NBER WORKING PAPER SERIES

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Working Paper 10465
http://www.nber.org/papers/w10465

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
May 2004

The authors gratefully acknowledge financial support from the Center for Aging at the University of Alabama at Birmingham (UAB). We thank Christine Bishop, Jeff DeSimone, Elizabeth Graddy, Dana Mukamel, Joann Spetz, and seminar participants at the Allied Social Science Associations meetings, Association of Public Policy and Management meetings, Southern Economic Association meetings, Southeastern Health Economics Study Group meetings, Cornell University, University of Rochester, Duke University, Harvard University, Indiana University-Purdue University Indianapolis and UAB Center for Aging for their helpful comments. The views expressed herein are those of the author(s) and not necessarily those of the National Bureau of Economic Research.

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NBER Working Paper No. 10465
May 2004
JEL No. I12, L1, J4

ABSTRACT

This paper studies factor substitution in one important sector: the nursing home industry. Specifically, we measure the extent to which nursing homes substitute materials for labor when labor becomes relatively more expensive. From a policy perspective, factor substitution in this market is important because materials-intensive methods of care are associated with greater risks of morbidity and mortality among nursing home residents. Studying longitudinal data from 1991-1998 on nearly every nursing home in the United States, we use the method of instrumental variables (IV) to address the potential endogeneity of nursing home wages. The results from the IV models are consistent with the theory of factor substitution: higher nursing home wages are associated with lower staffing, greater use of materials (specifically, physical restraints), and a higher proportion of residents with pressure ulcers. A comparison of OLS and IV results suggests that empirical studies of factor substitution should take into account unobserved heterogeneity in factor quality.

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Introduction

Nursing homes choose between labor-intensive and materials-intensive methods of providing many types of care, including feeding, incontinence, and wandering. Feeding of residents may be labor intensive, as when employees feed residents by hand, or materials-intensive, as when feeding tubes are used. Care of an incontinent patient may be labor-intensive, involving regularly scheduled toileting and bladder rehabilitation, or materials-intensive, involving urethral catheterization. Wandering may be countered with staff attention, or with the use of materials such as physical restraints and psychoactive drugs.

This paper tests whether increases in wages for nursing home direct care providers cause nursing homes to shift away from labor-intensive, and towards more materials-intensive, production of care. Results from this analysis have important implications for policy. The most recent National Nursing Home Survey counted 1.6 million Americans living in nursing homes in 1999 (National Center for Health Statistics, 2002). It has been projected that in the next twenty years, 46 percent of Americans who survive to age 65 will use a nursing home at some point in their lives (Spillman and Lubitz, 2002).[2] The market for long-term care is large; nursing home expenditures totaled $98.9 billion in 2001, which represents 7 percent of national health expenditures (National Center for Health Statistics, 2003). The provision of nursing home care in materials-intensive ways is of interest because such methods are associated with greater risks of morbidity and mortality (Zinn, 1993; Harrington et al., 1992) and the fact that

[2] The odds differ by gender; currently 33 percent of men and 52 percent of women who reach age 65 will use a nursing home at some point in their lives (Kemper and Murtaugh, 1991). Women are much more likely to use a nursing home than men because women have longer life expectancies than men and women tend to marry older men, leaving them at greater risk of becoming a widow than men's risk of becoming a widower.

nursing home residents are among the most vulnerable in society because of their deteriorated mental and physical condition and, often, their lack of family to monitor nursing home care (Hirth et al., 2000).

Factor substitution has been studied in hospitals (Jensen and Morrisey, 1986; Morrisey and Jensen, 1990), health maintenance organizations (Okunade, 2003), physician practices (Escarce and Pauly, 1998), hospital pharmacies (Okunade, 1993), dentist offices (Okunade, 1999), and for treatment of depression (Berndt, Frank, and McGuire, 1997). Two previous studies find evidence consistent with factor substitution in nursing homes. Weisbrod (1988, 1998), in the course of studying the differences between for-profit and not-for-profit health care providers, speculated that church-sponsored nursing homes face lower labor costs because their employees are willing to work for lower wages and in some cases as volunteers. He tested this hypothesis using data on nursing homes from the 1978 Survey of Institutionalized Persons and consistently found that, relative to proprietary nursing homes, church-related nonprofit nursing homes used significantly higher quantities of labor. He also found that although the percentage of residents admitted with a prescription for sedatives was roughly equal in for-profit and non-profit homes, those in for-profit homes received more than four times as many doses of sedative per month.

Zinn (1993) finds evidence of labor-materials substitution in 1987 Medicare/Medicaid Automated Certification Survey (MMACS) data. Specifically, higher wages for nursing home workers were associated with greater use of catheters, physical restraints, and feeding tubes.

A limitation of the cross-sectional data used in these studies is that local wages may be correlated with factor quality (i.e. the productivity of nursing home workers); nursing homes that employ more productive workers likely pay higher wages. For this reason, we pursue an instrumental variables approach. A comparison of our OLS and IV suggests that it is important for empirical studies of factor substitution to correct for unobserved heterogeneity in factor quality.

The current analysis seeks to improve on the previous literature in the following ways. First, our study uses recent (1991-1998) longitudinal data on nearly every nursing home in the United States. Second, we address the possibility that nursing home wages may be correlated with unobserved factor quality by employing IV estimation methods.

1. Factor Substitution in the Production of Nursing Home Care

This section describes the process and feasibility of factor substitution in nursing homes and presents hypotheses regarding factor substitution in nursing homes.

In the long run, a profit-maximizing firm chooses the cost-minimizing combination of capital (*K*), labor (*L*), and materials (*M*) to produce a given amount of output. However, in the short run, a firm's capital is fixed, and firms must minimize costs of production by adjusting their use of labor and materials. Assume that *v* and *w* are the prevailing per-unit costs of materials and labor, respectively. We assume that $\partial L / \partial w < 0$; all else equal, an increase in wage rate *w* will result in less labor *L* being hired. As *w* rises, there will also be an increase in *M* as firms substitute materials for labor in order to minimize costs. We show this graphically in Figure 1.

In Figure 1, the isoquant q_1 joins all bundles of labor and materials that can be combined to produce a given level of output (e.g., patient-days of nursing home care). The slope of the isoquant is equal to the marginal rate of technical substitution (MRTS) between labor and materials; specifically, the negative of the ratio of the marginal productivity of labor (MP_L) and the marginal productivity of materials (MP_M).

The point on the isoquant that a firm will choose is the bundle of materials and labor that minimizes cost, illustrated by the point of tangency between the isoquant and an isocost line with a slope equal to the ratio of the factor prices. At this point of tangency, the slope of the isoquant (the MRTS) is equal to the negative of the ratio of the factor prices: $MP_L / MP_M = w / v$. This condition can be rewritten as $MP_L / w = MP_M / v$, which indicates that when a firm has chosen the cost-minimizing mix of materials and labor, the last dollar a firm spends on labor and the last dollar a firm spends on materials generate equal marginal productivity. This implies that if wages *w* rise while the other three variables remain constant, a firm will seek to minimize costs by hiring less labor and more materials until the familiar condition of $MP_L / w = MP_M / v$ holds given the new wage *w*.

Assume that point A represents the bundle of labor (L_1) and materials (M_1) used to produce the quantity of output q_1. Next, suppose that wages rise. The total effect of the wage rise can be decomposed into two distinct parts. The first is the substitution effect, which is for the firm to buy more of the input that has become relatively less expensive (materials) and less of the input that has become relatively more expensive (labor), holding output constant. This effect is shown as the movement along isoquant q_1 from point A to point B – the quantity of labor used by the firm has fallen from L_1 to L_2, and the quantity of materials used by the firm has risen from M_1 to M_2. At point B, the cost-minimizing condition is satisfied for the new, higher *w*.

The increase in wages also causes an upward shift in the firm's marginal cost curve; the second part of the impact of a rise in wages is the output effect whereby the firm produces less output because of the increase in costs. This effect causes the firm to employ less of both labor and materials – the quantity of labor falls from L_2 to L_3 and the quantity of capital falls from M_2 to M_3. Whereas the substitution effect was a shift in labor and materials keeping output constant, the output effect is a shift in labor and materials to a different level of output; the output effect is represented as the movement from point B on the isoquant q_1 to point C on the lower isoquant q_2.

Excluding the very unlikely case in which labor is an inferior input (less labor hired at higher output levels), it is unambiguous that a rise in wages results in less labor being used in production; both the substitution and output effects work in the same direction. We assume that the net effect of a rise in wages is that more materials will be used in production; i.e. we assume that the substitution effect dominates the output effect. In terms of Figure 1, we assume that $M_3 > M_1$.[3]

The theory of factor substitution typically assumes that inputs are perfectly homogenous. However, factor units may differ in quality; that is, workers may differ in their productivity. If so, one might observe cross-sectionally that firms that produce using a high ratio of L to M may pay higher wages than firms that produce using a low ratio of L to M.[4] The possibility that there may be unobserved heterogeneity in factor

[3] In the long run a firm may also alter its level of capital used in production, but we limit our analysis to factor substitution in the short run.
[4] Philpot (1970) discusses how unobserved international variation in labor quality creates bias in estimates of factor substitution across countries.

quality makes it important to seek exogenous variation in factor prices when attempting to estimate the extent of factor substitution.

We next describe how factor substitution operates in nursing homes specifically. Nursing homes are staffed in part by registered nurses (RNs) and licensed practical nurses (LPNs), but these workers provide little direct patient care. Nurse aides (NAs) provide 80 to 90 percent of the direct care to patients (Institute of Medicine, 1996). More than 90 percent of NAs are women and three-fourths have not completed high school. They earn close to the minimum wage and less than half of them have any employer-provided health insurance coverage. The labor market for NAs in nursing homes is very fluid and is characterized by high turnover (Munroe, 1990).

The care provided by NAs is non-technical and consists primarily of helping residents with activities of daily living (ADLs) such as eating, dressing, bathing, toileting, and walking. For several types of such care, nursing homes choose between providing care in a relatively labor-intensive manner or in a relatively materials-intensive manner. For example, managing incontinence may be labor-intensive, through regularly scheduled toileting and bladder rehabilitation, or materials-intensive through urethral catheterization (Zinn, 1993). Nursing homes face a similar decision with respect to feeding residents; feeding may be labor-intensive (by hand) or materials-intensive (involving feeding tubes). A third example is monitoring and controlling residents' behavior. Homes may choose a labor-intensive method through constant monitoring, or they may choose materials-intensive methods such as physical or chemical restraints.

In some cases, the resident or a third-party payer shoulders some of the costs of materials-intensive care. For example, in some states nursing homes receive a higher

Medicaid reimbursement for tube-fed patients (Mitchell et al., 2003). Prescription drugs must be paid for by homes out of the Medicare per diem, but Medicaid pays a discounted price for drugs on a per-drug basis, and private payers pay the nondiscounted price of the drug (Mendelson et al., 2002). This may lead economists to ask why nursing homes do not minimize costs by reducing staffing and putting *all* residents on feeding tubes and psychoactive drugs.[5] It may be due to a sense of humaneness or fear of lawsuits, but answering that question is outside the scope of this paper; our focus is whether a rise in the price of labor, holding constant the price of materials, leads homes to substitute materials for labor.

Unlike hospital care that is predominantly provided by nonprofit facilities, roughly two-thirds of all nursing homes are for-profit facilities. Thus, nursing homes have strong incentives to choose the cost-minimizing combination of inputs in the production of care. Moreover, labor costs represent 60-70 percent of all nursing home costs, implying that homes have a strong incentive to quickly change their factor mix after labor becomes more expensive (Zinn, 1993). There is a high rate of turnover among NAs (Institute of Medicine, 1996), so nursing homes can quickly decrease the size of their staff simply by slowing the rate at which they replace departing staff members.

Homes do not have complete freedom in choosing the amount of labor used in production; minimum staffing laws impose constraints. The federal government requires that Medicaid and Medicare certified nursing homes have licensed practical nurses (LPNs) on duty 24 hours a day; a registered nurse (RN) on duty at least 8 hours a day, 7 days a week and an RN director of nursing in place (Omnibus Budget Reconciliation Act,

[5] In our sample, only 0.04 percent of homes had all of their residents on feeding tubes and only 0.37 percent had all their residents on psychoactive drugs.

1987). In some states, there are further legal limits on the minimum number of RNs and other nurses that must staff a nursing home (Institute of Medicine, 1996). These minimum staffing requirements prevent nursing homes that are at or close to the minimums from significantly altering their factor mix, and will cause attenuation bias in our results.

Substitution of materials-intensive methods of care for labor-intensive methods of care is of interest because materials-intensive methods of care in nursing homes are typically associated with a greater risk of morbidity and mortality. Urethral catheterization places the resident at greater risk for urinary tract infection; other long-term complications include bladder and renal stones, abcesses, and renal failure. Feeding tubes can result in complications including self-extubation, infections, aspiration, unintended misplacement of the tube, and pain. Immobility resulting from the use of physical restraints may increase the risk of pressure ulcers, depression, mental and physical deterioration, and mortality (Zinn, 1993). Psychotropic drugs may also result in mental and physical deterioration (Harrington et al., 1992).

Microeconomic models of factor substitution assume that quality of the output good is held constant, but for the reasons just described, in nursing homes a change in the input mix may change the quality of care. Under the conditions of perfect information, perfect rationality, costless mobility, and privately purchased care, one would predict that residents would respond to a decrease in nursing home quality by departing for a higher-quality nursing home. However, consumers in the nursing home market tend to be poorly informed, many are cognitively impaired, and many are without relatives to help them make decisions. Grabowski and Hirth (2003) find results consistent with nursing home markets operating under conditions of asymmetric information that can lead to the delivery of suboptimal levels of quality.[6] Residents whose nursing home care is paid for by Medicaid may face great search costs in finding another nursing home that will accept them. In general, moving between nursing homes can be very costly in time and effort, and although such transfers do occur, they are relatively uncommon (Hirth et al., 2000). Further, nursing homes cannot directly increase output prices to recoup higher costs incurred for care under these primarily prospective payment systems. Medicaid and Medicare are the primary payers for a majority of nursing homes, and payment rates are revised only periodically to reflect changes in input prices (GAO, 2003). All of these features of nursing home markets make it possible for nursing homes to adjust factor inputs and lower quality with few repercussions in terms of volume or revenue.

Our specific hypotheses regarding the effect of higher wages on the production of nursing home care are as follows.

Hypothesis 1. Increases in local wages for nursing home workers result in nursing homes employing fewer workers. We predict that homes will employ both fewer NAs and fewer professional nurses (LPNs and RNs).

Hypothesis 2. Increases in local wages for nursing home workers cause nursing homes to provide care in materials-intensive ways. As the wage rate for nursing home workers increases, nursing homes will look to substitute away from labor and towards materials such as catheters, feeding tubes, physical restraints, and psychoactive drugs.

[6] Chou (2002) finds that differences in the quality of care between not-for-profit and for-profit nursing homes are greater among residents who lack information about the quality of nursing home care (defined as residents who did not have a spouse or child visit them within a month after admission) than among those with better information (defined as residents who had a spouse or child visit them).

Hypothesis 3. Increases in local wages for nursing home workers are associated with a rise in indicators of low quality of care in nursing homes. We predict that the prevalence of pressure ulcers (which are commonly termed bedsores) will rise after the wages of nursing home workers rise.

2. The Online Survey Certification and Reporting System (OSCAR) Data

This study uses a longitudinal data set: the linked annual data of the federal Online Survey Certification and Reporting (OSCAR) system from 1991 through 1998 for the 48 contiguous United States (excluding Alaska, Hawaii, and the District of Columbia). The OSCAR system contains information from state surveys of all federally certified Medicaid nursing facilities and Medicare skilled nursing care homes in the U.S. Almost 96 percent of all facilities nationwide are federally certified (Strahan, 1997) so the OSCAR system includes the vast majority of nursing homes in the U.S. Collected and maintained by the Centers for Medicare and Medicaid Services (CMS), the OSCAR data are used to determine whether homes are complying with federal regulations. Every facility is required to have an initial survey to verify compliance. Thereafter, states are required to resurvey each facility at least every 15 months; in practice, the average is about 12 months (Harrington et al., 1998).

Although many of the elements in the OSCAR system are self-reported by the facilities, the data are generally considered accurate and reliable (Harrington et al. 2000). The OSCAR data have been recommended for more extensive use by a recent IOM expert panel on nursing home quality (IOM 2001). Our sample includes 121,627 complete surveys from 18,220 nursing homes conducted between 1991 and 1998 within the 48 contiguous states.

Summary statistics for the sample are contained in Table 1. The average home uses 2.15 Nurse Aide hours per resident day and 1.22 professional (i.e. LPN and/or RN) hours per resident day. The average home in the sample has 8.3 percent of residents with a catheter, 6.1 percent with a feeding tube, 18 percent under restraints, 38 percent on at least one psychoactive drug, and 7.2 percent of residents with pressure ulcers. The OSCAR files are supplemented with data from several sources. Data on the wages of nursing home workers is from the Covered Employment and Wages data collected by the Bureau of Labor Statistics (BLS). Table 1 indicates that the average state-level hourly wage of all nursing home workers is $8.19 (wages have been converted to 1998 dollars). Data on the costs of materials (pharmaceuticals, plastics and rubber) come from the BLS Producer Price Index. Aggregate county level demographic data are taken from the Bureau of Health Professions' Area Resource File (ARF). We also merge with the OSCAR data on the effective minimum wage rate law for each state and year. All variables expressed in dollars are converted to 1998 dollars using the BLS consumer price index.

3. Empirical Methods

3.1. Basic Model

We initially use OLS to estimate the following reduced-form regression of the relationship between the cost of labor and outcomes related to factor substitution:

$$Y_{HT} = W_{HT}\beta_W + V_T\beta_V + T\beta_T + X_{HT}\beta_X + \varepsilon_{HT} \qquad (1)$$

The dependent variable, Y_{HT}, represents one of several outcomes of interest at nursing home H at time T. The first set of dependent variables measures the quantity of labor used in production. There are two such outcomes of interest: the number of NA hours per resident day, and the number of professional nurse (RN and LPN) hours per resident day, employed by the facility. We predict that the sign of β_W, the coefficient on the real wages of nursing home workers, will be negative when the dependent variable measures the quantity of labor used in nursing home production.

The second set of dependent variables measures the extent of materials-intensive care. There are four such outcomes of interest: the proportion of residents in the facility with catheters, tube feedings, physical restraints, or on psychoactive drugs[7]. We predict that the sign of the coefficient on nursing home worker wages will be positive when the dependent variable measures the extent of materials-intensive care.

The final dependent variable measures the quality of care; specifically: the proportion of residents with pressure ulcers. Pressure ulcers (or decubitis ulcers), commonly associated with immobility, are areas of the skin and underlying tissues that erode as a result of pressure or friction and/or lack of blood supply. Pressure ulcers have been found to be associated with an increased rate of mortality (Brandeis et al., 1990). Pressure ulcers are a particularly good measure of quality because they are preventable and treatable conditions (Kane et al., 1989). We predict that the sign of the coefficient on nursing home worker wages will be positive when the dependent variable measures the quality of care.

[7] Psychoactive medications encompass antipsychotic, antianxiety, antidepressant, and hypnotic medications.

For each of the outcomes represented as a percentage of residents, we use the logit transformation so dependent variables are of the form $\ell n(\frac{P_i}{1-P_i})$ where P_i represents the proportion of residents of nursing home *i*. Because the logit transformation assigns no value when the percent is equal to either zero or one, zero values were recoded as .001 and values of one were recoded as .999.[8] In each regression, observations are weighted according to the number of residents in nursing home H at time T.

Among the independent variables in equation (1), W_{HT} is the real wage of nursing home workers in the local labor market of nursing home H at time T. For each state, we use the average state-level quarterly wage associated with Standard Industrial Classification (SIC) code 805: Nursing and Personal Care Facilities Employees. This category includes employees in skilled nursing care facilities, intermediate care facilities, and nursing and personal care facilities not classified in the first two categories. This classification *excludes* employees in medical offices and clinics, hospitals, medical and dental laboratories, home health care, and outpatient facilities.[9]

We measure factor substitution as wages rise holding constant the cost of materials. In equation (1), V_T is a vector of variables that measure of the cost of materials at time T. The variables included in that vector are the same variables that the Centers

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[8] Prior to this recoding, 9.01 percent of the home-year observations in our sample had 0 percent of residents on catheters while 0.04 percent had 100 percent of residents on catheters. Similarly, 10.21 percent of homes had 0 percent of residents under physical restraints and only 0.10 percent had 100 percent of residents under restraints. 21.86 percent of observations had 0 percent of residents on feeding tubes and only 0.04 percent had all residents on feeding tubes. 2.34 percent of observations had 0 percent of residents on antipsychotic drugs and only 0.37 percent had all residents on such drugs. 8.92 percent of observations had 0 percent of residents with pressure ulcers and 0.03 percent had all residents with pressure sores.

[9] We also estimated our models using the county-level wage, but this is measured at the 2-digit SIC code level. SIC code 80 includes not only nursing home workers but also all workers in medical offices, clinics, hospitals, medical and dental laboratories. Our estimates using the 2-digit SIC measure were generally not supportive of our hypotheses, we suspect because it is an inaccurate measure of the wages of nursing home workers.

for Medicare and Medicaid Services (CMS) uses to track changes over time in the costs of hospitals and nursing homes using the Hospital Input Price Index and the Skilled Nursing Facility Price Index. Specifically, we use the Producer Price Index for the components Pharmaceuticals and Plastics & Rubber. The cost of materials is assumed to be uniform nationally at a particular point in time.

T is a linear time trend, and X is a vector of control variables. At the home level, we include an index for activities of daily living to control for the underlying case-mix within the facility. This index is equal to the average number of activities of daily living (ADLs) with which residents need assistance, which reflects the average dependence of the residents in each facility. ADLs form the cornerstone of nursing home resident classification and play a major role in all state-level Medicaid case-mix adjustment payment systems. Total number of certified beds, profit status (for-profit, not-for-profit and government), hospital-affiliation and whether the home is part of a multiple-facility chain are also included as facility-level control variables.

A Herfindahl index is included to control for the competitiveness of the county nursing home market.[10] The population of individuals over age 75 per square mile in the county, and the real median income in the county, are also included as regressors. Given the importance of Medicaid as a payer of nursing home services (Grabowski, 2001), we also controlled for the real average state Medicaid payment rate.

Our data is a census of Federally-certified nursing homes, and as such, the point estimates of the coefficients could be interpreted as their true values; by this interpretation, standard errors are not informative and tests of statistical significance are

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[10] This index is constructed by summing the squared market shares of all nursing home facilities in the county. The index ranges from 0 to 1, with a higher value signifying a greater concentration of facilities.

unnecessary. However, standard errors are meaningful if one interprets the sample (which covers 1991-1998) as drawn from all possible years. For readers who wish to see tests of statistical significance, we provide standard errors and indicators of when p values meet the thresholds of traditional levels of statistical significance.

We adjust the standard errors for two types of correlation in error terms across observations. First, the "grouped" nature of the data (i.e. multiple observations from each home) may introduce heteroskedasticity and bias the estimates of the parameter standard errors, so we cluster-correct standard errors to account for the correlation within homes over time. Second, we adjust the standard errors to account for the fact that we are regressing individual nursing home outcomes on a regressor of interest (nursing home wages) that varies only by state and quarter. As a result of regressing micro outcomes on an aggregate regressor, unadjusted standard errors will be biased downwards, perhaps dramatically.[11] We adjust for this by bootstrapping the standard errors, selecting with replacement all observations by particular state and quarter.[12] As expected, this adjustment considerably increases the standard errors.

3.2. Instrumental Variables Model

One concern with the OLS model is that variation in labor costs may be correlated with variation in factor quality (i.e. nursing home worker productivity). For example, states with more productive nursing home workers will also likely have higher nursing home wages. Such unobserved heterogeneity will bias the OLS coefficients on nursing

[11] Moulton (1990). Donald and Lang (2001) and Bertrand, Duflo, and Mullainathan (2004) discuss this problem as it applies to the standard errors of difference-in-differences estimators.
[12] We conduct 50 replications to estimate the bootstrap standard errors, which is in the range recommended by Efron and Tibshirani (1993).

home worker wages. To address this problem, we estimate a model of instrumental variables.

Equation (2) shows that nursing home wages W may also be related to the variables X , V , and T from equation (1). Nursing home wages may also be a function of Z , a set of variables uncorrelated with the error term in the second-stage regression. The variable ν represents the residual.

$$W_{HT} = Z_{HT}\lambda_Z + X_{HT}\lambda_X + V_T\lambda_V + T\lambda_T + \nu_{HT} \qquad (2)$$

A key econometric issue is that nursing home wages W may be correlated with ε_{HT} , the error term in the second-stage regression. Changes over time in local wage rates for nursing home workers may be correlated with changes in the demand for labor-intensive nursing home care. In these cases, the error terms ε and ν will be correlated, which violates the assumptions underlying the linear regression model.

We can generate consistent estimates of the effect of nursing home wages on our outcomes of interest if we can identify a set of variables Z that are correlated with nursing home wages but not ε , the error term in the second-stage regression. Given Z , we can calculate an IV estimate of the effect of nursing homes wages on the outcomes of interest.

We identify two plausible instruments for the wages of nursing home workers. The first is the effective real minimum wage in the state. The effective minimum wage is the state's own legislated minimum unless the federal minimum is greater, in which case the federal minimum wage is the state's effective minimum wage. Nursing homes are primarily staffed by nurse aides who tend to be paid at or near the minimum wage (Institute of Medicine, 1996), so a change in the effective minimum wage rate represents an exogenous shock to nursing home wages (Machin, Manning, and Rahman, 2002).

Over the period 1991 to 1998, there were 17 instances in which states changed their effective minimum wage relative to the federal minimum wage. There were also two changes in the federal minimum wage over our period of study; the minimum wage increased from $4.25 to $4.75 in 1996 and from $4.75 to the current level of $5.15 in 1997. We assume that such changes are uncorrelated with worker productivity and uncorrelated with the demand for labor-intensive nursing home care.

Our second instrument is the state wage rate for similar workers in a non-health care industry; the correlation between wages in the two sectors identifies local wage shocks for a given skill level of worker that are uncorrelated with nursing home worker productivity or with the demand for labor-intensive nursing home care. Specifically, our second instrument is the average state real wage for Standard Industrial Classification (SIC) code 53: General Merchandise Stores; this SIC code includes employees in department stores, variety stores and miscellaneous general merchandise stores. This wage rate is likely to be correlated with nurse aide wages because, as stated in a 1996 Institute of Medicine (IOM) report, "wages of nursing assistants are generally near the minimum wage and are comparable to levels offered by fast food chains and retail establishments" (p. 160). The IOM committee "heard reports of NAs leaving health care for retail jobs when a K-Mart opened" (p. 263). In Section 5: Robustness Checks, we describe that our results are largely robust to the use of wages from other sectors as instruments.

Tests of overidentification are often used to determine the validity of instruments by testing whether the IV coefficient estimated one instrument is similar to the IV coefficient estimated using another instrument that is assumed to be valid. A weakness of overidentification tests is that two valid instruments may have different marginal effects and one may incorrectly conclude based on an overidentification test that an instrument is invalid. For example, the minimum wage is not binding in high-wage-paying nursing homes, but all homes may be affected by wages offered to their workers by the retail sector; for this reason, the two instruments may have different marginal effects. Overidentification tests (Sargan, 1958) indicate that our instruments seem to have similar effects in the staffing regressions, but different effects in the regressions concerning materials-intensive care. Given that the effective minimum wage and the wages in other sectors are very unlikely to be affected by nursing home decisions about methods of care, we believe that both instruments are valid, and that the results of the overidentification test reflect the fact that the instruments have different marginal effects.

The identifying assumption is that the effective minimum wage and wages for general merchandise store employees are correlated with W, the nursing home wage rate, but are uncorrelated with ε, the error term in the second-stage regression. In the first stage of IV estimation (Eq.3), the nursing home wage is regressed on these instruments plus the other regressors (X , V , and T) from the second stage of IV estimation. In the second stage, the various outcomes of interest are regressed on the instrumented nursing home wage rate and the other regressors X , V , and T . The IV analyses are weighted by the number of facility residents and the standard errors reflect Huber-White corrections for intra-home correlation.

Bound et al. (1995) argue that the use of instruments that explain little of the variation in the endogenous variable can do more harm than good. If a set of instruments is weakly correlated with the endogenous explanatory variable, then even a small correlation between the instruments and the error term in the second-stage regression can seriously bias estimates. Their results suggest that the partial R^2 and F-statistics on the excluded instruments in the first-stage regression are useful as rough guides to the quality of the IV estimates. Staiger and Stock (1997) argue that 10 is an acceptable value of the F-statistic associated with the hypothesis that the coefficients on the instruments in the first-stage regression are jointly equal to zero (Stock and Yogo, 2002).[13]

The set of instruments far exceeds the minimum standard of Staiger and Stock . In the first stage of IV estimation, the hypothesis that the coefficients on the instruments are jointly equal to zero is rejected. Appendix Table 1 indicates that in the first-stage regression, the instruments have an F-statistic equal to 185.05 and $\Delta R^2 = 0.06$. The first-stage coefficients on the instruments are of the expected sign. Both the minimum wage and the general merchandising store wage are positively correlated with nursing home wages. Each of these instruments is statistically significant at the 1 percent level.

IV raises standard errors, and this loss of efficiency should only be incurred if something is gained in terms of consistency. A Hausman test is one piece of evidence as to whether OLS estimates are inconsistent. Testing both instruments, we reject at the 1 percent level the null hypothesis of OLS consistency only for the professional staffing measure. If we test each instrument separately, we reject the null for professional staffing when we use the manufacturing wage as the instrument, and we reject the null for physical restraints and psychoactive drugs when we use minimum wage as the

[13] More recent work by Stock and Yogo (2002) has argued that this Staiger-Stock rule of thumb is somewhat general in that the strength of the instrument depends on the inferential task to which the instruments are applied and how that inference is conducted. The authors propose a more detailed set of F-statistics to account for different estimators and the number of endogenous regressors. Given our use of least squares with only one endogenous regressor, we will use the Staiger-Stock rule of thumb.

instrument. Although these Hausman test results suggest that only for certain outcomes is the OLS coefficient inconsistent, the failure to reject the null hypothesis should not be confused with confirmation of the null. Moreover, there is a reason to believe that OLS coefficients are inconsistent: there likely exists heterogeneity in factor quality, and when homes employ higher-productivity workers they may pay higher wages. The difference in point estimates between OLS and IV (even though often not statistically significant) and the likelihood that unobserved factor quality affects OLS results suggest that IV estimation offers gains in consistency that are worth the loss in efficiency.

The second part of the identifying assumption is that the instruments are uncorrelated with the error term in the second-stage regression. Although it is impossible to confirm the null hypothesis that they are uncorrelated, examining whether the instruments are strongly correlated with observable factors can be informative (McClellan, McNeil, and Newhouse, 1994). To this end, the sample was divided in two: observations for which the effective minimum wage was above the mean for the sample and observations for which it was below the mean for the sample. This process was repeated but with the division occurring on the basis of whether the general merchandise store wage was above or below the sample mean. Appendix Table 2 lists the means of the variables used in this study by group, and indicates with asterisks whether the differences in the means of the groups are statistically significant.

Appendix Table 2 is divided into three sections. The first is devoted to nursing home worker wages, the second to explanatory variables, and the third to outcome variables. The first section indicates that homes in states with above-average minimum wages pay on average 40 cents more per hour. Homes in states with above-average manufacturing wages pay on average $1.22 more per hour. These are consistent with the assumption that the instruments are correlated with the potentially endogenous regressor.

The second section of the table presents means of the explanatory variables for the two groups. In general, the means of the variables are similar for the observations associated with above-average and below-average values of the instrument; however, given the large sample, the difference in means is usually statistically significant. The largest differences in means occur between those above and below the average manufacturing wage for the following variables: number of beds, hospital-based, Herfindahl Index, per capita income, and elderly per square mile. It should be noted that the group means in this table are unconditional.

The outcome variables occupy the bottom section of Appendix Table 2. There are only slight differences between homes with high values of the instruments with those with low values of the instruments. This comparison represents a preliminary and unconditional IV estimate of the effect of wages on the outcomes.

In summary, the instruments used in this study appear to be strongly correlated with the endogenous regressor. Although the difference in observables between homes with high and low values of the instruments are usually statistically significant, the size of the difference is often small.

4. Empirical Results

Empirical results from fourteen regressions are presented in Table 2. Bootstrapped standard errors are presented in parentheses below the estimated coefficients. There are seven outcomes of interest, and column 1 contains results from

OLS and column 2 contains those from IV models. For each outcome and method of estimation, we report the coefficient on nursing home wages, the t statistic associated with that coefficient, and the elasticity of that outcome with respect to changes in wages.

4.1. OLS Results

We hypothesize that higher wages result in lower staffing, greater use of materials, and a rise in pressure ulcers. The OLS results in column 1 of Table 2 provide some support for these hypotheses. The point estimates indicate that higher wages are associated with fewer NAs and professional staffing. However, only the NA result is statistically significant. A 10 percent increase in nursing home wages is associated with 0.65 percent fewer NAs. Also consistent with our hypotheses, homes facing higher wages tend to have a greater proportion of their residents on physical restraints and a greater proportion of residents with pressure ulcers. The coefficient on feeding tubes is of the expected sign, but not statistically significant.

The coefficients on catheters and psychoactive drugs were not of the expected sign. Two Registered Nurses have pointed out to us that they believe that catheters are a complement, not a substitute, for nurse labor, given the need for nurse time to insert and supervise the catheter. Our results are consistent with their claim; higher nurse wages are associated with a smaller percentage of residents with catheters and the correlation is statistically significant. A 10 percent increase in nursing home wages is associated with 3.4 percent fewer residents with catheters.

Although these results show some support for Zinn's earlier cross-sectional estimates, the mixed results may reflect heterogeneity in factor quality. For example, when average nursing home worker productivity rises in a state, it is likely that nursing home worker wages also rise. To address this problem, we estimate IV models.

4.2 Instrumental Variables Results

The results from the IV models are presented in column 2 of Table 2. In general, the IV estimates provide stronger support for the predictions derived from the model of factor substitution. The coefficients on nursing home worker wages are negative, as predicted, in both the nurse aide and professional nurse regressions. However, while the coefficient is significant in the professional nurse regression, it fails to meet the 10 percent significance level in the NA regression. We find that a 10 percent increase in the wages of nursing home workers is associated with a 3.2 percent decline in professional staffing.

The IV estimates also support the hypothesis that higher wages will lead to increasingly materials-intensive provision of care. For example, a rise in wages of 10 percent is associated with an 8.7 percent rise in the number of residents under physical restraints.[14] The coefficients on wages in the feeding tubes and psychoactive drugs regressions are positive, as predicted, but they are not statistically significant.

The IV results also confirm that higher wages are associated with more pressure ulcers; specifically, a 10 percent increase in the wages of nursing home workers is associated with a 6.5 percent increase in the number of residents with pressure ulcers.

[14] In regressions in which the outcome of interest is a percentage, and the dependent variable has been logit transformed, the elasticity is calculated as: $\varepsilon = (1-\overline{p})\beta\overline{X}$ where $\overline{p}$ is the average outcome of interest in the sample, β is the coefficient on the wage of nursing home workers, and $\overline{X}$ is the average wage of nursing home workers in the sample.

The IV point estimates on nursing home worker wages in the catheter use regression are opposite to our prediction but are consistent with the claim that catheters are complements with nurse time. However, the coefficient is not statistically significant.

In general, the IV point estimates are larger in absolute magnitude than those from OLS. The contrast between the IV and OLS results is consistent with time-varying unobserved heterogeneity in factor quality that is correlated with factor prices. Of course, it does not prove the existence of such unobserved heterogeneity, it is merely consistent with it. Variation in average nursing home worker productivity in a state may be correlated with average nursing home worker wages in a state. For the purposes of this paper, we are agnostic about what causes changes over time in factor quality.

In summary, the IV results support our three hypotheses. The wage coefficient is of the expected sign in six of the seven models and three of the coefficients are statistically significant.

5. Extensions and Robustness Checks

We conducted the following robustness checks of these results. First, because our measures of the cost of materials are nationwide and annual, it is not possible to use indicator variables for year when also controlling for the cost of materials; instead, a time trend is included. In order to test whether our results are due to the failure to include indicator variables for year, we re-estimated our models dropping the cost of materials and adding a set of indicator variables for year. The results were robust.

Second, we were concerned that the mix of payers for nursing home residents may influence the results. In the previous results in this paper, we excluded as regressors the percent of nursing home residents whose stay was paid by Medicare and the percent paid by Medicaid, out of the concern that the labor-materials mix of care was simultaneously determined with payer type. As a robustness check, we re-estimated the models of this paper controlling for the percent of residents in the home whose stay was paid by Medicare, and the percent paid by Medicaid, and found no meaningful changes in the results.

Third, we re-estimated our IV models using as instruments wages from other occupations and sectors, including those related to health (SIC 808: home health care, SIC 806: hospitals, and SIC 801: offices and clinics of doctors of medicine) and sectors unrelated to health (SIC 581: eating and drinking places, and SIC 701: hotels and motels). We found that the results in the Nurse Aide, feeding tube, catheter, and bedsore regressions were remarkably robust to the choice of instrument. For the other outcomes of interest, professional staffing, restraints, and psychoactive drugs, results are generally robust to the choice of wages from health sectors as instruments, but are generally not robust to the choice of wages from a non-health sector as instruments.

Fourth, we experimented with dropping hospital-based nursing homes from our sample. This did not substantially affect our estimates.

6. Conclusion

This paper measures the extent of factor substitution in the nursing home industry by estimating IV models using longitudinal data from 1991-1998 on nearly every nursing home in the United States. We find that a 10 percent increase in nursing home worker wages is associated with a 3.2 percent decrease in professional nurse staffing, an 8.7

percent increase in the percentage of residents who are physically restrained, and a 6.5 percent increase in the percentage of residents who suffer from pressure sores.

The implications of these results extend beyond nursing homes. Buerhaus, Staiger, and Auerbach (2000) document a decline over the past twenty years in the number of younger women entering the nursing profession and predict that unless the trend is reversed the RN workforce will decline nearly 20 percent below projected workforce requirements by 2020. Ceteris paribus, this decrease in the supply of nurses will lead to higher wages. Policymakers should anticipate that health care providers will react to such a rise in nurse wages by substituting away from nurse labor and toward other inputs. If the other input is physician labor, there may be no adverse effects for patients, but if providers substitute towards lower-skilled staff, materials or capital, patients may experience a lower quality of care. A number of studies have already implicated low RN staffing as a source of adverse outcomes, including increased risk of mortality, experienced by medical and surgical patients (see Buerhaus et. al, 2002 for a discussion of this literature).

Given evidence that materials-intensive methods of care are associated with higher morbidity and mortality among residents, policymakers may wish to limit the flexibility of nursing homes to substitute materials for labor. In particular, policymakers may wish to combine minimum staffing standards with indexing of Medicaid payment rates to local labor market conditions so that homes with higher labor costs would receive higher Medicaid payments. Such indexing must be combined with minimum staffing requirements; otherwise homes in high-wage areas could pocket any additional Medicaid payment and continue to choose the factor mix that minimizes total costs.

This research also contributes to the broader economic literature on factor substitution. We offer a framework for addressing the possible endogeneity of wages that future work can extend to the study of factor substitution in other industries. Our findings suggest that empirical studies of factor substitution must consider the possibility of unobserved heterogeneity in factor quality and use methods like instrumental variables to generate consistent estimates of the effect of changing factor prices on the factor mix employed in production.

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Figure 1: Cost-Minimization by Firms in the Short Run

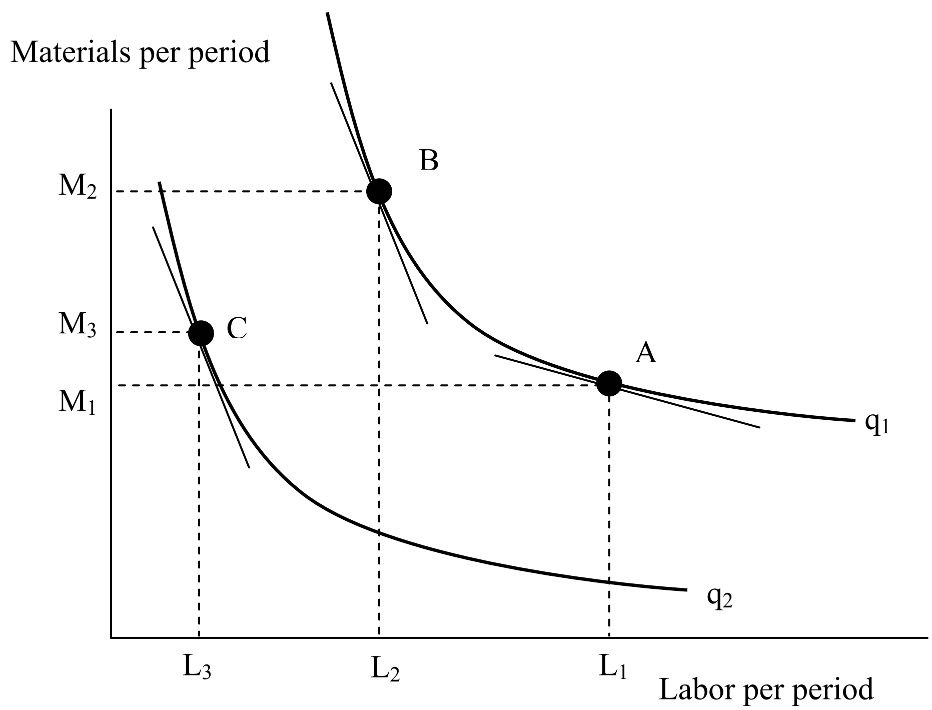

Table 1: Summary Statistics of OSCAR data (N=121,627)

Variable	Mean	S.D.	Min	Max
Nurse Aides Hours per Resident Day	2.15	1.47	0	24
Professional Nurse Hours per Resident Day	1.22	1.22	0	16
% Residents with Catheter	0.083	0.089	0.0001	0.9999
% Residents with Feeding Tube	0.061	0.080	0.0001	0.9999
% Residents with Restraints	0.18	0.16	0.0001	0.9999
% Residents with Psychoactive Drugs	0.38	0.18	0.0001	0.9999
% Residents with Pressure Ulcers	0.072	0.068	0.0001	0.9999
Average Hourly Wage of SIC 805 in State ($1998)	8.19	1.47	5.24	13.48
For-profit	0.67	0.47	0	1
Non-profit	0.27	0.44	0	1
Number of Beds	107.67	78.20	1	9,309
Hospital-Based	0.11	0.31	0	1
Chain	0.51	0.50	0	1
ADL Index	3.81	0.61	0	5
Herfindahl Index	0.21	0.24	0	1
Per Capita Income ($1998)	23,062.55	5,887.44	6,225.60	72,194.00
Elderly (65+) Per Square Mile	137.45	421.99	0.03	7,036.11
Average State Medicaid Payment Rate ($1998)	86.06	20.83	50.53	163.10
Producer Price Index – Pharmaceuticals	269.12	8.41	260.06	290.10
Producer Price Index – Plastics & Rubber	154.70	8.53	139.20	170.06
Effective Minimum Wage ($1998)	4.95	0.25	4.55	6.00
Average Hourly Wage of SIC 53 in State ($1998)	7.57	0.98	5.10	12.26
Year	1994.53	2.26	1991	1998

Table 2: Evidence of Factor Substitution

Nursing Home Wage Coefficients, (standard errors), and elasticities

N=121,627

Dependent Variable	1	2
	Ordinary Least Squares	**Instrumental Variables**
NAs Per Resident Day	-0.0168*	-0.031
	(0.0086)	(0.019)
	ε= -.065	ε= -.118
RNs and LPNs per Resident Day	-0.0046	-0.048***
	(0.0061)	(0.010)
	ε= -.031	ε= -.322
Catheters	-0.0445***	-0.025
	(0.0114)	(0.018)
	ε= -.338	ε= -.188
Feeding Tubes	0.026	0.019
	(0.023)	(0.041)
	ε= .200	ε= .146
Physical Restraints	0.069***	0.135**
	(0.023)	(0.055)
	ε= .463	ε= .873
Psychoactive Drugs	-0.011	0.0040
	(0.012)	(0.0245)
	ε= -.056	ε= .020
Pressure Ulcers	0.059***	0.085***
	(0.012)	(0.021)
	ε= .448	ε= .646

Notes:

1) * = statistically significant at 10% level; ** = statistically significant at the 5% level; *** = statistically significant at the 1% level.

2) Standard errors are bootstrapped, with clustering by state-quarter. From each bootstrapped sample, the regression is estimated with standard errors cluster-corrected at the nursing home level.

3) The other regressors in each regression are: number of beds, Herfindahl Index for the nursing home market, an index of the number of Activities of Daily Living with which residents need assistance, real county per capita income, number of elderly residents in county per square mile, the real state-level Medicaid payment rate, the producer price index for pharmaceuticals, the producer price index for plastics & rubber, year, and indicator variables for whether the nursing home is non-profit, part of a chain, or based in a hospital.

Appendix Table 1: First Stage of IV Estimation
Dependent Variable: Wage of Nursing Home Workers ($1998)

Regressor	**Coefficient and (t Statistic)**
Effective Minimum Wage ($1998)	0.28
	(3.06)
General Merchandise Store Wage ($1998)	0.42
	(18.45)
For-profit	-0.018
	(-0.93)
Non-profit	-0.062
	(-4.43)
Nursing home beds	0.000066
	(1.29)
Hospital-Based	0.033
	(2.09)
Chain	0.020
	(2.17)
Average ADLs	0.011
	(0.87)
Herfindahl Index	-0.25
	(-6.13)
Per capita income ($1998)	0.000021
	(12.56)
Population Age 65+ per square mile	-0.00005
	(-2.92)
Medicaid rate ($1998)	0.052
	(48.63)
Year trend	0.040
	(3.92)
PPI for Pharmaceuticals	0.003
	(0.70)
PPI for Plastics	0.0086
	(2.59)
Constant	-82.78
	(-4.18)
R^2	0.85
ΔR^2 associated with the instruments	0.06
F-statistic of instruments	185.05
Number of observations	121,627

Notes:
1) Regressions are weighted by the total number of residents in each facility.
2) T statistics reflect standard errors Huber-White adjusted for correlation in the error terms within state and quarter.

Appendix Table 2:
Comparison of Observables by Value of Instrument

Variable	Minimum Wage Rate		Manufacturing Wage Rate	
	Below-Average	Above-Average	Below-Average	Above-Average
Nursing Home Wage Rate	8.24	8.64**	7.77	8.99**
Explanatory Variables				
For-profit	0.68	0.67**	0.66	0.69**
Non-profit	0.25	0.26**	0.26	0.25**
Number of Beds	150.73	151.32	142.16	159.23**
Hospital-Based	0.055	0.055	0.055	0.055
Chain	0.50	0.50	0.53	0.48**
ADL Index	3.86	3.76**	3.83	3.82**
Herfindahl Index	0.19	0.18**	0.23	0.14**
Per Capita Income	23,235	24,709**	22,299	25,249**
Elderly per sq mile	221.19	207.72**	116.25	309.17**
State Medicaid Payment Rate	87.93	91.51**	84.45	93.96**
PPI – Pharmaceuticals	268.03	270.55**	268.64	269.40**
PPI – Plastics & Rubber	155.40	153.82**	155.02	154.54**
Outcomes				
Nurse Aides Hours	2.03	2.00**	2.04	2.00**
Professional Nurse Hours	0.97	0.99**	0.98	0.98*
% with Catheter	0.077	0.072**	0.076	0.74**
% with Feeding Tube	0.062	0.062	0.061	0.063**
% with Restraints	0.21	0.16**	0.19	0.19**
% with Psychoactive Drugs	0.37	0.40**	0.38	0.38**
% with Bedsores	0.070	0.067**	0.066	0.072**
Number of observations	72,786	48,841	61,447	60,180

Notes*:*
1) The means are weighted by the total number of residents in each facility.
2) * = Difference in means is statistically significant at 5% level; ** = Difference in means is statistically significant at 1% level