurgent ED visits | 161.81 | 124.64 |
| Ln nonurgent ED visits | 4.90 | 0.56 |
| Total ED costs | 83 843.94 | 32 038.24 |
| Ln total ED costs | 11.27 | 0.37 |
| Urgent ED costs | 60 377.06 | 21 348.45 |
| Ln urgent ED costs | 10.94 | 0.35 |
| Nonurgent ED costs | 23 394.81 | 17 354.97 |
| Ln nonurgent ED costs | 9.88 | 0.55 |
| Obs. | 44 470 | |

# Appendix C Cost-Savings Calculation

Recall that the after-hours fee variable in our data, or the bonus paid to the physician for providing a service after hours, is the after-hours premium that year, $\pi_t$, times the base payment to the physician. Therefore, the total (base plus bonus) payment corresponding to after-hours fees of $\$x_a$ in year $t$ is $\$x_a\left(1+\frac{1}{\pi_t}\right)$.[15] The first-stage regression in Table 5 gives us the partial correlation coefficient of the premium on after-hours fees per 1,000 patients (per physician per year) of \$699.82 (with a standard error of 172.67), which corresponds to a change in total after-hours payments (per 1,000 patients per physician per year) with respect to the premium of $699.817\left(1+\frac{1}{\pi_t}\right)$, which when multiplied by the mean physician's roster size in year $t$ and number of physicians in the sample that year returns the total change in after-hours payments due to a change in the premium for year $t$; denote this amount $T_{\text{all},t}$. Finally, we can calculate the change in total after-hours payments relative to the lowest level ($\pi_{2004} = 0.10$) by multiplying $T_{\text{all},t}$ by $(\pi_t - 0.10)$. The total increase in after-hours payments attributable to increases in the after-hours premium is then $\sum_{t'=2005}^{2013} T_{\text{all},t'}\left(\pi_{t'} - 0.10\right) = \$33,014,816$.

Analogously, we can compute the total reduction in nonurgent ED costs by using the estimated effect of nonurgent ED costs per 1,000 patients per physician per year, which we estimate to be \$-14,351.92 (with a standard error of 1342.46), which does not need to be corrected for the change in $\pi_t$, and then proceeding similarly, returning a total nonurgent ED cost reduction of $\$126,518,106$.

[15] If $B$ is the base payment and T is the total payment, then $\$x_a = \pi_t B \Rightarrow B = \$x_a/\pi_t$. Then the total payment is $T = B + \$x_a = \$x_a\left(1+\frac{1}{\pi}\right)$.