Appendix for Online Publication Only

A Extended Model

In this appendix we present a model that explicitly incorporates time use, with investments that take the form of time spent on non-patient care activities. Physicians maximize utility, as opposed to just profit. We assume that utility is quasi-linear in profit, with convex disutility from time spent either investing or treating patients. We start with a single period version of such a model, where utility is described by the equations below:

$$U(\pi(i, q_H, q_L), i, q_H, q_L) = \pi(i, q_H, q_L) + v(i + \gamma(i)(q_l + q_h)) \tag{A.1}$$

$$\pi(i, q_H, q_L) = q_H r_H + q_L r_L - \theta(i) C(q_H + q_L), \tag{A.2}$$

Here $v(i + \gamma(i)(q_l + q_h))$ is the disutility of labor time. Labor time is the sum of investment time i and total patient care hours $\gamma(i)(q_l + q_h)$ where $\gamma(i)$ represents the time per patient. It would be straightforward to add scalars on q_L and q_H to denote different time per patient across patient types. Investment improves the efficiency with which the physician processes patients, so $\gamma(i)' < 0$, and lowers the financial cost per patient, so $\theta(i)' < 0$. We assume that $v()$ is sufficiently convex to avoid corner solutions in time use. Assume that $\gamma(i)'' > 0$ and $\theta(i)'' > 0$, *i.e.* returns to time investment are diminishing. Dollar-valued investment has been removed, so investment only requires the physician's time. Aside from these key differences, the model remains the same as in the baseline model in section 1 of the main text.

A more complicated model would keep dollar-denominated investment. Within such a model, it would be necessary to discuss complementarity between time investment and dollar-denominated investments. This extension, however, is not relevant to our key points.

Taking Case C, where $q_h = S(i_j, s_{-j})$ and $\overline{q_h} < \tilde{q}^{'}$, the optimality conditions are:

$$q_H^* = \bar{q_H} = s(i_j^*, i_{-j})Q_H \tag{A.3}$$

$$q^* = q_H^* + q_L^* \tag{A.4}$$

$$\underbrace{r_L}_{\text{MR of group } L \text{ patients}} = \underbrace{\theta(i^*)C'(q^*) + v^{'}(q^*, i^*)\gamma(i)}_{\text{MC of extra patient}}. \tag{A.5}$$

$$v^{'}(q^*, i^*) = \underbrace{s'(i_j^*, i_{-j}^*)Q_H\left[r_H - \theta(i^*)C'(q^*)\right]}_{\text{Net profit of group H patients attracted by } i} - \tag{A.6}$$

$$\underbrace{\theta'(i^*)C(q^*)}_{\substack{\text{cost savings on} \\ \text{existing patients} \\ (\theta'(i)<0)}} - \underbrace{v^{'}(q^*, i^*)\left[\gamma^{'}(i^*)q^* + \gamma(i)s'(i_j^*, i_{-j}^*)Q_H\right]}_{\text{Marginal change in patient care time cost}} \tag{A.7}$$

There are some new terms relative to our baseline model:

1. $v^{'}(q^*, i^*)\gamma(i)$ is the marginal time cost of an extra patient.

2. $v^{'}(q^*, i^*)$ is the new implicit price of investment. In the dollar-denominated investment model, the price of investment is constant.

3. $v^{'}(q^*, i^*)\left[\gamma^{'}(i^*)q^* + \gamma(i)s'(i_j^*, i_{-j}^*)Q_H\right]$ is the marginal change in time cost due to (a) the changing time per patient and (b) the increase in patients due to recruitment.

4. In terms of visual exposition, the marginal cost curves illustrated in the figures should be reinterpreted as $\theta(i)C^{'} + \gamma(i)v^{'}$.

Combining the two conditions shows that, at the optimum, the net time cost of investment is equal to the increased profit from swapping high for low paying patients plus the reduced cost of treating infra-marginal patients.

$$\underbrace{v^{'}(q^*, i^*)}_{\text{Marginal Cost of Investment}} = \underbrace{s'(i_j^*, i_{-j}^*)Q_H[r_H - r_L] - \theta'(i^*)C(q^*) - v^{'}(q^*, i^*)\gamma^{'}(i^*)q^*}_{\text{Marginal Benefit of Investment}} \tag{A.8}$$

A.1 High-Level Conditions on Functional Form

Defining $q_L^*(i)$ as the optimal choice of low paying patients conditional on an investment level, optimal investment is determined by the intersection of marginal cost $MC(i, q_L^*(i))$ and marginal benefit $MB(i, q_L^*(i))$. In the dollar-denominated investment model, the marginal cost of investment is constant. In the time investment model, MC can vary with i. For the first-order conditions to generate a single optimal allocation, we need a single crossing point of MC and MB with respect to i. Below we outline an intuitive set of sufficient conditions for this:

1. **Zero investment is never optimal:** $MC(0) < MB(0)$ This rules out situations where, for instance, $\theta(i)' = \gamma(i)' = 0$ and $s'(0, i_{-j})Q_H[r_H - r_L] < v'(q_L^*(0))$, i.e. investment is purely a recruitment device, and the time cost of recruitment is less than the payoff. Given the large difference between r_H and r_L in practice, this seems to be a reasonable assumption.

2. **Marginal Cost Slopes Upwards:** $\frac{dMC(i)}{di} > 0$. This requires $i + \gamma(i)[q_H^* + q_L^*]$ to be strictly increasing in investment, which means $\frac{d[\gamma(i)q(i)^*]}{di} = \gamma'(i)q^* + \gamma(i)\frac{\frac{\partial q^*}{\partial i}}{q^*} > -1$. That is, the reduction in time per patient $\gamma(i)$ has to be sufficiently small relative to the increase in new patients. In our reduced-form empirical analysis, this assumption appears to hold in the aggregate since total hours weakly increase in response to a rate-induced investment increase.

   To express the above condition in terms of model primitives, we need an expression for $\frac{\frac{\partial q^*}{\partial i}}{q^*}$. This is derived by totally differential (A.5) with respect to i and re-arranging to arrive at:

$$\frac{\partial q^*}{\partial i} = \frac{-\left[\theta'(i)C'(q^*) + \gamma'(i)v'(q^*) + \gamma(i)v''(q^*)\left[1 + \gamma' q^*\right]\right]}{\theta(i)C''(q^*) + v''(q^*)\gamma(i)^2} \tag{A.9}$$

$$= \frac{\text{Change in Marginal Cost of Patient Care (Given } q^*\text{) Due to Increase in } i}{\text{Slope of Marginal Cost of Patient Care}} \tag{A.10}$$

3. **Marginal Benefit Slopes Downwards** $\frac{dMB(i)}{di} < 0$: There are two components of marginal benefit. The first is the business stealing effect of swapping low- for high-paying patients $s'(i_j^*, i_{-j}^*)Q_H[r_H - r_L]$. An intuitive condition for this term to be downward sloping is that there be diminishing marginal returns of time investment into recruitment $s''(i_j^*, i_{-j}^*) < 0$.

   The second term is the reduction in marginal costs on existing patients $-\theta'(i^*)C(q^*) - v'(q^*, i^*)\gamma'(i^*)q^*$. Similar conditions are required here, albeit more complex. Totally differentiating this term with respect to i gives:

$$-\big[\underbrace{\theta^{''}C()}_{>0}+\underbrace{\theta^{'}C^{'}()}_{<0}+\underbrace{q^{*}v^{''}\gamma^{'}\frac{\partial q*}{\partial i}}_{<0}+\underbrace{q^{*}\gamma^{''}v^{'}}_{>0}+\underbrace{\frac{\partial q*}{\partial i}v^{''}\gamma^{'}}_{<0}\big] \tag{A.11}$$

We need the term inside the bracket to be positive. In the simpler version of the model without time use, such that only the first two terms exist, this requires that $\frac{-\theta^{''}}{\theta^{'}} > \frac{C^{'}()}{C()}$: the productivity returns to investment need to diminish faster than the proportional increase in marginal costs from an extra patient. With time use, similar logic holds: by requiring that the sum of the last three terms be positive, and rearranging, we need that $\frac{-\gamma^{''}}{\gamma^{'}}\big[1-\frac{\frac{\partial q^{*}}{\partial i}}{q^{*}}\big] > \frac{\frac{\partial q^{*}}{\partial i}}{q^{*}}\frac{v^{''}}{v^{'}}$. That is, the investment returns to time efficiency need to be sufficiently diminishing compared to the rate at which marginal dis-utility of time rises.

Examining equation (A.9), we can determine when an increase in investment causes an increase in the total number of patients. Intuitively, if investment shifts out the marginal cost curve, total patients will increase. The denominator is positive due to convexity, so the result depends on whether the numerator is positive. In the simple model, the numerator would be $-\theta^{'}(i)C^{'}(q^{*})$ which is positive since $\theta^{'}(i) < 0$. With time investment, this is not guaranteed. The term $\gamma(i)v^{''}(q^{*})\big[1+\gamma^{'}q^{*}\big]$ is positive when $\big[1+\gamma^{'}q^{*}\big] > 0$ (note the relation to the sufficient condition set out above: $1+\gamma^{'}(i)q^{*}+\gamma(i)\frac{\frac{\partial q^{*}}{\partial i}}{q^{*}} > 0$). If it is sufficiently positive, the numerator could be negative, which is more likely when v is extremely convex at the optimal allocation.

A.2 Adding a Second Period

This section generalizes the model to two periods. Physicians invest in the first period, which affects productivity and market share in both periods. The physician now maximizes discounted lifetime utility:

$$U(\{\pi(i,q_H^j,q_L^j),q_H^j,q_L^j\}_{j=1,2},i) = \pi(i,q_H^1,q_L^1)+v(i+\gamma(i)(q_l^1+q_h^1)) \tag{A.12}$$

$$+\beta\big[\pi(i,q_H^2,q_L^2)+v(\gamma(i)(q_l^2+q_h^2))\big], \tag{A.13}$$

where β is her discount factor. Investment i is assumed to occur only in period 1 for simplicity. With quasi-linear utility, the physician will consume everything in the first period, or everything in the second period, depending on whether interest rates are higher or lower than their discounting $1 + r \leq\geq \frac{1}{\beta}$. Assuming $1 + r = \frac{1}{\beta}$ implies that the physician is indifferent between consumption in the two periods, delivering effectively the same outcome as assuming no borrowing. We will assume this, although it does not generally matter for studying investment and care provision.

With two periods, the payoff of investment has doubled assuming no depreciation across periods of the accrued productivity. Even with depreciation, equilibrium time investment in the first-time period will be higher than the single period model.

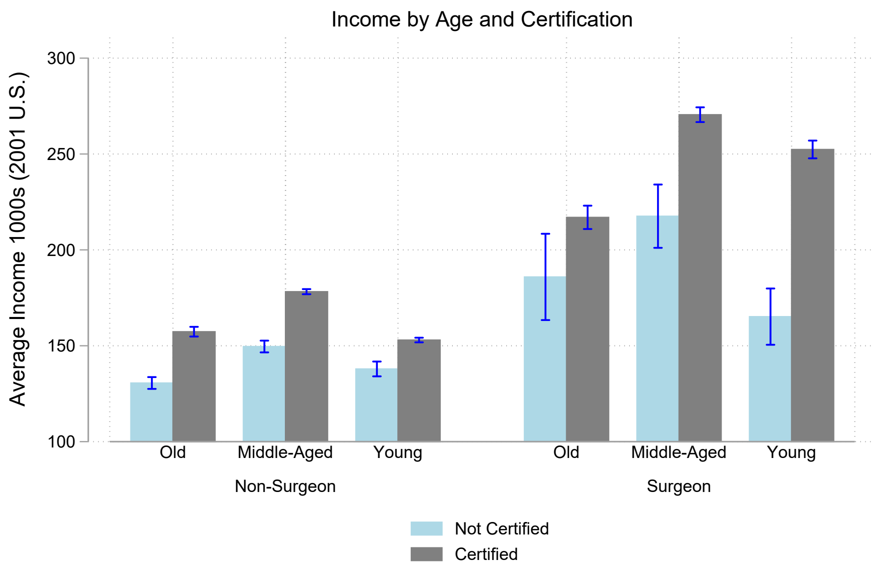
Because there is no investment in the second period, the second period marginal cost curve $\theta(i)C' + \gamma(i)v'$ shifts outward because v is convex in time. This implies that a higher level of investment in the first period will result in a greater quantity of care for low-paying patients in the second period, following the condition that $r_L = \theta(i)C' + \gamma(i)v'$.

How does an increase in r_H beginning in period 1, and applying to both periods, affect investment? As before, the marginal effect of this policy change on the payoff of investing (in Case C) comes from rectangle $[q'_h - q_h][r'_H - r_H]$. With two periods, the physician earns this return twice, causing the investment response to a given reimbursement to be higher. A higher investment response implies a greater reduction in marginal costs, and therefore is more likely to increase care provision to low-paying patients. This is especially true for period 2 because the marginal cost curve is flatter when $i = 0$. Nonetheless, if $\frac{\partial S}{\partial i}$ is large enough relative to the reduction in marginal costs, a reduction in low-paying patient care will still ensue. But, as in the baseline model, considering market-level responses when all physicians invest to compete in a zero-sum game to attract high-paying patients, the supply to low-paying patients will unambiguously expand in the second period.

How does the increase in r_H affect patient care time $\gamma(i)[q_H^1 + q_L^1]$ and $\gamma(i)[q_H^2 + q_L^2]$? This largely depends on the shape of $\gamma(i)$. Even in period 2 with no investment to crowd out patient care time, an investment-driven increase in quantity might not increase patient care hours if the efficiency gain in time per patient $(\gamma(i) - \gamma(i'))$ is sufficiently large.

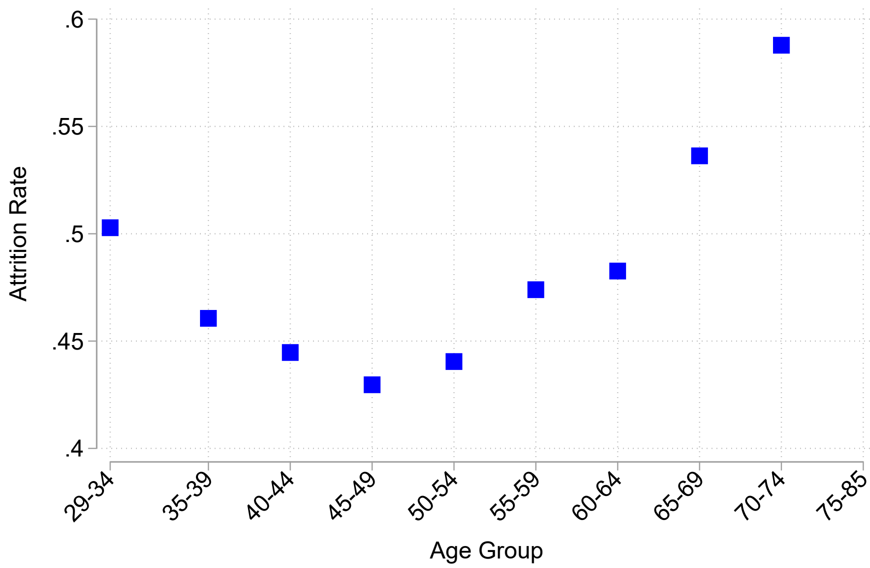
B Supplementary Results and Robustness

Appendix Figure B.1: Cross-Sectional Relationship between Certification Status and Income



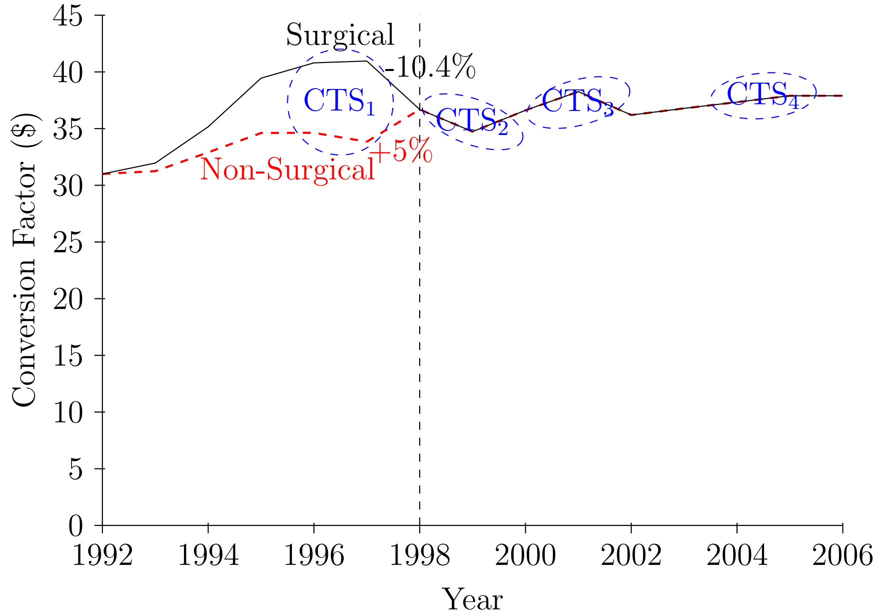
Note: This figure presents data on the incomes of physicians with and without board certification across age groups and specialties. At all age groups, and for both surgical and non-surgical specialties, certification is correlated with higher incomes. 95 % confidence intervals of the means are shown. Source: Authors' calculations based on data from the Community Tracking Study, 1996/97 wave only (Center for Studying Health System Change, 1999).

Appendix Figure B.2: Attrition Rates by Age



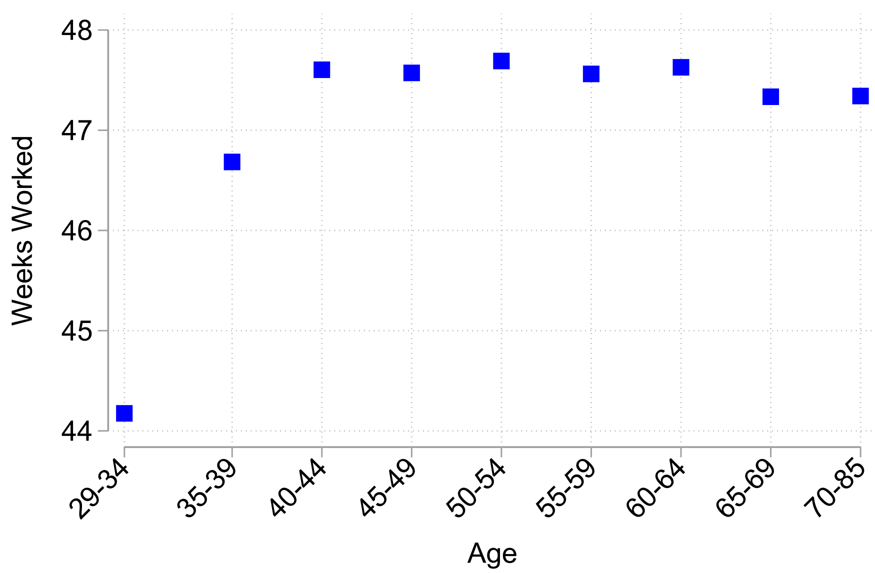
Note: This figure plots raw sample attrition rates by age group. Doctors aged 40–55 have a hazard rate of between 0.4 and 0.45, with this rate steadily rising to 0.65 by ages 75–85. This is suggestive of retirement driving increases in sample attrition for older physicians. Assuming that attrition among doctors aged 45–49 is unrelated to retirement, and that retirement is the sole reason for increased attrition among older physicians, then we can infer that 19% of attrition among doctors aged 65–69, and 25 percent among physicians aged 70–74, is caused by retirement. To see this, note that the 10 percentage point differential between ages 45–49 and 65–69 is 19% of total attrition for the 65–69 age group. Similarly, the 15 percentage point differential between ages 45–49 and 70–74 is 25% of attrition among the 70–74 group. Source: Authors' calculations based on data from the Community Tracking Study (Center for Studying Health System Change, 1999).

Appendix Figure B.3: Evolution of Medicare Conversion Factors



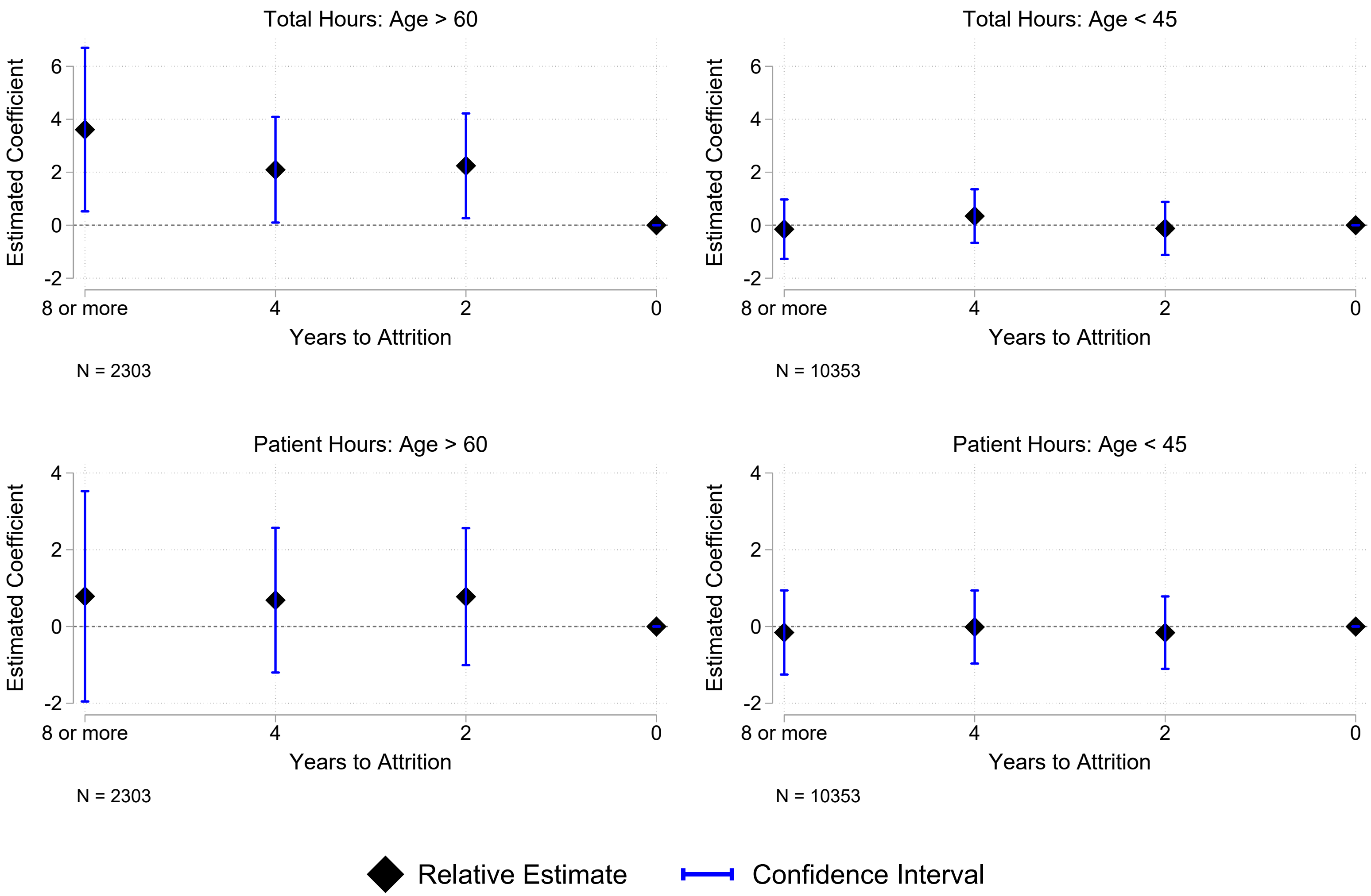
Note: This figure is adapted from Clemens and Gottlieb (2017). It plots the evolution of the Conversion Factors for surgical and non-surgical procedures in the Medicare payment schedule. The dotted circles show the survey waves of the Community Tracking Study. Original source: *Federal Register*, various issues

Appendix Figure B.4: Weeks Worked by Age



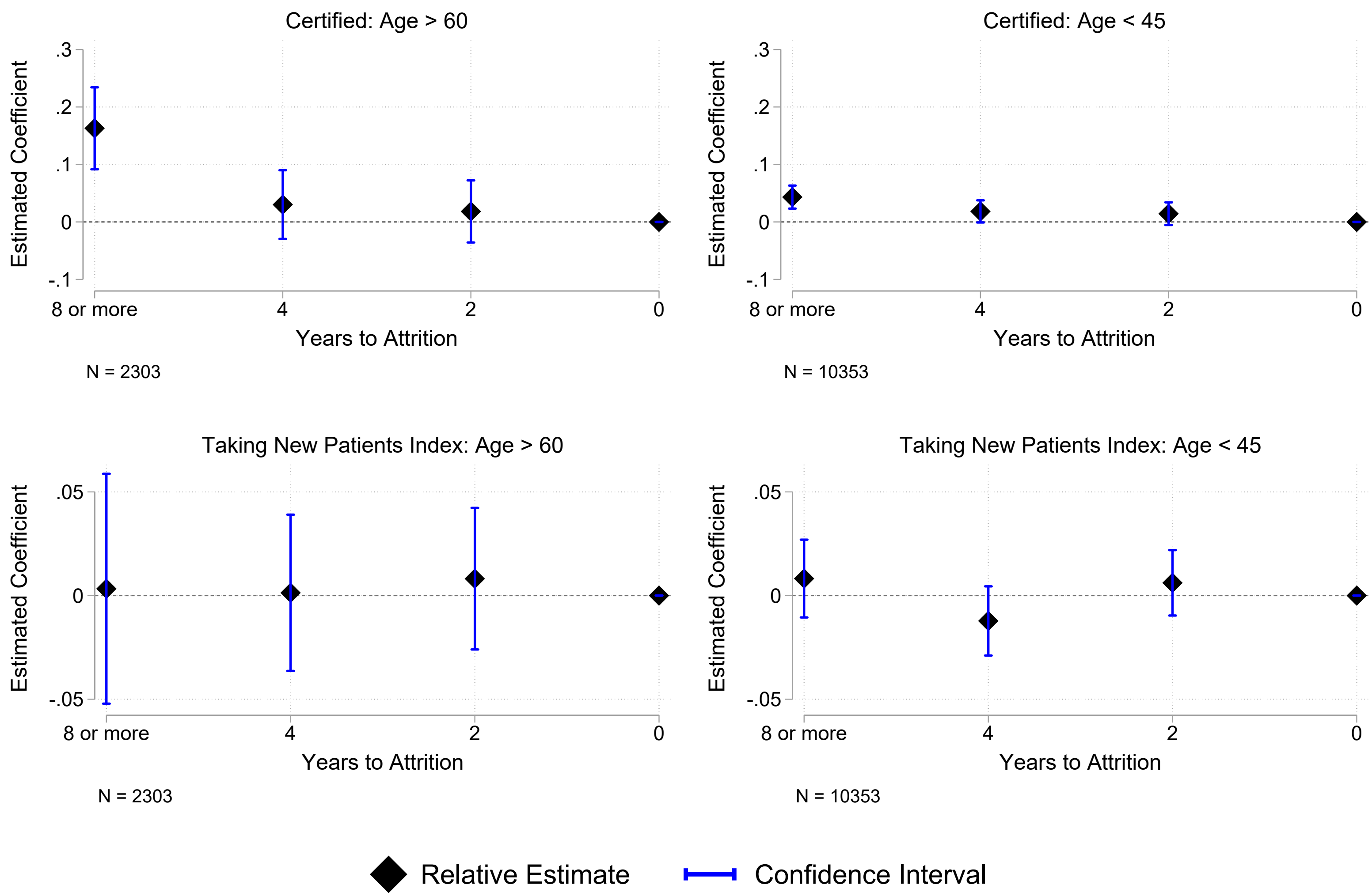
Note:

Appendix Figure B.5: Labor Supply Before Retirement



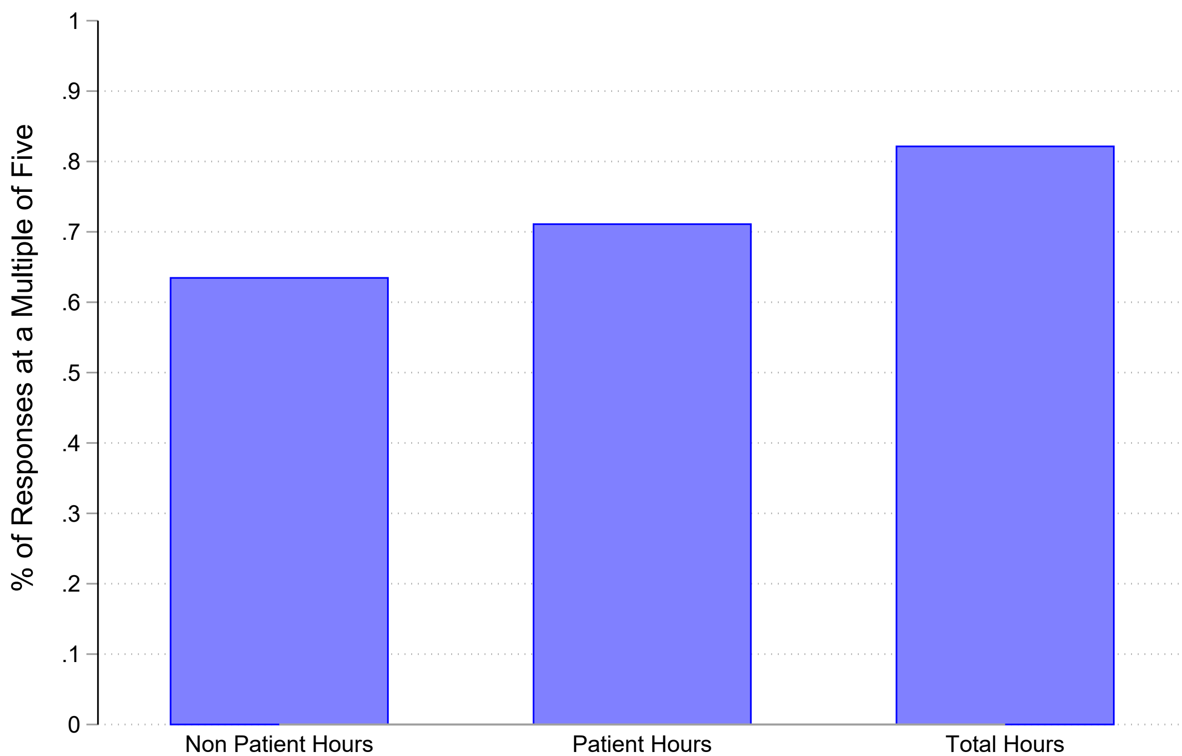
Note: The estimated coefficients from equation (13) are shown above for total hours and patient care hours as the outcome variables. Each dot represents the difference in the outcome variable relative to the base group that attrits immediately. For physicians age 60 or older, non-patient hours decline as they approach their final year in the Community Tracking Study panel. For young physicians, the number of years until attrition from the panel does not predict non-patient hours. Source: Authors' calculations based on data from the Community Tracking Study (Center for Studying Health System Change, 1999).

Appendix Figure B.6: Other Investments Before Retirement



Note: The estimated coefficients from equation (13) are shown above for board certification and taking new patients as the outcome variables. Each dot represents the difference in the outcome variable relative to the base group that attrits immediately. Source: Authors' calculations based on data from the Community Tracking Study (Center for Studying Health System Change, 1999).

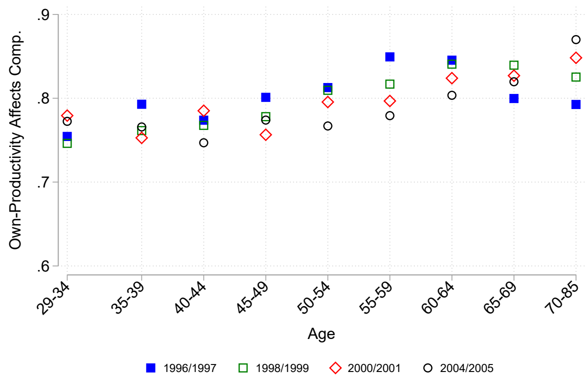
Appendix Figure B.7: The Magnitude of Round Number Reporting



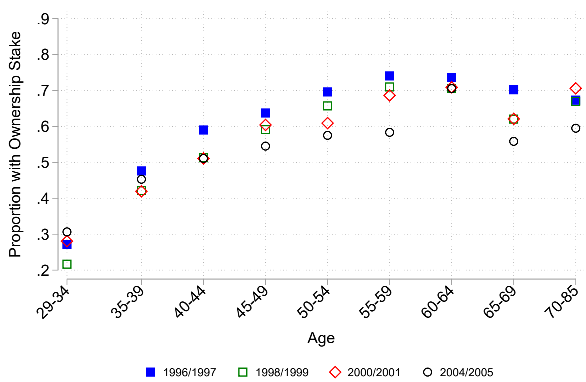
Note: This figure plots the percent of responses that are a multiple of five for each of the three hours variables. Responses with reported hours of zero are excluded from both the numerator and denominator. Source: Authors' calculations based on data from the Community Tracking Study (Center for Studying Health System Change, 1999).

Appendix Figure B.8: Cross-Sectional Age Profile of Ownership and Salary Structure

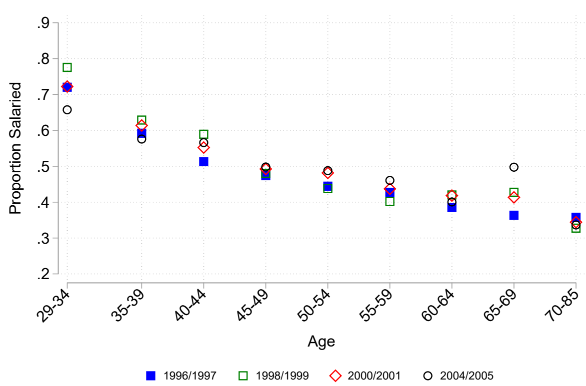
Panel A: Own-Productivity Affects Compensation



Panel B: Ownership Stake in Primary Practice



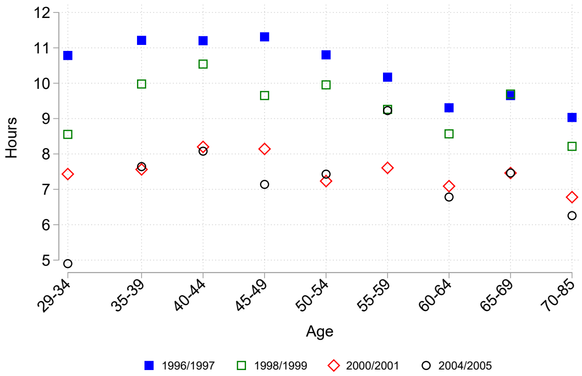
Panel C: Remunerated on a Salary Basis



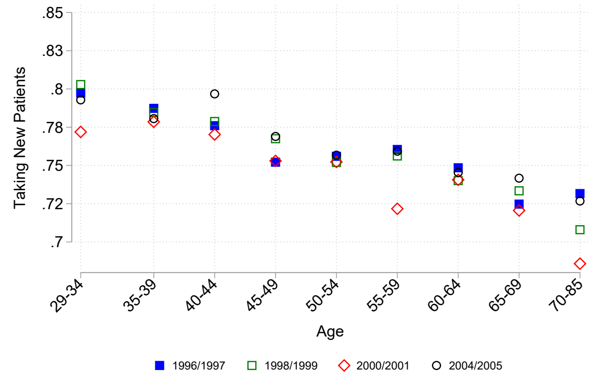
Note: Panel A plots the percent of physicians reporting that their own-productivity affects their compensation. Panel B plots the percent that are full or partial owners of their practice. Panel C shows the proportion of physicians that report being remunerated on a salary basis, each by age group. These variables may affect a physician's incentive and ability to adjust on-the-job investments in response to price changes. Given the strong correlations with age, these factors could influence the age gradient of how on-the-job investments respond to Medicare payment changes. Source: Authors' calculations based on data from the Community Tracking Study, 1997–98 wave only (Center for Studying Health System Change, 1999).

Appendix Figure B.9: Age Patterns by Survey Wave

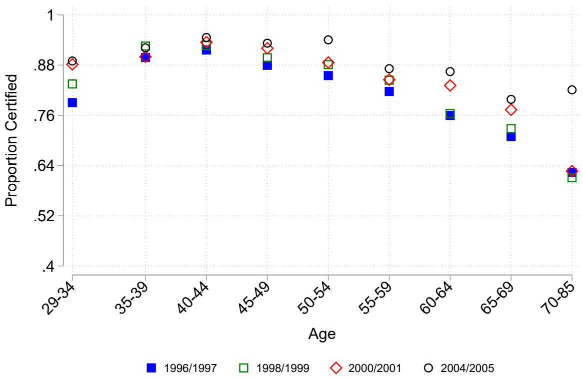
Panel A: Non-Patient Hours



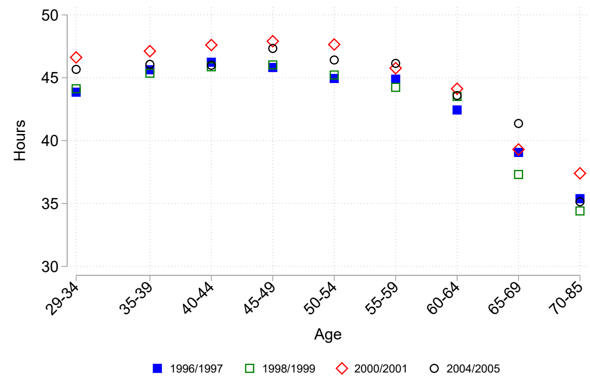
Panel B: Taking New Patients



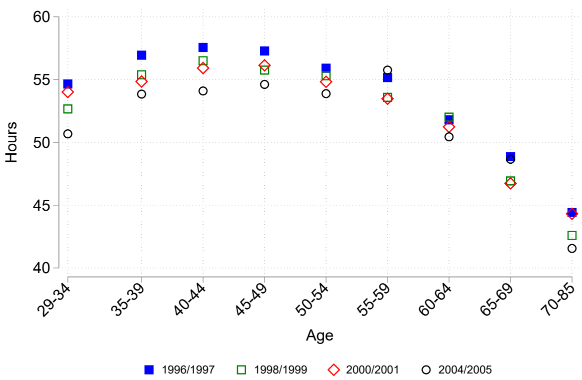
Panel C: Board Certified



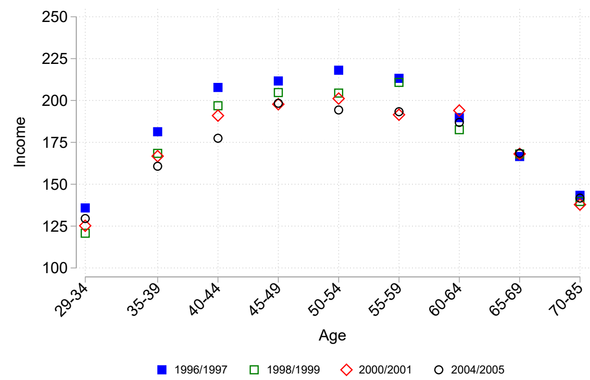
Panel D: Patient Care Hours



Panel E: Total Hours



Panel F: Income



Note: This figure plots average weekly patient care hours, and total weekly hours worked, by age group. Source: Authors' calculations based on data from the Community Tracking Study, 1996/97 wave only (Center for Studying Health System Change, 1999).

Appendix Table B.1: **Practice Type**

	Count
Solo Practice	12577
Group Practice	12093
Privately-Owned Hospital	5021
Medical School/Univ	3429
Two Physician Practice	3008
Group Model HMO	1258
Free-Standing Clinic	1150
Staff Model HMO	1134
State/local Government Hospital	621
State/local Government Clinic	531
Other	510
Integrated Health System	466
PPM	455
Community Health Center	367
Independent Contractor	321
State/local Government Other	211
PHO	185
Foundation	99
MSO	89
Locum Tenens	89
Other Insurance	79
Employer-based Clinic	74
Total	43767

This table displays the frequency of different practice types as reported by respondents. Solo practice, two-physician, and group practice make up the large majority of respondents. Source: Authors' calculations based on data from the Community Tracking Study (Center for Studying Health System Change, 1999).

Appendix Table B.2: Descriptive Statistics by Panel Length

	Number of Times Observed in Panel			
	1	2	3	4
Patient Hours	44.26	44.16	44.22	45.04
Non-Patient Hours	9.16	8.80	9.06	8.91
Total Hours	53.50	53.06	53.35	54.02
Weeks Worked	46.81	47.28	47.50	47.50
Certified	0.83	0.86	0.86	0.91
Taking New Patients	0.75	0.74	0.73	0.74
Income	167	169	173	187
Age	46.78	47.66	49.39	49.96
Gender (Male 0 Female 1)	0.27	0.26	0.23	0.20
Full/Partial Owner	0.50	0.51	0.56	0.61
Salaried	0.56	0.55	0.52	0.48
Own-Productivity Affects Compensation	0.78	0.78	0.79	0.81
N	11984	5522	4345	1926

This table reports means by the number of survey waves in which the physician appeared. The maximum is four, corresponding to being observed in all four survey waves. Source: Authors' calculations based on data from the Community Tracking Study (Center for Studying Health System Change, 1999).

B.1 Extensions and Robustness Checks

This section discusses additional extensions and robustness checks.

B.1.1 Cohorts

First, we investigate whether cohort trends confound the interpretation of the age profiles from section 3 by plotting the profile of labor supply and investment within each survey wave in Figure B.9. Encouragingly, the age profiles for patient hours, total hours, taking new patients, and income are invariant over time. In contrast, the profile for non-patient hours shifts downwards for all age groups. The late-career decline diminishes slightly, but remains visible in later waves. The percent decline from age 45-49 to age 60-85 in 1996/97 was 18 percent; in 2000/01, it was 12 percent. Finally, board certification propensity increased among older age groups, but remained constant among the young. This indicates higher certification rates among younger cohorts, which would overstate the old-age decline apparent in 1996/97.

C Data Appendix

C.1 Questionnaire Wording

Total Labor Supply

The CTS uses the following wording to elicit total hours of work:

> Thinking of your last complete week of work, approximately how many hours did you spend in all medically related activities? Please include all time spent in administrative tasks, professional activities and direct patient care. Exclude time on call when not actually working.

Patient Care Hours

Immediately after asking about total hours, the following question is asked to measure patient care hours:

> Thinking of your last complete week of work, about how many hours did you spend in direct patient care activities? (If necessary, read:) INCLUDE time spent on patient record-keeping, patient-related office work, and travel time connected with seeing patients. EXCLUDE time spent in training, teaching, or research, any hours on-call when not actually working, and travel between home and work at the beginning and end of the work day.

Income

In each survey wave, respondents are ask to report their income net of expenses for the calendar year preceding the survey wave:

> During 1995 [**authors' note: or 1997, 1999, 2003**], what was your own net income from the practice of medicine to the nearest $1,000, after expenses but before taxes? Please include contributions to retirement plans made for you by the practice and any bonuses as well as fees, salaries and retainers. Exclude investment income. (If code "2" in # A4, read:) Also, please include earnings from ALL practices, not just your main practice. (If necessary, read:) We define investment income as income from investments in medically related enterprises independent of a physician's medical practice(s), such as medical labs or imaging centers.

Weeks Worked

Similarly, respondents report their number of weeks worked in the year prior to the survey wave:

> Considering all of your practices, approximately how many weeks did you practice medicine during 1995 [**authors' note: or 1997, 1999, 2003**]? Exclude time missed due to vacation, illness and other absences. (If necessary, read:) Exclude family leave, military service, and professional conferences. If your office is closed for several weeks of the year, those weeks should NOT be counted as weeks worked.

C.2 Variable Construction

We winsorize each of the hours variables at 105 hours per week. This is equivalent to 15 hour work days seven days a week. This is a fairly extreme upper bound on what a "usual" work week can feasibly look like.

Willingness to Accept New Patients

The original survey asks:

Medicare:

> Is the practice accepting all, most, some, or no new patients who are insured through Medicare, including Medicare managed care patients?

Medicaid:

> Is the practice accepting all, most, some, or no new patients who are insured through Medicaid, including Medicare managed care patients?

Private:

> Is the practice accepting all, most, some, or no new patients who are insured through private or commercial insurance plans including managed care plans and HMOs with whom the practice has contracts? This includes both fee for service patients and patients enrolled in managed care plans with whom the practice has a contract. It excludes Medicaid or Medicare managed care.

All, most, some, and none correspond respectively to 4, 3, 2, and 1 in the survey coding. We sum the responses to each of the three questions, subtract 3, and divide by 9 so that the resulting index ranges from 0 to 1.

Board Certification

In the 1996/97, 1998/99, and 2000/01 waves, we use the derived variable BDCERT. Physicians are classified into one of four mutually-exclusive categories: (i) Board certified in any specialty, (ii) Board eligible in any specialty, (iii) Neither, (iv) Not Ascertained. If the physician fell in group (ii), (iii), or (iv) we classified them as not certified.

In the 2004/05 wave, the BDCERT variable was replaced by BDCTANY, which simply classifies respondents into two mutually-exclusive categories: (i) Board certified in any specialty, (ii) Not board certified in any specialty.

Does Productivity Determine Compensation

The survey specifically asks physicians if their own productivity influences compensation. We capture this use a binary variable derived from the answer to the following question:

> I am now going to read you a short list of factors that are sometimes taken into account by medical practices when they determine the compensation paid to physicians in the practice. For each factor, please tell me whether or not it is EXPLICITLY considered when your compensation is determined:
>
> YOUR OWN productivity
>
> (If necessary, read:) Examples include the amount of revenue you generate for the practice, the number of relative value units you produce, the number of patient visits you provide, or the size of your enrollee panel.