Commute Costs and Labor Supply:
Evidence from a Satellite Campus*

Abstract

Whether, and how much, increased commute costs decrease labor supply is important for transport policy, city growth, and business strategies. Yet empirical estimates are limited and biased downward due to endogenous choices of residences, workplaces, commute modes, and wages. Using the transition of undergraduate teaching from a university's urban to suburban campus we test how labor supply responds to a longer commute. Exogeneity is ensured because few faculty change residences, nearly all use a free shuttle, and we control for wages.

Based on difference-in-difference estimates using individual changes in commute costs, the 1.0 to 1.5-hour (40-kilometer) increase in round-trip commute time reduces annual undergraduate teaching hours by 22 (8.4%) implying an elasticity of work time or income with respect to commute time of -0.044. Consistent with higher per-day commute costs, annual undergraduate teaching days decrease by 18 (21%) and daily undergraduate teaching hours increase by 0.50 (16%). Substitution to alternative work activities is minor: graduate teaching is unaffected and research output decreases. The university accommodated the reduced teaching time primarily by increasing class sizes likely lowering education quality. Larger classes may have increased preparation time outside class but class size increases are only minimally correlated with individual commute costs and do not significantly confound our estimates.

Keywords: commuting; commute costs; labor supply; value of time; satellite campus
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1. Introduction

Because commute costs are variable with respect to work days but fixed within a work day, theoretically a longer commute can either increase or decrease total work time depending on the relative changes in days worked and daily hours (Cogan, 1981; Parry and Bento, 2001).[1] In what direction, and how much, commute costs affect work time is therefore an empirical question. Because controlling for endogeneity and selection bias in estimation are difficult, extant answers are limited and biased downward. Using a unique empirical setting, we estimate the causal effect without selection bias and find a large work time reduction.

A significant labor supply response to commute costs has important ramifications for government policy, city growth, and business strategies.[2] Cost-benefit analyses of transportation infrastructure investments and traffic congestion policies should consider not only the opportunity cost of commute time changes but also the accompanying change in labor supply and therefore output. The negative relationship between congestion and long-run employment growth (Hymel, 2009 and Duranton and Turner 2008), the presence of coordination and knowledge spillovers in cities (Moretti, 2004), and the longer commute times and distances caused by urban sprawl (Glaeser and Kahn, 2001) imply that commute time's influence on labor supply plays a role in city growth. For firms, understanding the causal effect of commute costs on labor supply helps them design policies to attract talent and influence their work time and productivity.

Quantifying the effect of commute costs on labor supply has been difficult because they are endogenous and suitable instruments are scarce.[3] Workers consider commute costs when choosing residences, job locations, and commute modes and firms consider them when choosing wages and locations.[4] Workers with high commute-cost sensitivity are likely to choose residence-job combinations with short commutes while workers with low sensitivity are likely to tolerate those with longer commutes. Failing to correct for endogeneity will understate commute costs' effect on work time. Measuring commute costs is also difficult. Commute costs can include time, monetary costs, and disutility and even time and distance are usually measured imprecisely.[5]

Most extant evidence on this question is either indirect or subject to endogeneity. Gibbons and Machin (2006) state there is no direct empirical evidence of commute time's causal effect on labor supply. The only subsequent papers we know of that deal

[1] Daily work hours could also change as workers adjust their start and end times to avoid congested periods of the day as in "bottleneck" theories examined by Vickrey (1969); Arnott, de Palma, and Lindsey (1990, 1993); and Arnott, Tilman, and Schöb (2005).
[2] Commute time may also influence labor supply through the labor participation rate. We are able to measure only the increase in work time of already-employed workers.
[3] Burchfield, *et al.* (2006) emphasize quantifying the consequences of urban sprawl but note the necessity of using good instruments.
[4] Many papers examine these equilibrium outcomes. Manning (2003) provides empirical evidence on the positive relationship between commute costs and wages. Gin and Sonstelie (1992) examine residential location changes due to commute cost changes. Zax (1991) and Zax and Kain (1996) empirically examine residence and job changes in response to commute cost changes. Van Ommeren and Rietveld (2005) provide a theoretical relationship between commute time and wages in a job-matching model. White (1988) provides a theoretical model of location choice with endogenous residence and work locations.
[5] Examples of monetary commute costs are gasoline, depreciation, and tolls. Disutility includes discomfort from noise, pollution, or effort.

with the endogeneity issue are Gutierrez-i-Puigarnau and van Ommeren (2010a), Mulalic, van Ommeren, and Pilegaard (2014), and Gershenson (2013). The first two use workplace relocations and exclude workers who change residences to maintain exogeneity. While this solves the in-sample endogeneity problem, it understates the out-of-sample effects because workers who change residences have high commute-cost sensitivity. The commute costs measures may also involve error because transport mode is unobserved in the first paper and commute time is self-reported in the second. The effects for the in-sample groups are small: fifteen fewer work minutes per week from an extra 40 kilometers in daily round-trip commute distance in the first paper and an insignificant effect of commute time in the second. Gershenson (2013) uses random daily assignments of substitute teachers to schools to overcome the endogeneity problem and estimates commute time's effect on teachers' daily job acceptance probabilities rather than their work time.

Our causal estimates are based on the addition of a suburban satellite campus to a main urban campus at a typical, well-established Chinese university. For classes taught at the satellite campus, commute time increases exogenously since faculty has a strong financial incentive not to quit their jobs or move their residences to the satellite campus and virtually none do. Moreover, the increased time and distance are known and homogeneous across teachers[6] since virtually all faculty live at or near the main campus and ride a free university shuttle bus. Faculty members also do not quit their jobs due to the increased commute time.[7] Faculty members choose their teaching time freely within an internal labor market and are paid on a piece-rate system subject to a linear wage[8] allowing us to measure the market response of work time.

The transition sequence of undergraduate teaching to the satellite campus allows us to use teacher-level variation to identify the causal effect of commute costs on teaching time. The satellite campus opens in academic year 2004[9] (a "year" will refer to an "academic year" unless otherwise noted) but undergraduate students transition one class level per year until all four levels are taught there in 2007. This incremental transition imposes different levels of commute costs on different teachers in different years depending on their course schedule. Teaching a freshmen course[10] imposes commute costs beginning in the transition's first year, a sophomore course beginning in the second year, a junior course beginning in the third year, and a senior course beginning in the fourth year. This allows a difference-in-differences (DD) analysis comparing work time effects for teachers with differential changes in commute time. This is immune to confounding factors not correlated with individual-level commute time. In particular, university-wide changes such as wages, student body size, faculty size, class size, and teaching load are differenced out. We provide evidence that possible individual-level confounders do not materially affect our estimates – in particular class size. Because the transition sequence was known only shortly before it

[6] For brevity, we will use the terms "teacher" and "teachers" interchangeably with "faculty member" and "faculty" even though our sample includes faculty who both teach and research.

[7] We found no evidence of faculty quitting due to the increased commute. Leaving is costly – tenure-track faculty would have to break a three-year contract with huge financial penalties if untenured or give up secure employment if tenured – and faculty could relocate to subsidized housing at the satellite campus once it opened in 2010.

[8] We discuss later the possibility of administrators intervening in the market and applying non-wage pressures.

[9] As in U.S. universities, academic year t spans fall semester of calendar year t to spring semester of calendar year $t + 1$.

[10] When we use the term "course," we allow for the possibility of multiple sections. We therefore use the term "class" to refer to a course with a single section or one section of a course with multiple sections.

began faculty could only avoid these commute costs through very costly efforts of developing new courses.

The 1.0 to 1.5 hour increase in commute time per teaching day reduces annual undergraduate teaching time by 21.9 "class hours" (a "class hour" is the amount of time a faculty member spends in the classroom to receive one "hour" of pay) per teacher after the full transition or 8.4% of the pre-transition average of 260.0 "class hours." The elasticity of work time with respect to commute time is -0.044 and teachers value commute time at 18 to 27% of their hourly wage. Since wages are linear the elasticity of income with respect to commute time is also -0.044. Commute costs vary with days worked but are fixed with respect to daily hours conditional on working that day. Consistent with this, we find that the full transition reduces a teacher's annual undergraduate teaching days by 18 and increases daily undergraduate "class hours" by 0.50. This means confounding factors are even less likely. They must decrease days worked but increase daily hours and operate at the individual faculty level – affecting those with longer commute times by more than those with shorter.

Faculty may substitute to other work activities to offset their reduced undergraduate teaching time. Possibilities include graduate teaching, research, and consulting. Since the location of these is unaffected, they become relatively more attractive once undergraduate teaching transitions. However, time spent on these activities might decrease if increased time and fatigue from commuting crowds them out. The effect on graduate teaching is insignificant. Research output falls with the number of academic research papers published in top journals decreasing significantly. We are unable to observe consulting time but the drop in undergraduate teaching time for assistant professors, who rarely consult, is similar to the effect for more senior faculty. Unless research productivity fell dramatically, time diverted to other work activities is minimal and the total decrease in work time approximately equals the decreased undergraduate teaching time.

Since we do not observe preparation time outside the classroom we cannot quantify the effect on work time inclusive of it.[11] If preparation time per "class hour" remained unchanged after the transition then our estimates understate the decrease in total work time by the ratio of preparation time to in-class plus preparation time. If preparation time changed because of the transition then we need to worry whether this confounds our estimates. In particular, since the university accommodated the decreased teaching time primarily by increasing class sizes, preparation time outside class may have increased causing faculty to further reduce their "class hours." However, if increased preparation time is uncorrelated with individual changes in commute time then the DD estimates are unbiased. Class size increases are correlated with commute time changes at the individual level but the magnitude is small. Thus, our estimates will difference out most of the effect of class size increases on preparation time.

As we examine a specific type of worker, university professors, how well might our results extend to other types of workers? Equilibrium commute times and distances generally increase with education (Groot, de Groot, and Veneri, 2012) suggesting that our estimates may understate the effects more generally. On the other hand, for

[11] This problem is faced by any study of work time since unofficial work is unobserved as is sharing of household chores and paid work within the household (Knowles, 2013).

workers that have less flexibility on the intensive margin of labor supply, our estimates may overstate the effects. However, a nontrivial fraction of workers have significant discretion over their work time and this fraction is expected to increase.[12] The proportion of "knowledge workers," who generally have flexible schedules, is projected to increase over time (Moretti, 2012) and smartphone applications are allowing increasing numbers of people to work flexibly.[13] At least 19% of employed urban workers in China have some amount of flexibility over their work time.[14]

Russo, van Ommeren, and Rietveld (2012) offer some evidence to determine which of these opposing effects, education or flexibility, dominates. They estimate a long-run marginal willingness to pay (WTP) to avoid commuting for faculty at a Dutch university and find it equals approximately 35% of their wage.[15] This is somewhat lower than the 50% midpoint estimate for workers more broadly (Gibbons and Machin, 2006) which suggests that our estimates underestimate the effects for other types of workers.

The next two sections provide institutional and theoretical background for our estimates. We then provide the econometric model, data, sensitivity analysis and results before concluding.

2. Institutional Details

We examine commute costs created from transitioning the location of undergraduate teaching at a well-established Chinese university.[16] The university is a research institution serving both undergraduate and graduate students and is a highly-ranked specialized (in particular academic disciplines) rather than general university. Capacity-constrained and faced with acquiring very expensive land adjacent to the original campus in the city center, the university decided to add a satellite campus 20 kilometers away in a suburban area.

Planning began in calendar year 2000 with a search for land and the university signed a contract with the city government to buy a parcel the next calendar year. Bidding for the campus design was held in calendar year 2002 and later that year a national newspaper announced that incoming freshman would live and be taught at the satellite campus beginning in 2003, later postponed to 2004. The timing of this announcement is critical because it means that prior to late 2002 faculty was aware that a campus was being built but unaware of the transition timing. This is after academic year 2002 had begun and teaching schedules had been finalized for that year. Therefore, any

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[12] "Millennials at Work: Reshaping the Workplace," (PwC, 2011) estimates that 32% of millennials expect to have mainly flexible working hours in the future.
[13] "There's an App for That," *The Economist*, January 3, 2015. According to a survey of 5,000 working Americans 34% engage in some form of freelancing ("Freelancing in America: A National Survey of the New Workforce," Elance-oDesk, 2014).
[14] Based on the 2005 *China Inter-Census Population Survey*. The survey classifies urban workers into one of four categories (hired, employer, self-employed, and family business). We classify the first category as lacking flexibility and the last three as having flexibility.
[15] The paper estimates a WTP based on job quits of €9.8 for the whole sample which includes all university workers and a WTP of €11.7 for non-faculty. Non-faculty workers represent 74% of the sample implying a WTP of €4.5 (35% of the average wage) for the faculty subsample. The paper cannot directly estimate a WTP for the faculty subsample because the effect of wage on job quits is not precisely estimated for the subsample.
[16] For confidentiality reasons we cannot identify the university nor can we provide references for the background information on the campus opening all of which were obtained from local newspapers.

faculty efforts to change their teaching schedule away from teaching freshman classes (to delay commuting) began in academic year 2003 at the earliest.

The school held a groundbreaking ceremony in early calendar year 2003 and in academic year 2004 the entering freshmen lived and took courses at the satellite campus while higher class levels remained at the main campus. In 2005, the entering class again lived and took courses at the satellite campus so that freshman and sophomores took courses at the satellite campus while juniors and seniors remained at the main campus. In 2006 only seniors remained at the main campus while the other class levels lived and took courses at the satellite campus. From 2007 onward all four class levels lived and took courses at the satellite campus. Our data spans the years 2000 to 2009. This provides four years before the transition and three years in which all four undergraduate class levels took courses at the satellite campus.

Graduate courses remained at the main campus during the undergraduate transition. Entering Master's students began taking courses at the satellite campus in 2008. Since they generally study for two years, one-half of them were at the satellite campus in 2008 and all of them were at the satellite campus in 2009.[17] Entering Ph.D. students began taking courses at the satellite campus in 2009. Since most Ph.D. students study for three years, approximately one-third took courses at the satellite campus in 2009. After the end of our sample period, Ph.D. students finished transitioning to the satellite campus and executive MBA, professional education, continuing education, some business classes, some research institutes, and some offices remained at the main campus.

Almost all teachers resided at or near the main campus during the sample period because the university continued to provide subsidized housing in residential neighborhoods adjacent to the main campus and did not complete construction of similar subsidized housing at the satellite campus until after 2010.[18] The university provided a convenient shuttle bus between the two campuses by which virtually all faculty commuted. The shuttle was free so we estimate the effect of increased commute time but not monetary costs. The shuttle trip takes about 30 minutes one way plus up to 15 minutes of walking and waiting on each end. Since the time required depends on random variation in weather, traffic, and wait times, we assume that commute time increased 1.0 to 1.5 hours round-trip per commute day (a "teaching day" refers to a day on which a faculty member teaches at least one class regardless of location while a "commute day" refers to a "teaching day" at the satellite campus).

Our primary data consists of the university's complete undergraduate class schedule from 2000 to 2009. For each class we know its course title, academic semester, teacher, class level (freshman, sophomore, junior, senior, other), number of students (class size), day and time of meeting, weekly "class hours," and number of weeks. We can identify class level because in China most undergraduate courses are taught to a

[17] Most Master's programs in China take three years but some universities have two-year programs.
[18] The provision of faculty housing on or near the university campus is a common practice among Chinese public universities and most Chinese universities are public. Limited faculty offices and overnight apartments were available at the satellite campus and might limit the teaching time decline resulting from the longer commute.

single class level. This is important since it allows us to determine which classes were taught at which campus during the transition.[19]

Our primary measure of labor supply is a "class hour" (50 minutes at the main campus and 45 minutes at the satellite campus). We do not observe time spent outside of class preparing, grading, and responding to students. If outside time remains the same per "class hour" after versus before the transition, our estimates can be scaled up by the appropriate multiplier to obtain total hours from "class hours" and our estimates are not biased. If preparation time increased because of the transition (e.g., due to the accompanying increase in class sizes) our estimates would be biased. We present evidence when we discuss our results that changes in class size are largely orthogonal to changes in individual commute time so that bias in our DD estimates is minimal.

Teachers allocate their time among five major activities: undergraduate teaching, graduate teaching, research, consulting, and leisure. A teacher's total annual compensation can be represented as $F + B(T^R) + w^U T^U + w^G T^G$. F is a fixed payment based on seniority, position, and administrative duties and is primarily based on a nationwide standard. B is an annual bonus paid for research publications where T^R is time spent on research and we assume that there are diminishing or constant returns to research ($B(0) = 0$, $B' > 0$ and $B'' \leq 0$). Research also provides non-pecuniary benefits such as prestige, personal satisfaction, and future career advancement and we can think of B as including these effects as well.[20] The last two components are the linear payments for teaching where w^U and w^G are "hourly" wages for undergraduate and graduate teaching and T^U and T^G are annual "class hours" taught for each. The "hourly" undergraduate wage increased over time: RMB 20 in 2001 and 2002, RMB 40 in 2003 and 2004, RMB 60 from 2005 to 2007, and RMB 90 from 2008 onward.[21] Domestic faculty were compensated for a graduate "class hour" at 1.5 times the rate for undergraduate "class hours" and those with a foreign Ph.D. (from a non-mainland China university) were compensated at the same rate for both. F, B, w^U, and w^G are otherwise common to all faculty and do not change within academic years.

The minimum annual teaching load was 240 "class hours" from 2001 to 2004 and 225 hours from 2005 onward.[22] Teachers are paid for "class hours" both used to satisfy their teaching load and those above. Teachers may fulfill this minimum through other

[19] Three categories of courses are offered to all class levels – "sports," "university," and "double degree" courses – which we call "other." "Sports" courses teach athletics and "university" courses relate to culture or personal development. Courses are usually taught only to students within a major (corresponding to a university department) and only to a single class level. The exceptions to this, "double-degree" courses, are offered to students outside of the major and can be taken by any class level.

[20] Faculty with a foreign Ph.D. and domestic faculty hired since 2006 have three-year contracts. All other domestic faculty has permanent contracts. Regardless of contract length, research output affects promotion from an assistant to an associate or from an associate to full professor.

[21] We do not believe that faculty anticipates wage changes because they are determined by human resources or a university-level committee and only then announced to faculty members. Therefore, they will not change their teaching schedules dynamically in anticipation of wage changes.

[22] This is for department-specific courses. For "university-wide" and "sports" courses the minimum was 320 "class hours" per year from 2001 to 2004 and 300 from 2005 onward. These courses are taught primarily by faculty in the English, sports, and math departments. For the few teachers with a foreign Ph.D. the minimum was 160 "class hours" per year. The university did not allow faculty to carry-forward or carry-back teaching credits and examined faculty workload year-by-year. The financial penalties for not meeting the teaching load were severe.

activities (and get paid for them) that we do not observe. These include supervising graduate theses, administrative tasks, and supervising student internships and study trips.[23] Therefore, many faculty have fewer "class hours" than the minimum. Although we do not observe these activities we show that our results are robust to them.

Unlike at many American universities in which department heads or deans have more control, faculty at most Chinese universities including the one we study have great discretion in choosing their teaching time. Subject to the wage, a teacher chooses teaching hours to maximize their utility. The process is the following. Each faculty member submits their chosen courses to the department staff which figures out course scheduling. The schedule is submitted to a university-wide administrative office that assigns classrooms. At this university faculty could also choose their teaching time in fine increments for three reasons. First, course credits range from one to six. A course credit corresponds to one "class hour" per week over a 16-week semester. Thus, courses allow annual teaching time to be chosen in increments as small as 16 "class hours." Second, co-teaching arrangements further reduce this increment. Co-teaching with one person allows annual teaching time to be chosen in increments of eight "class hours" and co-teaching with more than one faculty member is allowed and common. Third, seminar-style classes, which meet once, allow faculty members to receive teaching credit in increments as small as two "class hours."

Figure 1 illustrates this flexibility. It shows the distribution of annual undergraduate "class hours" across all faculty members from 2000 to 2009. Although the distribution exhibits spikes at some multiples of course credits, it exhibits significant dispersion. Given faculty's flexibility to adjust their "class hours," how could the university accommodate a decrease in teacher "class hours" while still providing sufficient student "class hours"[24] for graduation and distribution requirements? The university could adjust along two dimensions: class sizes and faculty size. We provide rough numbers on the adjustment after we discuss our results. The figure also shows many faculty with fewer "class hours" than the minimum. This is consistent with it not binding due to availability of substitute activities. We return to this issue in our results.

Faculty members also had significant flexibility in allocating their "class hours" across days of the week. Classes of three credits or less met once per week and a faculty member could choose the day of the week. Longer classes met twice per week (e.g., a four-credit course meets twice per week for two "class hours" each day) and the faculty member could choose any two non-contiguous days. There was an overall constraint of not scheduling too many courses for a particular class level on the same day which might require "horse-trading" of days among colleagues.[25]

Faculty size, student enrollment, graduation requirements, and class sizes could affect university-level teaching demand. However, contractually the university could only

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[23] The activities available for meeting the minimum teaching load vary by rank. For example, only associate and full professors can supervise Masters' theses and only full professors can supervise Ph.D. theses. We check the robustness of our results to this by including faculty rank controls in some specifications.

[24] One teacher "class hour" yields x student "class hours" where x is the class size being taught. Throughout the paper a "class hour" refers to a teacher "class hour" unless otherwise qualified.

[25] To the extent that this constraint was binding during the transition years it was due to avoiding scheduling conflicts for students – the satellite campus was well below capacity without all class levels present.

require teachers to fulfill their minimum teaching load. Above this, the university could influence demand in the internal labor market only through the wage it offered. Department heads may attempt to pressure faculty to teach more or less. Pressure applied to all teachers will be differenced out in our DD estimates. Individualized pressure would bias our results away from zero only if department heads systematically exerted more pressure on faculty facing longer commute costs to teach less. The opposite seems more likely. If a faculty member facing a commute to teach freshman at the satellite campus were convinced to teach less the department head would have to then convince another teacher unfamiliar with the course to commute and teach it.

3. Theoretical Background

We model the effect of increased commute time on daily "class hours," annual teaching days, and annual "class hours." For manageability, we first consider a model with no graduate teaching or research ($T^G = T^R = 0$) so that all work time is subject to commute costs and all teaching days are commute days. We reintroduce these in an alternative model in Appendix B. Because additional commute time increases fixed costs per teaching day, faculty will concentrate more "class hours" per day in fewer annual teaching days. Total teaching time could increase or decrease. We show this using a modified version of the model in Gutierrez-i-Puigarnau and van Ommeren (2009). They generalize a labor supply model with commute costs to allow for the choice of days worked and daily hours. We adapt their model to our setting in two main ways. Their model allows for a concave wage function due to declining marginal productivity. We instead use a linear wage function and assume that a convex effort cost diminishes the value of leisure. We also exclude monetary commute costs consistent with the university's free shuttle service. The two models' implications are qualitatively similar.

A teacher's annual utility is $v = V(C, L)$ where C is annual consumption, L is annual leisure time, and V is differentiable with $V_L > 0, V_C > 0, V_{LL} < 0, V_{CC} < 0$, and $V_{CL} > 0$. Without graduate teaching and research, annual compensation is $F + w^U DH$ where annual undergraduate "class hours" (T^U) is decomposed into annual days (D) and daily "class hours" (H). A teacher's annual budget constraint is $C = Y + F + w^U DH$ where Y is annual non-labor income. Annual time is divided between undergraduate teaching and leisure and each teaching day requires round-trip commute time of t.[26] Daily "class hours" require effort that decreases utility from daily leisure by $e(H)$ with $e'(H) > 0$ and $e''(H) > 0$ denominated in leisure hours. The disutility can be interpreted as diminishing the quality of each leisure hour or additional time spent resting to recover from the fatigue of commuting. Although we have stated annual teaching days, daily "class hours," and annual "class hours" in terms of in-class time, it is simple to allow for exogenous fixed preparation time outside the classroom. If total work hours per "class hour" is $H' = \rho H$ with $\rho > 1$, we can redefine the effective hourly wage as $w^{U'} = w^U/\rho$ and all the results go through.

[26] As discussed earlier, teachers may have other work obligations besides teaching such as consulting. Time spent on these is subsumed into leisure and income from these is subsumed in Y. Our model assumes an equal number of "class hours" across teaching days. In our data they are unevenly distributed but this does not qualitatively change the model's implications.

A teacher's annual time constraint is $\bar{T} = L + D\big(H + t + e(H)\big)$ where $\bar{T}$ is total annual hours. Substituting the budget and time constraints:[27]

(1) $v = V\left(Y + F + w^U DH, \bar{T} - D\big(H + t + e(H)\big)\right)$.

The two first-order conditions are

(2) $F_H \equiv \partial v/\partial H = V_C w^U D - V_L D\big(1 + e'(H)\big) = 0$, and
(3) $F_D \equiv \partial v/\partial D = V_C w^U H - V_L\big(H + t + e(H)\big) = 0$.

Equation (2) says that the marginal utility of consumption from an extra daily "class hour" equals the foregone marginal utility of daily leisure including the effect of fatigue. Equation (3) says the same from working an extra teaching day during the year. Combining these two, the optimally chosen daily "class hours" fulfills

(4) $e'(H) = \frac{t+e(H)}{H}$.

The teacher equates the marginal disutility of effort to the average daily disutility of working (including commute time and effort). The teacher smoothes daily "class hours" across days to avoid escalating the costs from working very long days (e.g., it is better to have two ten-hour days than one 24-hour day).[28] If we totally differentiate Equation (4) letting daily "class hours" adjust to a change in commute time, it follows that an increase in daily commute time increases daily "class hours"

(5) $\frac{dH}{dt} = \frac{1}{e"(H)H} > 0$.

Given a longer daily commute, teachers work more "class hours" once at the satellite campus so as to avoid additional trips on other days. In Appendix A we show that increased commute time decreases annual teaching days. Teachers concentrate their teaching in fewer days to avoid the extra commute time incurred each teaching day. Thus, increased commute time increases daily "class hours" but decreases annual teaching days. In Appendix A we also show that increased commute time could increase or decrease annual "class hours" (DH). Which happens depends in particular on the curvature of the effort costs. If effort costs do not increase too rapidly with daily "class hours" then increased commute time may increase annual "class hours."

In Appendix B we modify the model to consider two work activities – one affected by commute time (undergraduate teaching) and the other not. The other activity could either be paid according to a wage linear in hours worked (as with graduate teaching) or increase a teacher's annual bonus according to a weakly concave function of hours worked (as with research). To simplify the analysis we collapse the separate choices of annual teaching days and daily "class hours" into a single choice of annual "class hours" for each activity. The model shows that time spent on the other activity could

[27] The problem should also include constraints on the maximum number of daily "class hours" and for the minimum teaching load. For simplicity, we assume an interior solution.
[28] Consistent with this, Connolly (2008) finds that male workers increase their work time on rainy days and decrease it the following day to equalize the marginal utility of leisure across days.

increase or decrease with commute time when undergraduate teaching time decreases. Faculty may substitute toward these activities since they do not require commuting; however, increased commute time may crowd them out.

4. Data

Our primary sample is the university's complete undergraduate course schedule provided by the university's Undergraduate Education Administrative Office. We supplement this data with rank, gender, and Ph.D. source for each teacher from the university's website. A teacher is included in this sample as long as they taught at least one undergraduate course. If a teacher taught only graduate level courses or no classes at all they are not included.[29]

For each class, we use weekly "class hours" and number of weeks taught to compute total "class hours." For co-taught classes, we divide total "class hours" by the number of co-teachers to obtain total "class hours" for each teacher. We then aggregate across all classes for a teacher in a year to obtain annual "class hours" for each teacher-year observation. To determine the number of teaching days for each teacher we use the days of week for each class they teach to identify all the dates on which their classes are taught during the semester.[30] We then identify any overlap in these dates to obtain unique teaching dates for each semester. Aggregating across the two semesters, we obtain annual teaching days for each teacher-year observation. Finally, we compute daily "class hours" (conditional on teaching that day) for each teacher-year observation by dividing annual "class hours" by annual teaching days.

A second sample consists of graduate course information. Since we were unable to obtain complete graduate course data from the university's administration, we downloaded it from its graduate school website. As a result, we do not observe day and time of meeting or class size but we do observe course title, academic semester, teacher, weekly "class hours" and number of weeks. A teacher is included in this sample if they taught at least one graduate course. Teachers who taught only undergraduate courses or no classes at all are not in this sample.

A third sample consists of data on faculty research output from the university's Research Support Office website. We observe author's name, journal name, and publication date. Because it is important in both determining faculty salaries and promotions and establishing the university's reputation, we believe the data is accurate and comprehensive. During our sample period, China's Ministry of Education attributes research output only to the first author's affiliation. The university applied this same criterion in evaluating faculty so we count a paper only

[29] We drop class-year observations taught by faculty appearing in only one year that would be dropped with teacher fixed effects and those missing a teacher name. We also drop those taught by teachers under short-term contracts who are not permanent staff including visiting, retired, rehired (after retirement), and adjunct faculty. The number of observations for faculty rank information is slightly lower because we were unable to collect this information for some faculty.

[30] For co-taught courses we assign each teaching day to all teachers of the course. Although we would ideally allocate them proportional to the number of co-teachers this is impossible because these courses often meet multiple times per week and we do not observe which teacher teaches on which day. This makes it impossible to determine the overlap with each co-teacher's other courses. Since we are unable to allocate them we make the conservative assumption to overstate teaching days and therefore commute days.

toward the first author. We designate papers as appearing in either "top" or "non-top" journals[31] and compute annual publications per teacher.

Table 1 summarizes how various undergraduate teaching variables evolve over time. The aggregate teacher "class hours" data in Column 7 hint at the effect that our formal tests reveal. Prior to the transition, "class hours" increase each year. They drop significantly in 2004 when the transition begins and remain low. Comparing Columns 1 and 2 shows that class-level-specific courses comprise a large and stable fraction of all classes over the sample period until 2009.[32] Table 1 also hints at how the university responded to the decreased teaching time: by increasing the average number of students per class (Column 10).

5. Identification Strategy

Our identification strategy is similar to Duflo (2001) who implements DD estimation in which treatment intensity varies by geographic region. In our case, treatment intensity varies across faculty and increases differentially for faculty as the campus transition progresses. We take advantage of individual commute-cost variation by using the fact that class levels transition one at a time each year to the satellite campus. Work time should be disproportionately affected for those who teach class levels that have transitioned relative to those who teach levels that have not. We assume that a teacher's exposure to commute costs during the transition period is proportional to the commute days a teacher would incur based on their teaching schedule in 2003 – just prior to the transition. We call this the expected commute days for teacher i in year t (CD_{it}) and calculate it as the annual number of days a teacher would commute during and after the transition if their 2003 schedule had persisted. For our DD estimation we exclude "other" courses in our calculation of expected commute days because we cannot infer their location but include them in calculating work time. This will understate expected commute days and bias against finding an effect.[33]

To illustrate, consider a teacher who taught sixteen weeks in 2003 and taught a freshman and a junior class on Monday, a freshman and a sophomore class on Tuesday, no classes on Wednesday, two senior classes on Thursday, and a sophomore and a junior class on Friday. Prior to 2004 expected commute days is zero. In 2004, when freshmen transition to the satellite campus, expected commute days equals the number of unique dates that a teacher taught freshman classes in 2003: 32 in this example (two commute days weekly for 16 weeks). In 2005, when freshmen and sophomores are taught at the satellite campus, it equals the number of unique dates that a teacher taught freshman or sophomore classes or both in 2003. In this example it would equal 48 (three commute days weekly for 16 weeks). Expected commute

[31] The Research Support Office ranks Chinese journals as "A1," "A2," "B1," "B2", or "C" and English journals as "A," "B," or "C." "A1" and "A2" Chinese journals are the top general interest and field journals in China. English "A" journals are top general interest journals and "B" are top field journals. Since publishing papers in English is difficult, we designate Chinese "A1" and "A2" and English "A" and "B" journals as "top." All other journals we designate as "non-top."

[32] The drop in 2009 occurs because the university re-classified some courses that were department-specific and offered separately to the four class levels as university-wide courses taught to the four class levels collectively.

[33] This could also bias our results if "other" courses were primarily taught by teachers with low or high commute-cost sensitivity and also primarily located at either the main or satellite campus. We have no means to check for this possibility. It is unnecessary to allocate "other" courses to a class level for before-after estimation because all undergraduate courses were taught at the main campus before and all at the satellite campus after the transition.

days in 2006 equals the number of unique dates that a teacher taught freshman, sophomore, or junior classes or some combination. In the example, it would remain 48 because there are no dates on which junior classes are taught that freshman or sophomore classes are not. In 2007 and after, expected commute days equals unique dates on which any class level or some combination is taught: 64 in this example (four days weekly for 16 weeks).

We believe that a teacher's 2003 schedule provides the best available measure of commute costs. It is necessary to use a measure from the pre-treatment period to avoid conflating the treatment and causal effects: once the transition begins teachers alter their schedules to avoid teaching classes that impose more commuting.[34] We also want as current a measure as possible because teachers' schedules may change over time for random reasons such as changes in student or teacher interests. This will not bias the estimates but it will lower their precision. This suggests using the last year before the transition. For the same reason our main results use only the pre-transition and transition periods (2000 to 2007); however, we show that our results are robust to also including the post-transition period (2008 and 2009).[35]

Since the transition sequence was announced in late 2002 there was a brief window in which faculty could attempt to shift away from teaching freshman and sophomore courses which would transition first. If this occurs, this would be reflected in their 2003 teaching schedule and the causal effect would be biased toward zero. This behavior is endogenous because it affects the treatment intensity. It is separate from teachers attempting to consolidate their teaching into fewer teaching days once the transition begins – the causal effect we estimate. Such avoidance behavior is costly as it requires incurring fixed costs to develop a new junior or senior course. If such avoidance behavior is significant, a teacher's freshman and sophomore "class hours" should decline in 2003 relative to 2002. On average, across 452 faculty teaching undergraduates in both 2002 and 2003, their fraction of freshman "class hours" dropped by only 2.2% in 2003 and is insignificant (standard error of 1.9%).[36] The fraction of sophomore "class hours" actually increased by 2.0% although not significantly (standard error of 1.9%). This is consistent with little avoidance behavior occurring in 2003.

Table 2 contains descriptive statistics for our three samples. We focus on 2000 to 2007 data since this is used in most of our estimates. Panel A shows data for the 513 faculty teaching undergraduates in 2003 (necessary to calculate expected commute days) and at least one year after 2003 (necessary to aid in identification). An observation is a teacher-year.[37] Expected commute days increase from an average of

[34] This includes both not teaching courses that require commuting and consolidating classes in fewer teaching days to reduce the number of commute days. A similar issue arises in the environmental literature. In estimating the causal effect of pollution on health outcomes it is important to control for the fact that people will avoid the impact of pollution by, for example, spending less time outside or wearing protective masks (Zivin and Neidell, 2013).
[35] Post-transition estimates are also affected by the transition of graduate and Ph.D. students to the satellite campus as well as the re-classification in 2009 of other courses shown in Table 1.
[36] This is not a tautology: annual "class hours" per teacher ("class hours" summed across all courses taught by a teacher) can change on average across all teachers even as total student "class hours" across all students stays the same as the university changes class sizes or number of faculty.
[37] Day and time is available for classes meeting on weekends only beginning with the second semester of 2005. Before this, we have no way of determining whether a missing value is due to the class being taught on a weekend or some other reason. To be conservative, we include weekend days taught as a teaching day after second semester

24.6 in 2004 to 75.4 in 2007 with the smallest increase in 2007 due to fewer senior courses being taught. Panel B summarizes the data for graduate teaching for the 275 faculty who taught undergraduate students in 2003 (necessary to compute expected commute days) and taught undergraduate (necessary to identify the teacher fixed effects) and graduate students in at least one year from 2004 to 2007. Expected commute days are lower for this group given their graduate teaching requirements. Panel C summarizes the research output data which spans 2001 to 2008 because we lag teaching measures in our research estimation. This includes the 521 teachers who taught undergraduates in 2002 and in at least one year from 2003 to 2007 (necessary to identify the teacher fixed effects).

The idea of our identification strategy is illustrated in Table 3. The top panel shows means of annual "class hours" before versus during the campus transition for high versus low commute cost groups based on their 2003 teaching schedule. The high-cost group – those in the top decile of annual freshman teaching days – faces greater commute costs than those in the low-cost group – those in the top decile of annual senior teaching days. The high-cost group teaches more overall, both before and during the transition, than the low-cost group. Both groups decrease their teaching during the transition although only significantly so for the high-cost group. The difference of these differences is the causal effect assuming that in the absence of the transition the groups' work times would not significantly differ. The transition decreased work time by 16.7 "class hours" annually and the effect is very significant. The middle panel shows the same estimate for annual teaching days and implies a significant decrease of 18.2 days while the bottom panel shows a significant increase in daily "class hours" of 0.72.

6. Econometric Model

We generalize this identification approach in a regression model of teacher i's work time in academic year t:

(6) $Y_{it} = \alpha_i + \delta_t + \beta Tr_t * CD_{it} + X_{it} + \varepsilon_{it}$,

where Y_{it} is one of three measures of work time (annual "class hours," annual teaching days, and daily "class hours"), α_i is a teacher fixed effect, δ_t is a year fixed effect, and Tr_t is a dummy variable set to one after the transition begins in 2004 (the treatment effect) and zero before. Expected commute days (CD_{it}) captures the treatment intensity for faculty member i in year t and equals the expected number of days teacher i would have to commute to the satellite campus based on their 2003 academic-year schedule. We control for teacher-year characteristics X_{it} such as rank. β captures the effect of an additional commute day on work time.

Appendix C shows that Equation (6) is consistent with a model allowing for heterogeneous commute costs across teachers as long as these costs are independent of the individual's treatment intensity and the error structure allows for general heteroskedasticity and clustering within teacher-transition cell (pre- versus post-transition). We therefore allow for this.

2005 but drop missing values both prior to and after this. This will understate teaching days prior to 2006 and bias us against finding a decrease in annual teaching days due to the transition.

Our DD estimates compare the responses during the transition of teachers with varying levels of expected commute days. A teacher's expected commute days, based on their pre-transition teaching schedule, determines the intensity of their treatment effect. Identification of the treatment effect requires that conditional on the control variables in Equation (6) the treatment effect is uncorrelated with the error. Bias will be introduced if confounding factors not controlled for in the regression are correlated with teacher-specific expected commute days.

The academic year fixed effects (δ_t) in Equation (6) capture year-specific unobserved factors affecting work time. These include university-level changes in wages, student enrollment, faculty size, class size, curriculum, graduation course requirements, and national education policies since these are constant within an academic year as well as any aggregate trends in work time common to all faculty.[38] The teacher fixed effects (α_i) in Equation (6) absorb unobserved teacher-specific work-time preferences that are invariant across years such as the value of leisure time. Time-varying, teacher-specific changes could bias the estimates if correlated with individual expected commute days. For example, individual-level changes in returns to outside activities such as consulting would bias the estimates if they were correlated with individual expected commute days. In particular, a key identifying assumption of Equation (6) is that work time trends would be identical for the control and treatment groups absent the treatment (Angrist and Pischke, 2009).

Table 4 provides evidence that this "common trends" assumption holds. It compares the pre-treatment (2000 to 2003) trend in annual "class hours" for those in the top and bottom deciles of freshman teaching in 2003 based on two different measures: annual "class hours" and annual teaching days. Under either measure the results are similar. Annual "class hours" follow a significant trend prior to the transition using either a linear or quadratic trend. However, the trend is not significantly different for the top and bottom deciles. In our results we also show that estimates for Equation (6) are robust to controlling for teacher-specific time trends rather than year dummies.

As a further test of the "common trends" assumption, Imbens and Lemieux (2008) suggest implementing a placebo test on both sides of the policy change using the midpoint as the start of an artificial policy change. We can only implement this in the pre-treatment period. During the transition the policy is gradually implemented and there are only three years of data post-transition (2007 through 2009). We therefore implement a partial falsification test using the years 2000 through 2003 and assume the policy begins in 2002 so that the freshman transition in 2002 and sophomores in 2003. This provides two years pre-treatment and two years post-treatment for the placebo test. Table 5 displays the results defining the expected commute days placebo based on a teacher's 2001 teaching schedule. The artificial policy does not have a significant effect on any of the three work time measures consistent with an absence of pre-existing trends that would bias the estimates.

[38] Online courses were not used by the university and teaching support and research fund guidelines did not change over time.

7. Results

Annual Undergraduate "Class Hours": The left panel of Table 6 shows the results of DD estimates using Equation (6) with annual undergraduate "class hours" as the dependent variable. These estimates are based on an unbalanced panel that includes any faculty present in 2003 and in at least one year of the transition. This relates individual-level changes in teaching time to individual-level changes in commute time during the transition years. Column 1 includes teacher and year fixed effects. This is our preferred specification and it shows that an increase of one additional expected commute day decreases annual "class hours" by 0.27 at a very high level of significance. Since faculty taught an average of 82.3 days annually prior to the transition this implies a decrease of 21.9 annual "class hours" from the full transition – 8.4% of the average pre-transition of 260.0 annual "class hours." This implies an elasticity of -0.044 for work time with respect to commute time or distance.[39] Since wages are linear the elasticity of income with respect to commute time is the same. Gutierrez-i-Puigarnau and van Ommeren (2010a) estimate an elasticity of -0.009 for work time with respect to commute distance, consistent with their excluding workers with high commute-cost sensitivity, the workers in our sample having more flexibility over work time, or both.

In unreported results we estimate the baseline model but include the post transition years of 2008 and 2009. This potentially adds more noise because it is further in time from the 2003 data used to proxy for commute costs; nonetheless, the estimates are very similar to the baseline results (a significant decrease of 21.3 "class hours"). Column 2 of Table 6 allows for a piecewise linear effect of commute costs. It uses dummy variables to indicate each quintile of expected commute days and weights each by the average expected commute days within the quintile so that the coefficients represent the marginal effect of an additional expected commute day regardless of quintile. The coefficients are jointly significant at the 2% level and, with the exception of the third quintile, yield estimates (-0.16 to -0.40) that bracket our baseline estimate (-0.27). Column 3 introduces teacher-specific time trends $(\alpha_i t)$ that relax the parallel slopes assumption. This also allows for the possibility that an individual teacher's desire to work may change over time due to promotions, changes in research productivity, changing financial conditions, or changes in the attractiveness of outside options. The point estimate is greater in magnitude although it is not statistically significantly different than the baseline estimate. In Column 4 we allow for a teacher-specific quadratic time trend. The quadratic coefficient is significant and collectively the coefficients are significant at better than the 1% level. Evaluated at the mean annual pre-transition teaching days, the estimates imply a decrease of 15.5 annual "class hours" – a little below the baseline estimates.

The next two subsections provide additional evidence consistent with commute time as the cause of decreased teaching time by testing theoretical predictions for annual teaching days and daily "class hours."

[39] This is calculated using the midpoint method, a decrease of 21.9 "class hours" per year, and an average of 260.0 annual "class hours" prior to the transition. The percentage change in commute time or distance is 200% since there was no commute before the transition.

Annual Undergraduate Teaching Days: The middle panel of Table 6 shows estimates of Equation (6) for annual undergraduate teaching days. Our preferred specification with academic-year and teacher fixed effects in Column 5 shows a decrease of 0.21 annual teaching days for each additional expected commute day. Grossing this up in the same way as for annual "class hours" implies a decrease of 17.5 annual teaching days from the full transition or 21.3% of the pre-transition 82.3 annual teaching days. In unreported results the estimate is robust to extending the data through the post-transition period (significant decrease of 17.2 days). For quintile estimates (Column 6) all but one coefficient is significant on its own and jointly they are significant at better than the 0.1% level. The five coefficients (-0.13 to -0.23) bracket the baseline estimate (-0.21). A teacher-specific time trend (Column 7) yields results almost identical to the baseline. A quadratic teacher-specific time trend (Column 8) is highly significant and yields a somewhat lower decrease (12.8 annual teaching days) evaluated at the mean annual teaching days pre-transition.

Daily Undergraduate "Class Hours": The right panel of Table 6 shows the DD estimates of Equation (6) for daily undergraduate "class hours." The preferred specification in Column 9 shows an increase of 0.0061 daily "class hours" for each additional expected commute day. Grossing up these changes over the full transition yields an increase of 0.50 daily "class hours" or 16.2% of the pre-transition average of 3.1 daily "class hours." In unreported results, the estimate is almost identical if the post-transition years are included (significant increase of 0.51 "class hours"). For quintile estimates (Column 10) all but one coefficient is significant on its own and jointly they are significant at better than the 0.1% level. They (0.0030 to 0.0073) bracket the baseline estimate (0.0061). Allowing for teacher-specific time trends reduces the estimate by about one-half (Column 11) to an increase of 0.22 daily "class hours" from the full transition. Using a teacher-specific quadratic time trend (Column 12) the coefficients are jointly significant at the 6.7% level. Grossing this up by the mean annual teaching days pre-transition yields an estimate close to that from the linear function (0.27 "class hours").

Summary: Together, these results confirm the theoretical predictions of Section 3. Annual teaching days decrease and daily "class hours" increase consistent with a longer commute imposing higher daily fixed costs. Teachers averaged 82.3 annual undergraduate teaching days before the transition. Given a daily round-trip commute time of 1 to 1.5 hours, this would require 82.3 to 123.4 commute hours per year after the transition. We estimate teachers decreased annual "class hours" by 21.9 in response to this implying that they value commute time at 18 to 27% of their "hourly" wage.[40] Multiplying by the wage, the average teacher would pay RMB 16 – 24 (USD 2.5 – 3.8)[41] to avoid one commute hour given their year 2011 "hourly" wage of RMB 90 (USD 14.2). Put differently, faculty on average dislike undergraduate teaching more than commuting and would prefer 3.8 to 5.6 hours commuting to one "class hour" teaching. This is consistent with greater dis-amenity from undergraduate

[40] Many studies estimate the value of commute relative to work time. These only estimate the equilibrium trade-off and do not provide structural parameters for evaluating transport policy or labor market outcomes (Gibbons and Machin, 2006, p. 7). This literature has yielded a large range for the tradeoff: from 0.2 to 3 times the wage rate (Calfee and Winston, 1998; Small, 1992; Timothy and Wheaton, 2001, Small and Verhoef, 2007). Gibbons and Machin (2006) place the center of these estimates at 0.5.

[41] Throughout the paper we use an exchange rate as of August 2012: 6.35 USD:RMB.

teaching than commuting (Becker, 1965) or it may partially reflect preparation time spent outside the classroom.

Shirking could increase as a substitute for leisure time lost to longer commutes.[42] Such effects are likely small in our setting given that teachers work in front of a class. Longer commute times can also increase absenteeism (Gutierrez-i-Puigarnau and van Ommeren, 2010b) but in this case teachers must make up any missed classes.

The estimates for annual teaching days and daily "class hours" imply roughly the same impact on overall work time as the direct estimates of annual "class hours." Teachers taught 3.22 daily "class hours" and 81.2 annual teaching days in 2003. Using our preferred estimates and calculating (daily "class hours" in 2003 + estimated change in daily "class hours")*(annual teaching days in 2003 + estimated change in annual teaching days) – (daily "class hours" in 2003)*(annual teaching days in 2003) yields a decrease of 24.7 "class hours" which is close to our estimate of a decrease of 21.9 annual "class hours."

Robustness Checks: Table 7 contains robustness checks for our baseline estimates of annual "class hours" reproduced in Column 1. Column 2 tests whether teachers with a high degree of flexibility in course scheduling were differentially affected relative to those with little. This serves as a test of how sensitive our results are to our assumption that faculty freely choose their working time subject to the university's offered wage. If they are not freely able to choose then we might expect the commute time response to be lower for the group that displays less flexibility.

We quantify a teacher's flexibility based on changes across class levels in their schedule from 2002 to 2003.[43] Specifically, we define flexibility as the absolute value of the change in "class hours" between class levels across all levels: $\sum_{j\in\{Fr,So,Ju,Se\}}\left|H_{i2003}^{j} - H_{i2002}^{j}\right|$ where H_{it}^{j} is annual "class hours" teacher i taught class level j in year t. We then identify those teachers in the top and bottom deciles of this measure and estimate Equation (6) distinguishing the effect of commute costs for these two groups. This also serves as a test of whether avoidance behavior in the window between 2002 and 2003, when the transition sequence became known, is of concern. Comparing teachers that change schedules greatly (and likely have greater discretion to engage in avoidance behavior) to those who do not serves as a test of this avoidance behavior. Although the significance is lowered by a smaller sample, Column 2 shows that commute time has a negative effect on annual "class hours" which is not statistically different than the baseline estimate and that the effects on high- and low-flexibility teachers are not significantly different.

The university reduced the minimum teaching load during the transition (in 2005) from 240 to 225 annual "class hours;" however this does not appear to confound our estimates. The proportion of faculty at the minimum of 240 "class hours" is 2 out of 225 (proportion of 0.0089 with a standard error of 0.0063) in 2003 just before the transition and 7 out of 254 (proportion of 0.0276 with a standard error of 0.0103) in 2004 right after the transition begins. Although the fraction is somewhat higher right

[42] Ross and Zenou (2008) find evidence for this among highly-supervised blue-collar workers.
[43] Because of changes in course names and numbers over time it is impossible to trace the evolution of specific courses over time to see how frequently the faculty who teach them change.

after the transition it is not statistically significantly different. These small fractions are also consistent with no significant bunching at the minimum thresholds which is confirmed by the absence of any significant discontinuities in Figure 1. Because of the availability of substitutes for teaching (supervising graduate theses, administrative tasks, and supervising student internships and study trips), there is also a significant proportion of faculty at or below the minimum: 0.439 (standard error of 0.022) in 2003, 0.518 (0.023) in 2004, and 0.477 (0.024) in 2005. The fraction is slightly higher once the transition begins but not statistically so and the fraction falls in the second year of the transition.

Columns 3 and 4 of Table 7 use regression analysis to test whether the reduction in the minimum teaching load in 2005 caused some of the reduction in teaching time. In Column 3 we create a dummy variable set to one across all years if the teacher's annual "class hours" were close to the threshold (between 240 and 250 annual "class hours" inclusive) in 2003 (pre-transition) and zero otherwise. These are the teachers for whom the minimum constraint was most binding in 2004 and therefore should adjust their teaching time the most in 2005. We then interact this dummy variable with expected commute days in each year to distinguish the effect of commute costs on this group. The interaction term is positive and insignificant while the baseline effect of expected commute days is unchanged. This is consistent with reduced teaching time being attributable to increased commute costs rather than the minimum teaching load change. Column 4 widens the definition of "close to the threshold" to between 240 and 260 "class hours." The results are very similar.

Column 5 tests whether there is a differential effect on teachers who are above the minimum teaching load in the previous year (240 annual "class hours" in 2003 and 2004 and 225 in 2005 through 2007). It is useful to check this subsample because they are less likely to use other activities besides teaching to fulfill their minimum teaching load and we do not observe the change in these. "Class hours" decrease by 0.25 per expected commute day. Average annual teaching days for this subsample pre-transition is 108.3 implying a decrease of 27.1 annual "class hours" from the full transition. This is above the estimate from the full sample; however, the effects are actually somewhat lower in percentage terms – 6.9% (the sub-sample averages 391 annual "class hours" pre-transition) versus 8.4% for the full sample.

Any confounding factors that would bias our DD results must be correlated with teacher-specific changes in commute days. Unilateral actions by the university to increase class sizes do not confound our estimates if they fell equally on all faculty members. Although increased class sizes might require faculty to spend more time preparing outside the classroom, a university-wide increase would be uncorrelated with teacher-specific changes in commute costs and wash out of the DD estimates. More problematic for our estimates is that teachers who face large commute time increases may face greater pressure from administrators to teach larger classes because few faculty will tolerate commuting. Larger classes may require more outside preparation time and could lead teachers with larger commute time increases to further reduce their in-class teaching time leading to a bias away from zero. We show this more formally in Appendix D by extending our theoretical model to allow effort to depend on class size in addition to "class hours."

At the aggregate level, average class size at the satellite campus does exceed that at the main campus during the transition years (71.0 versus 63.0 significant at the 1% level) consistent with faculty wishing to avoid commuting. This is a relatively small difference and, even if the larger class sizes at the satellite campus required more outside preparation time, this would bias our DD estimates only if class sizes are correlated with individual-level commute costs. Otherwise, they are differenced out. To examine whether this is the case we estimated Equation (6) using class size as the dependent variable to relate class size to individual-level commute costs. The results are shown in Column 6 of Table 7. Since class size is influenced by university administration and is not unilaterally set by the teacher, this is a descriptive not causal regression. Expected commute days is significantly correlated with class size; however, the effect is small. Each additional expected commute day is associated with an additional 0.065 students. Grossing up by the average pre-transition teaching days implies a class size increase of 5.3 students from the full transition. This is only 8.6% of the average pre-transition class size of 61.8 students. Thus, most of the class size increase is differenced out in our DD estimates.

Role of Demographics: Table 8 examines the role of faculty demographics in the response of annual undergraduate "class hours" to commute time. Column 1 allows for a differential effect of the transition by gender and finds no significant difference. This result contrasts with previous evidence that female work time is more sensitive to commute costs.[44] Column 2 controls for rank (assistant professor is omitted) since outside options to undergraduate teaching may differ with position. Graduate courses are usually taught by associate or full professors, full professors are the only faculty rank legally allowed to supervise Ph.D. theses, and senior faculty has greater consulting opportunities. The transition has a similar effect across all ranks. It is possible that we find no significant difference by gender because a disproportionate fraction of senior faculty are male and the increased bargaining power that conveys offsets higher commute cost sensitivity among female faculty. Interacting rank and gender (Column 3) reveals no significant differences.[45]

Possible University Responses: How did the university accommodate the decrease in per-teacher undergraduate teaching time? We cannot precisely answer this question but we offer some evidence based on the annual demand for and supply of undergraduate student "class hours:"

(7a) $Demand = (Number\ of\ Students) * (Student\ "Class\ Hours"/Student)$,
(7b) $Supply = (Number\ of\ Teachers) * (Teacher\ "Class\ Hours"/Teacher) * (Class\ Size)$.

There are four possible margins of adjustment which are not mutually exclusive. The university could reduce demand for teaching time by: 1) admitting fewer students or 2) reducing the number of student "class hours" required per student; or it could increase

[44] Blau and Kahn (2007) provide evidence of significant female labor supply changes but also conclude that female labor supply characteristics converge toward those of males over time. Black, Kolesnikova, and Taylor (2014) find that female work time is more sensitive to commute costs as an equilibrium outcome. White (1986) finds evidence that male and female commute times respond differently to income, home ownership, and presence of children.
[45] Using the same specification as in Column 3 we also tested for demographic differences in annual teaching days and daily "class hours." We found no significant differences in either across the different groups.

supply by: 3) hiring more teachers or 4) increasing class sizes.[46] In Appendix E we approximate these margins of adjustment by taking differentials of Equations (7a) and (7b) and evaluating the changes using the average of 2003 (just before the transition) and 2007 (just after the full transition) data.

Demand for undergraduate teaching time increased by 2.83 million student "class hours" between 2003 and 2007. A large increase in the student body increased demand by 3.32 million student "class hours" which was offset by 0.49 million due to an aggregate decline in student "class hours" per student. Given such a large increase in demand, the university was likely encouraging faculty to teach more rather than applying pressure for them to teach less or effectively demoting them by reducing their teaching time and therefore wages.

A larger faculty size increased the supply of teaching time by 2.97 million student "class hours" between 2003 and 2007.[47] However, decreased teaching time per faculty member decreased aggregate supply by 6.02 million student "class hours." Therefore, without accounting for class size changes, supply decreased by 3.05 million student "class hours" annually and demand exceeded supply by 5.88 million. This excess was met by a dramatic increase in class size. The university increased the average number of students per class by 51.9 students between 2003 and 2007. Thus, preparation time outside of class likely increased on average for all faculty. However, as the estimates in Column 6 of Table 7 show this was largely uncorrelated with individual-level commute costs and therefore differenced out in our DD estimates.

Graduate Teaching and Research Output: Column 1 of Table 9 presents estimates from a DD specification using Equation (6) with annual graduate "class hours" as the dependent variable and expected commute days based on undergraduate teaching as the explanatory variable. A teacher is included in this sample if they taught undergraduates in 2003 and in at least one year after that and taught graduate students in at least one year of the transition. The results show no evidence of substitution toward graduate teaching due to the increased commute costs.

We estimate the effect on annual research output using a DD specification based on lagged commute costs:

(8) $Y_{it} = \alpha_i + \delta_t + \beta Tr_t * CD_{it-1} + UT_{it-1} + GT_{it-1} + \varepsilon_{it}$,[48]

where Y_{it} is a measure of annual research output (total publications, top publications, and non-top publications) per teacher. We control for lagged undergraduate (UT_{it-1}) and graduate (GT_{it-1}) "class hours" taught by teacher i. Faculty heavily involved in undergraduate teaching may have insufficient time to actively research. Graduate teaching time might either detract from research because it takes time otherwise available for research or enhance research if there are sufficient synergies. We lag

[46] The number of teachers, students, and student "class hours" per student are clearly determined by the university. Teachers indirectly influence class size through their teaching quality and class requirements; however, the equilibrium effects are determined university-wide.

[47] Temporary and adjunct faculty played a tiny role in the university's response – the teacher-course observations we dropped for them numbered only 109 over the ten years.

[48] Since we allow teaching time to affect research we would ideally estimate research output and teaching time jointly using a seemingly-unrelated regression (SUR); however, this does not allow us to include fixed effects.

these and expected commute days by one year since we estimate it takes about one year to write and publish a paper in a Chinese journal and 96.5% of the publications in our sample appear in such journals. A teacher is included in this sample if they taught undergraduates in 2002 and in at least one year after that. We also estimate using an "active researcher" subsample of faculty who also produced at least one research paper during the transition.

The results are shown in Columns 2 through 7 of Table 9. Commuting has no effect on total publications (Columns 2 and 3). If we separate effects, commuting has no effect on non-top publications (Columns 4 and 5) but appears to "crowd out" top publications using either all faculty or active researchers (Columns 7 and 8). The latter could be caused by increased fatigue or more juggling of tasks due to interruptions from commuting (Coviello, Ichino, and Persico, 2015). Using the results for all teachers, each additional expected commute day reduces publications produced a year later by 0.00015. Grossing up using the average annual days taught pre-transition implies 0.012 fewer annual per-capita publications.

8. Sensitivity Analysis

In this section we perform two sensitivity analyses. An alternative estimate of the effect of commute costs is an interrupted time series comparing work time before (2000 to 2003) versus after (2007 to 2009) the transition of all four undergraduate class levels to the satellite campus:

(9) $Y_{it} = \alpha_i + \theta t + \lambda Tr_t * t + \beta Tr_t + X_{it} + \varepsilon_{it};\ t \in \{00, \dots, 03; 07, \dots, 09\}$,

where β is the main coefficient of interest and captures the average effect across all teachers on the outcome variable Y_{it} of transitioning all class levels to the satellite campus. θ captures any aggregate trends in the work time measure before the transition and λ does the same after. We center the pre-transition time trend at mid-2001 and the post-transition time trend in 2008 so that β captures the difference in the mean effects pre- versus post-transition. We cluster standard errors in cells defined by a teacher before versus after the transition and allow for general heteroskedasticity. Appendix F contains summary statistics for the before-after sample.

Since we do not have a comparison group to perform a comparative interrupted time series (St. Clair, Cook, and Hallberg, 2014), the identification conditions for an interrupted time series are defined by Shadish, Cook, and Campbell (2002): history, selection, instrumentation, regression, and maturation. Instrumentation is not a concern in our setting since measurement of work time remained the same before and after the transition. Regression is also not a concern since in the before-after estimation all teachers are exposed to commute costs. We rule out selection by examining a balanced panel. We control for maturation and history by including teacher fixed effects and asymmetric time trends in the before and after periods. Nonetheless, confounding factors that change during the transition period unrelated to the increase in commute costs may remain. Therefore, we view this merely as a sensitivity analysis for our DD estimates.

Formally, identification of the before-after effect requires that conditional on α_i, t, and X_{it}, Tr_t is uncorrelated with ε_{it}. That is, the controls are sufficiently flexible to capture any factors besides the commute costs that changed between 2003 and 2007. The fixed effects capture any teacher-specific time-constant unobservables affecting work time while the time trends capture university-level changes over time including wages, student enrollment, faculty size, class size, curriculum, graduation course requirements, and national education policies. This would also capture aggregate changes in the quality of outside options because teachers commit to a teaching schedule prior to the academic year and therefore must rely on the expected return to outside activities in the coming academic year in choosing their teaching time. The asymmetric trends allow these to differ before versus after the transition. Despite these flexible controls, identification is more problematic than for the DD estimates. Confounding factors that do not change year-by-year but change only with the transition would be problematic; in particular, other repercussions of the transition that affect work time. The advantage of the before-after model is that it does not rely on using a teacher's 2003 schedule to measure the treatment effect and therefore avoids the "aging" of this measure as the transition progresses.

Column 1 of Appendix G shows estimates for annual "class hours" using a balanced panel of faculty present over the entire time period from 2000 to 2009. Annual "class hours" decline by 20.3 due to the transition which is similar to our DD estimate of 21.9. Before-after estimates for annual teaching days (Columns 2) are larger (a drop of 27 days) than the DD estimates (a drop of 18 days). Column 3 shows before-after estimates for daily "class hours." These estimates (an increase of 0.91 daily "class hours") are somewhat higher than our DD estimate of 0.50.

As a second sensitivity analysis, we compare teachers with high commute costs to those with low to examine whether the timing of the commute costs effects is consistent across the different groups. It also serves as another test of the parallel trends assumption across the groups. We construct a "highly treated" group that includes teachers for whom freshman teaching hours comprised 80% or more of their total "class hours" and who were in the 80th percentile of total freshman "class hours."[49] We impose both a share and a total hours cutoff to avoid teachers with many freshman teaching hours but a low share of hours simply because they teach a lot while at the same time avoiding teachers with a high share of freshman teaching hours but that are only minimally affected by the policy because they teach very few total hours. We test the robustness of increasing these thresholds to "85" and "90."

The results are shown in Columns 1 through 3 of Table 10. Expected commute days significantly reduce annual undergraduate "class hours" and the effects are larger for this "highly treated" group than for our full sample. Each additional expected commute day lowers annual "class hours" by 0.69 for the "80" cutoff up to 0.99 for the "90" cutoff compared to 0.27 for the full sample.

Because senior students take fewer classes than other class levels there is less data available to construct a "minimally-treated" group. In order to get a large enough subsample we consider both junior and senior courses. We construct the sample in a manner analogous to that for the "highly treated" group although because of the lack of data we cannot impose such stringent cutoffs. We include teachers for whom junior

[49] We were unable to apply a 100% cutoff for either the "highly treated" or minimally treated groups because the sample sizes were too small.

plus senior "class hours" comprise 60% or more of their total "class hours" and who were in the 60th percentile or above of total junior plus senior "class hours." We then test the robustness of increasing these thresholds to "65" and "70."

For this "minimally treated" group, we should see little reduction in the first two years of the transition because junior and senior class levels have not yet transitioned to the new campus. However, we should see effects in the third and fourth years of the transition when juniors and seniors move. This is what we see in Columns 4 through 6 of Table 10. Effects in the first two years of the transition are insignificant while "class hours" are significantly reduced in the last two years and by more than that for the full sample.

9. Conclusion and Discussion

There is little evidence about the causal effect of commute costs on labor supply. The few available results are subject to endogeneity, imprecise measures of commute costs, or lack of comparability in predicting out of sample. Subject to these caveats, previous results indicate a small or no change in labor supply from commute costs changes. In contrast, we find that teaching time drops significantly in response to an exogenous increase in commute time, estimating a commute distance elasticity of work time of -0.044 which is almost five times larger than previous estimates. Vis-à-vis the previous literature, our results suggest caution in concluding that work time responds little to commute costs.

Our results suggest that cost-benefit analyses of transportation design should consider labor supply responses to changes in commute costs. Similarly, evaluations of policies alleviating traffic congestion such as driving restrictions, staggered work hours, and reversible lanes should incorporate the resulting work time changes. It has been suggested that congestion taxes replace income taxes because the former reduces the negative externalities from driving even though both distort labor supply.[50] Our results imply that faster commutes under a congestion tax will offset some of the labor market distortion arising from monetary commute costs. Our results also have ramifications for theoretical labor supply models. Some assume that work days are fixed and daily hours chosen (Cogan, 1981) while others assume the opposite (Parry and Bento, 2001). We find that both margins adjust.

Our results imply a role for commute time in the long-run level and rate of city growth. Longer commutes will directly negatively impact a city's productivity especially as it concerns attracting high human capital or knowledge workers. The presence of knowledge spillovers in the workplace (Fu, 2007; Rosenthal and Strange, 2008) implies that productivity growth would also suffer from less workplace time. This is particularly relevant given the longer commute times caused by urban sprawl (Brueckner, 2001). The competition between "edge" and core cities will also be affected by the decreased work time of those who commute between the two (Henderson and Mitra, 1993).

[50] Parry and Bento 2001; De Borger and van Dender, 2003; and Mayeres and Proost, 2001 discuss endogenizing work time in theoretical models analyzing the welfare implications.

Those with flexible work time (to which our estimates are most relevant) exert an outsized effect on the economy. The self-employed, especially entrepreneurs, create positive employment spillovers (van Praag and Versloot, 2008). Their work time and these spillovers are affected by longer commutes (Viard and Fu, 2015). Florida (2004) argues that a "creative class," about 30 percent of the U.S. workforce, sets their own hours and is critical to development of post-industrial U.S. cities. High human-capital and high-technology workers often have flexible schedules and exert a multiplier effect on local employment due to increased demand for local goods and services (Moretti, 2010; Moretti and Thulin, 2013). City growth is particularly sensitive to the presence of high human-capital workers due to spillovers from knowledge sharing (Jovanovic, 1992; Glaeser, 2003).

For businesses, our results suggest that locating close to employees or easing their commutes can yield more time at work and likely higher productivity (Gutiérrez-i-Puigarnau and van Ommeren, 2010b; Ross and Zenou, 2008). Firms must compensate workers who have longer commutes with higher wages (Timothy and Wheaton, 2001; Fu and Ross, 2013) suggesting an added benefit for a firm in shortening commutes.

Our results have important implications for the expansion of higher education in China. Total undergraduate enrollment in China increased from 2.0 million in 1998 to 8.7 million in 2010.[51] The number of universities has not kept pace leading to higher enrollments: about 14,000 students per university in 2006 compared to 4,000 in 1997. Universities have accommodated this expansion by increasing campus sizes – often by adding satellite campuses. As of 2009, more than 60 universities had established satellite campuses.[52] Use of satellite campuses will lead to reduced teaching supply which, unless compensated for with a larger faculty, will reduce faculty-student interaction and diminish educational quality (Angrist and Lavy, 1999; Arias and Walker, 2004; DeGiorgi, Pellizzari, and Woolston, 2012).

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[51] According to Ministry of Education data available at http://www.moe.gov.cn/.

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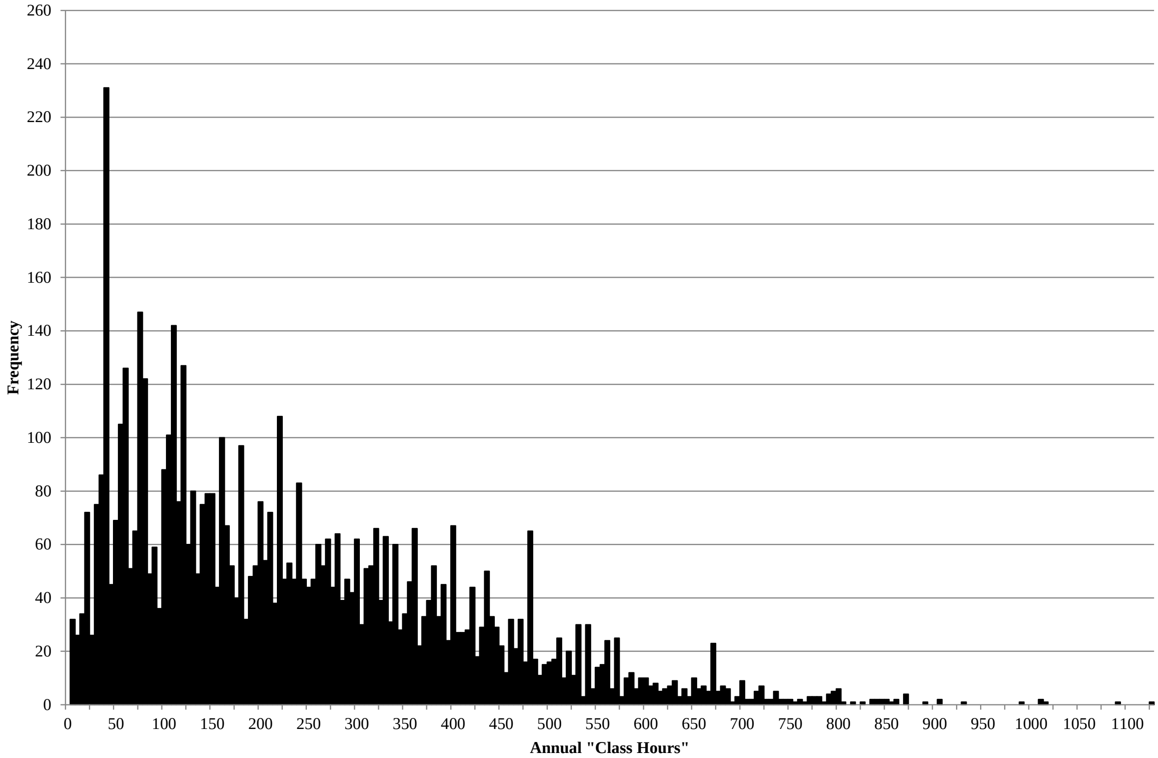
Figure 1 Distribution of Annual Undergraduate "Class Hours" Across All Faculty and Years (2000 to 2009) (N = 6,068)



Annual undergraduate "class hours" for all faculty members in all years of the sample (2000 to 2009). An observation is a faculty member-year combination. Class hours range from 2 to 1,121.

Table 1 Undergraduate Classes, Student Enrollments, Faculty Size, “Class Hours,” and Class Sizes across Academic Years (2000 – 2009)

	1	2	3	4	5	6	7	8	9	10
	# of Classes						Teacher "Class Hours" (1000s)	Student "Class Hours"		
Academic Year	Class-Level Specific	"Other"[1]	Total	# of Students	# of Teachers[2]	Student-Teacher Ratio		Total (millions)	Per Student	Average # Students Per Class
2000	1,448	252	1,700	7,370	413	17.8	72.5	5.76	781	79.5
2001	2,121	265	2,386	8,846	484	18.3	100.6	7.46	843	74.1
2002	2,140	298	2,438	10,415	500	20.8	111.6	7.80	749	70.0
2003	2,517	366	2,883	11,366	536	21.2	131.2	7.87	692	60.0
2004	2,310	398	2,708	12,506	590	21.2	118.1	8.15	652	69.0
2005	2,437	423	2,860	13,692	599	22.9	115.1	8.75	639	76.0
2006	2,793	614	3,407	14,893	653	22.8	117.1	10.90	732	93.0
2007	3,036	457	3,493	16,289	719	22.7	95.7	10.70	657	111.8
2008	3,471	554	4,025	16,201	802	20.2	97.8	11.90	735	121.6
2009	3,066	1,323	4,389	15,910	772	20.6	100.1	12.30	773	122.9

Data on number of students assumes no attrition in enrollment by students over time. Data on classes, student enrollments, and "class hours" from the university's Dean of Undergraduate Education Office. Data on number of teachers from the university's Human Resources Department. [1] "Other" classes include university-wide, double degree, and sports classes as described in the text. "Other" classes jump dramatically in 2009 due to the university re-classifying many class-specific courses as "other." [2] Total number of teachers involved in undergraduate teaching.

Table 2 Descriptive Statistics

Variable	N	Mean	Std. Dev.	Min	Max
PANEL A: Undergraduate Teaching 2000 - 2007; 513 Teachers					
Annual Undergraduate "Class Hours"	3,402	260.25	171.16	2.00	1,121.00
Annual Undergraduate Teaching Days[1]	3,399	75.36	39.07	3.00	196.00
Daily Undergraduate "Class Hours"[1]	3,399	3.34	1.41	0.21	10.00
Expected Commute Days - 2004	490	24.60	36.91	0.00	162.00
Expected Commute Days - 2005	438	52.62	44.45	0.00	172.00
Expected Commute Days - 2006	414	72.15	42.12	0.00	176.00
Expected Commute Days - 2007	387	75.43	41.27	0.00	195.00
Male	3,402	0.58	0.49	0.00	1.00
Position - Assistant Professor	3,402	0.50	0.50	0.00	1.00
Position - Associate Professor	3,402	0.29	0.46	0.00	1.00
Position - Full Professor	3,402	0.17	0.37	0.00	1.00
PANEL B: Graduate Teaching 2000 - 2007; 275 Teachers					
Expected Commute Days - 2004	185	15.91	31.48	0.00	126.00
Expected Commute Days - 2005	209	39.18	38.41	0.00	156.00
Expected Commute Days - 2006	223	58.98	39.41	0.00	176.00
Expected Commute Days - 2007	239	66.84	40.40	0.00	195.00
Annual Graduate "Class Hours"	1,319	111.34	78.28	6.00	696.00
PANEL C: Research Output 2001 - 2008: 521 Teachers					
Lagged Expected Commute Days - 2005	456	25.07	36.93	0.00	162.00
Lagged Expected Commute Days - 2006	426	52.38	45.00	0.00	172.00
Lagged Expected Commute Days - 2007	399	70.03	42.51	0.00	176.00
Lagged Expected Commute Days - 2008	386	73.34	42.65	0.00	195.00
Annual Publications per Teacher	3,367	0.96	1.58	0.00	15.00
Annual Top Publications per Teacher	3,367	0.01	0.10	0.00	2.00
Annual Non-Top Publications per Teacher	3,367	0.95	1.56	0.00	15.00

Panel A includes data for faculty who teach undergraduates in 2003 and in at least one year after. Panel B includes data for faculty who teach undergraduate students in 2003 and teach undergraduate and graduate students in at least one year after. Panel C includes data for any faculty who teach undergraduate students in 2002 and in at least one year after. [1] Number of observations for annaul teaching days and daily "class hours" is less than 3,402 because some class-year observations are missing day-of-week information. These are included for annual "class hours" because hours are available even if day of week is not.

Table 3 Mean Annual Work Time Measures for High and Low Commute Costs Cohorts before (2000 – 2003) versus during (2004 – 2007) Campus Transition

Annual "Class Hours"

	Pre-Transition (2000 - 2003)	During Transition (2004 - 2007)	Difference
Top Decile - Freshman Annual Teaching Days	403.6	372.4	-31.2 *
	(158.8)	(186.0)	(17.1)
	204	205	
Top Decile - Senior Annual Teaching Days	265.7	251.2	-14.5
	(136.0)	(167.4)	(13.9)
	226	251	
Difference	137.9 ***	121.2 ***	-16.7 ***
	(14.3)	(16.7)	(1.5)

Annual Teaching Days

	Pre-Transition (2000 - 2003)	During Transition (2004 - 2007)	Difference
Top Decile - Freshman Annual Teaching Days	113.3	79.9	-33.4 ***
	(34.7)	(32.3)	(3.3)
	204	205	
Top Decile - Senior Annual Teaching Days	85.8	70.6	-15.2 ***
	(37.0)	(35.9)	(3.4)
	224	251	
Difference	27.5 ***	9.3 ***	-18.2 ***
	(3.5)	(3.2)	(0.3)

Daily "Class Hours"

	Pre-Transition (2000 - 2003)	During Transition (2004 - 2007)	Difference
Top Decile - Freshman Annual Teaching Days	3.60	4.64	1.04 ***
	(1.24)	(1.77)	(0.15)
	204	205	
Top Decile - Senior Annual Teaching Days	3.13	3.45	0.32 ***
	(0.99)	(1.31)	(0.11)
	224	251	
Difference	0.47 ***	1.18 ***	0.72 ***
	(0.11)	(0.15)	(0.01)

The three panels compare work time before (2000 - 2003) versus during (2004 - 2007) the transition for teachers in the top decile of freshman annual teaching days with those in the top decile of senior annual teaching days based on their 2003 teaching schedule. The top panel compares the change in annual "class hours" for the two groups, the middle panel annual teaching days, and the bottom panel daily "class hours" (conditional on working that day). Each cell displays the mean, standard deviation, and number of observations. * = 10% significance, ** = 5% significance, *** = 1% significance for differences in means.

Table 4 Test of Pre-Treatment (2000 – 2003) Trends in Annual Undergraduate "Class Hours"

	1	2	3	4
	Pre-Treatment Trends in Annual "Class Hours" Top versus Bottom Deciles Based on:			
	Annual "Class Hours"		Annual Teaching Days	
Time Trend	41.5 ***	-24.9	39.9 ***	-9.9
	(10.5)	(51.5)	(9.1)	(42.9)
(Time Trend)^2		83.6		9.7
		(83.0)		(8.1)
(Top Decile Freshman)*	-8.2	13.0	4.2	101.3
(Time Trend)	(14.3)	(9.7)	(13.7)	(77.8)
(Top Decile Freshman)*		-17.9		-18.9
(Time Trend)^2		(15.8)		(14.4)
Teacher Fixed Effects	Yes	Yes	Yes	Yes
Academic-Year Fixed Effects	Yes	Yes	Yes	Yes
Number of Teachers	104	104	126	126
Prob > F (Time Trends)		0.000		0.000
Prob > F (Interaction Terms)		0.435		0.427
N	359	359	429	429
R^2	0.664	0.667	0.661	0.664

Dependent variable is annual undergraduate "class hours." Columns 1 and 2 categorize faculty into top and bottom decile based on number of annual freshman undergraduate "class hours." Columns 3 and 4 catageorize faculty into top and bottom decile based on number of annual freshman undergraduate teaching days. Standard errors in parentheses. Standard errors allow for clustering within teacher-transition cell and general heteroskedasticity in all regressions. * = 10% significance, ** = 5% significance, *** = 1% significance. The F-tests are p-values for the joint significance level of the coefficients on the linear and quadratic expected commute day terms and the joint significance of the interactions between decile and linear and quadratic time trends.

Table 5 Placebo Tests for Pre-Treatment (2000 – 2003) Trends in Work Time Measures

	1 Annual "Class Hours"	2 Annual Teaching Days	3 Daily "Class Hours"
Expected Commute Days Placebo	0.004 (0.278)	-0.073 (0.074)	0.003 (0.002)
Teacher Fixed Effects	Yes	Yes	Yes
Academic-Year Fixed Effects	Yes	Yes	Yes
Number of Teachers	468	468	468
R^2	0.852	0.811	0.746
N	1,702	1,701	1,701

Dependent variable is: annual undergraduate "class hours" in Column 1, annual undergraduate teaching days in Column 2, and undergraduate daily "class hours" (conditional on teaching that day) in Column 3. Standard errors in parentheses. Standard errors allow for clustering by teacher and general heteroskedasticity in all regressions. All regressions include a teacher-specific linear time trend. * = 10% significance, ** = 5% significance, *** = 1% significance.

Table 6 Effect of Expected Commute Days on Work Time Measures (2000 – 2007)

	1	2	3	4	5	6	7	8	9	10	11	12
	Annual Undergraduate "Class Hours"				Annual Undergraduate Teaching Days				Daily Undergraduate "Class Hours"			
			Teacher-Specific Trends				Teacher-Specific Trends				Teacher-Specific Trends	
	Baseline Model	Quintiles	Linear Effect	Quadratic Effect	Baseline Model	Quintiles	Linear Effect	Quadratic Effect	Baseline Model	Quintiles	Linear Effect	Quadratic Effect
Expected Commute Days	-0.266 ***		-0.414 ***	0.448	-0.213 ***		-0.203 ***	-0.021	0.0061 ***		0.0026 **	0.0051 *
	(0.100)		(0.152)	(0.332)	(0.024)		(0.041)	(0.092)	(0.0008)		(0.0012)	(0.0029)
(Expected Commute Days)^2				-0.0077 ***				-0.0016 **				-0.00002
				(0.0027)				(0.0007)				0.00002
(Quintile Indicator)*(Avg. Expected Commute Days in Quintile):												
1st Quintile		-0.164				-0.129				0.0030		
		(0.478)				(0.127)				(0.0046)		
2nd Quintile		-0.226				-0.233 ***				0.0073 ***		
		(0.251)				(0.062)				(0.0022)		
3rd Quintile		-0.014				-0.142 ***				0.0065 ***		
		(0.160)				(0.042)				(0.0015)		
4th Quintile		-0.168				-0.190 ***				0.0061 ***		
		(0.128)				(0.031)				(0.0012)		
5th Quintile		-0.399 ***				-0.228 ***				0.0051 ***		
		(0.116)				(0.028)				(0.0009)		
Teacher Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Academic-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of Teachers	513	513	513	513	513	513	513	513	513	513	513	513
Prob > F (Linear + Quadratic)				0.001				0.000				0.067
Prob > F (Quintiles)		0.020				0.000				0.000		
R^2	0.635	0.636	0.744	0.745	0.522	0.523	0.655	0.656	0.550	0.549	0.678	0.678
N	3,402	3,402	3,402	3,402	3,399	3,399	3,399	3,399	3,399	3,399	3,399	3,399

Dependent variable is: annual undergraduate "class hours" in left panel, annual undergraduate teaching days in middle panel, and undergraduate daily "class hours" (conditional on teaching that day) in right panel. Standard errors in parentheses. Standard errors allow for clustering within teacher-transition cell and general heteroskedasticity in all regressions. * = 10% significance, ** = 5% significance, *** = 1% significance. The F-tests are the p-value for the joint significance level of the coefficients on the five quintile expected commute day terms in Column 3, 7 and 11 and the joint significance of the coefficients on the linear and quadratic expected commute day terms in Columns 4, 8, and 12.

Table 7 Effect of Expected Commute Days on Undergraduate Annual “Class Hours” (2000 – 2007) – Robustness Checks

	1	2	3	4	5	6
			Close to Minimum Teaching Load			
	Baseline Model	"High" Versus "Low" Flexiblity	240 ≤ 2003 "Class Hours" ≤ 250	240 ≤ 2003 "Class Hours" ≤ 260	Above Minimum Threshold	Class Size
Expected Commute Days	-0.266 ***	-0.392 *	-0.266 ***	-0.267 ***	-0.251 *	0.065 ***
	(0.100)	(0.205)	(0.100)	(0.101)	(0.135)	(0.014)
(Expected Commute Days)* ("Low" Flexiblity)		0.002				
		(0.253)				
(Expected Commute Days)* (Close to Threshold)			0.154	0.119		
			(0.777)	(0.400)		
Teacher Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Academic-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Number of Teachers	513	322	513	513	288	513
N	3,402	928	3,402	3,402	2,020	3,400
R^2	0.635	0.752	0.635	0.635	0.533	0.410

Dependent variable in Columns 1 through 5 is annual undergraduate "class hours" and in Column 6 is class size. Columns 1, 3, 4, and 6 include teachers present in 2003 and in at least one year after 2003. The number of observations in Column 6 differ due to missing class size information for some teachers. Column 2 includes teachers in the top and bottom deciles of flexiblity as defined in the text. Column 5 includes all teachers present in 2003 and in at least one year after 2003 and exceed the minimum teaching load in the previous year. The variable "Close to Threshold" is set equal to one in Column 3 (4) if the teacher had between 240 and 250 (260) "class hours" inclusive in year 2004 and zero otherwise. Standard errors in parentheses. Standard errors allow for clustering within teacher-transition cell and general heteroskedasticity in all regressions. * = 10% significance, ** = 5% significance, *** = 1% significance.

Table 8 Effect of Expected Commute Days on Annual Undergraduate “Class Hours” (2000 – 2007) – Role of Demographics

	1 Effect of Gender	2 Effect of Position	3 Gender-Position Interaction
Expected Commute Days	-0.259 **	-0.289 **	-0.336 **
	(0.125)	(0.118)	(0.160)
Female*(Expected Commute Days)	-0.016		
	(0.124)		
Associate Professor*(Expected Commute Days)		0.089	
		(0.127)	
Full Professor*(Expected Commute Days)		0.003	
		(0.185)	
Female Assistant Professor*(Expected Commute Days)			0.108
			(0.181)
Female Associate Professor*(Expected Commute Days)			0.157
			(0.187)
Male Associate Professor*(Expected Commute Days)			0.122
			(0.185)
Female Full Professor*(Expected Commute Days)			-0.027
			(0.220)
Male Full Professor*(Expected Commute Days)			0.091
			(0.262)
Teacher Fixed Effects	Yes	Yes	Yes
Academic-Year Fixed Effects	Yes	Yes	Yes
Number of Teachers	513	513	513
N	3,402	3,402	3,402
R^2	0.635	0.635	0.635

Dependent variable is annual undergraduate "class hours." Standard errors in parentheses. Standard errors allow for clustering within teacher-transition cell and general heteroskedasticity in all regressions. * = 10% significance, ** = 5% significance, *** = 1% significance. All regressions include teacher and academic-year fixed effects.

Table 9 Effect of Expected Commute Days on Annual Graduate “Class Hours” (2000 to 2007) and Annual Research Output (2001 – 2008)

	1	2	3	4	5	6	7
		Total Publications (2001 to 2008)		Non-Top Publications (2001 to 2008)		Top Publications (2001 to 2008)	
	Annual Graduate "Class Hours" (2000 to 2007)	All Teachers	Active Researchers	All Teachers	Active Researchers	All Teachers	Active Researchers
Expected Commute Days	0.0165						
	(0.1059)						
Lagged Expected Commute Days		0.0003	0.0003	0.0004	0.0005	-0.00015 *	-0.00017 *
		(0.0010)	(0.0011)	(0.0010)	(0.0011)	(0.00008)	(0.00009)
Lagged Annual Undergraduate "Class Hours"		-0.0002	-0.0002	-0.0002	-0.0002	0.00000	0.00000
		(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.00002)	(0.00002)
Lagged Annual Graduate "Class Hours"		0.0002	0.0002	0.0002	0.0002	0.00006	0.00006
		(0.0007)	(0.0007)	(0.0007)	(0.0007)	(0.00005)	(0.00005)
Teacher Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Academic-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of Teachers	448	521	441	521	441	521	441
N	1,319	3,367	2,909	3,367	2,909	3,367	2,909
R^2	0.598	0.527	0.498	0.520	0.491	0.255	0.255

Dependent variable is annual graduate "class hours" in Column 1, annual output of total research publications in Columns 2 and 3, annual output of top research publications in Columns 4 and 5, annual output of non-top research publications in Columns 6 and 7. Standard errors in parentheses. Standard errors allow for clustering within teacher-transition cell and general heteroskedasticity in all regressions. * = 10% significance, ** = 5% significance, *** = 1% significance. Column 1 includes any faculty who teach undergraduate students in 2003 and at least one year after 2003 and graduate students in at least one year of the transition. Columns 2, 4 and 6 include faculty who teach undergraduate students in 2002 and at least one year after. Columns 3, 5, and 7 include faculty who teach undergraduate students in 2002 and at least one year after and produced at least one research paper during the transition.

Table 10 Effect of Expected Commute Days on Annual Undergraduate "Class Hours" (2000 – 2007) for Highly- and Minimally-Treated Groups

	1	2	3	4	5	6
	Highly Treated: Mostly Freshman Teaching			Minimally Treated: Mostly Senior/Junior Teaching		
	80th Percentile/ > 80% Share	85th Percentile/ > 85% Share	90th Percentile/ > 90% Share	60th Percentile/ > 60% Share	65th Percentile/ > 65% Share	70th Percentile/ > 70% Share
Expected Commute Days	-0.686 *	-0.950 **	-0.985 *			
	(0.380)	(0.452)	(0.588)			
Expected Commute Days*				-0.013	-0.249	-0.600
Academic Year 2004 - 2005				(0.418)	(0.670)	(0.721)
Expected Commute Days*				-0.885 ***	-0.738 **	-0.842 **
Academic Year 2006 - 2007				(0.343)	(0.352)	(0.388)
Teacher Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Academic-Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Number of Teachers	158	142	110	248	200	152
R^2	0.610	0.554	0.540	0.498	0.496	0.506
N	293	252	178	511	380	283

Dependent variable is: annual undergraduate "class hours." Standard errors in parentheses. Standard errors allow for clustering within teacher-transition cell and general heteroskedasticity in all regressions. * = 10% significance, ** = 5% significance, *** = 1% significance. Columns 1 through 3 include teachers with high exposure to commute costs. Column 1 includes teachers in the 80th percentile of freshman "class hours" and with more than 80% of annual "class hours" devoted to freshman teaching. Columns 2 and 3 are similar but apply cutoffs of "85" and "90" respectively. Columns 4 through 6 include teachers with low exposure to commute costs in the first two years of the transition but high exposure in the last two years of the transition. Column 4 includes teachers in the 60th percentile of junior and senior "class hours" and with more than 60% of annual "class hours" devoted to junior or senior teaching. Columns 5 and 6 are similar but apply cutoffs of "65" and "70" respectively.

Online Appendix A Theoretical Results

Effect of Commute Time on Annual Undergraduate Teaching Days

This appendix follows Gutierrez-i-Puigarnau and van Ommeren (2009) with modifications for our setting as described in the main text. The effect of an increase in commute time on annual undergraduate teaching days can be determined by totally differentiating Equation (3) in the main text with respect to commute time allowing annual undergraduate teaching days and daily undergraduate "class hours" to vary

(A1) $\frac{dD}{dt} = \frac{V_{LC}w^U DH + V_L - \frac{dH}{dT}D\left[V_{CC}(w^U)^2 H - V_{LC}\left(1+e'(H)+w^U(H+t+e(H))\right) - V_{LL}\left(1+e'(H)\right)(H+t+e(H))\right]}{V_{CC}(w^U H)^2 - 2V_{LC}w^U H(H+t+e(H)) + V_{LL}(H+t+e(H))^2}.$

This is negative since Equation (5) in the main text shows that dH/dt is positive, the first term in the numerator is positive by concavity of the utility function, the term in brackets in the numerator is negative by concavity of the utility function and convexity of the effort function, and the denominator is negative by concavity of the utility function and convexity of the effort function.

Effect of Commute Time on Annual Undergraduate "Class Hours"

The effect of an increase in commute time on annual "class hours" is given by

(A2) $\frac{d(DH)}{dt} = H\frac{dD}{dt} + D\frac{dH}{dt}.$

Totally differentiating Equations (2) and (3) from the main text and allowing daily undergraduate "class hours" and annual undergraduate teaching days to adjust to a change in commute time

(A3a) $\frac{dH}{dt} = \frac{\begin{vmatrix} \frac{-\partial F_H}{\partial t} & \frac{\partial F_H}{\partial D} \\ \frac{-\partial F_D}{\partial t} & \frac{\partial F_D}{\partial D} \end{vmatrix}}{|Hessian|},$

(A3b) $\frac{dD}{dt} = \frac{\begin{vmatrix} \frac{\partial F_H}{\partial H} & \frac{-\partial F_H}{\partial t} \\ \frac{\partial F_D}{\partial H} & \frac{-\partial F_D}{\partial t} \end{vmatrix}}{|Hessian|}.$

A local maximum requires that the Hessian be negative definite

(A4) $\frac{\partial F_H}{\partial H} < 0$, and

(A5) $|Hessian| = \frac{\partial F_H}{\partial H}\frac{\partial F_D}{\partial D} - \frac{\partial F_H}{\partial D}\frac{\partial F_D}{\partial H} > 0.$

Given Equations (A2) and (A5)

(A6) $sign\left[\frac{d(DH)}{dt}\right] = sign\left[H\left(\frac{\partial F_D}{\partial H}\frac{\partial F_H}{\partial t} - \frac{\partial F_H}{\partial H}\frac{\partial F_D}{\partial t}\right) + D\left(\frac{\partial F_H}{\partial D}\frac{\partial F_D}{\partial t} - \frac{\partial F_D}{\partial D}\frac{\partial F_H}{\partial t}\right)\right],$

where:

(A7a) $\partial F_H/\partial H = V_{CC}(w^U D)^2 - 2V_{LC}w^U D^2\left(1+e'(H)\right) + V_{LL}D^2\left(1+e'(H)\right)^2 - V_L De''(H),$

(A7b) $\partial F_D/\partial H = \partial F_H/\partial D = V_{CC}(w^U)^2 DH - V_{LC}w^U D\left[H\left(1+e'(H)\right) + \left(H+t+e(H)\right)\right] + V_{LL}D\left(1+e'(H)\right)\left(H+t+e(H)\right),$

(A7c) $\partial F_D/\partial D = V_{CC}(w^U H)^2 - 2V_{LC}w^U H\left(H+t+e(H)\right) + V_{LL}\left(H+t+e(H)\right)^2,$

and:

(A8a) $\partial F_H/\partial t = -V_{LC}w^U D^2 + V_{LL}D^2\big(1 + e'(H)\big)$,

(A8b) $\partial F_D/\partial t = -V_{LC}w^U DH + V_{LL}D\big(H + t + e(H)\big) - V_L$.

We now consider two cases of the model to illustrate that it is possible for annual undergraduate "class hours" to either decrease (Case 1) or increase (Case 2).

Case 1: To show that $d(DH)/dt$ can be negative consider $V_{LC} = 0$ and $V_{LL} \approx 0$ (close to zero). Then

(A9a) $\partial F_H/\partial H \approx V_{CC}(w^U D)^2 - V_L De''(H)$,

(A9b) $\partial F_D/\partial H \approx \partial F_H/\partial D = V_{CC}(w^U)^2 DH$

(A9c) $\partial F_D/\partial D \approx V_{CC}(w^U H)^2$,

and

(A10a) $\partial F_H/\partial t \approx 0$,

(A10b) $\partial F_D/\partial t \approx -V_L$.

In this case

(A11) $sign\left[\frac{d(DH)}{dt}\right] = sign[-V_L^2 DHe''(H)]$,

which is negative.

Case 2: To show that $d(DH)/dt$ can be positive consider $V_{LC} = 0$, $V_{CC} \approx 0$ (close to zero) and $e''(H) \approx 0$ (close to zero). Then

(A12a) $\partial F_H/\partial H \approx V_{LL}D^2\big(1 + e'(H)\big)^2$,

(A12b) $\partial F_D/\partial H \approx \partial F_H/\partial D = V_{LL}D\big(1 + e'(H)\big)\big(H + t + e(H)\big)$,

(A12c) $\partial F_D/\partial D \approx V_{LL}\big(H + t + e(H)\big)^2$,

and

(A13a) $\partial F_H/\partial t = V_{LL}D^2\big(1 + e'(H)\big)$,

(A13b) $\partial F_D/\partial t = V_{LL}D\big(H + t + e(H)\big) - V_L$.

In this case

(A14) $sign\left[\frac{d(DH)}{dt}\right] = sign\big[-V_{LL}V_L D^2\big(1 + e'(H)\big)\big(t + e(H) - He'(H)\big)\big]$.

which is positive as long as long as effort costs do not increase too quickly: $e'(H) < \frac{t+e(H)}{H}$.

Online Appendix B Theoretical Models with Two Activities

A Model with Undergraduate Teaching and Research Time

We modify the model in Appendix A to consider two activities (undergraduate teaching and research) with only one of the activities (undergraduate teaching) affected by commute time. To keep the analysis manageable we collapse the choices of annual undergraduate teaching days and daily undergraduate "class hours" into a single choice of annual undergraduate "class hours" for each activity. A teacher's annual utility after substituting out the budget and time constraints (Equation (1) in the main text) is now

(B1) $v = V\left(Y + F + B(T^R) + w^U T^U, \bar{T} - T^U(1+t) - T^R - e(T^U + \gamma T^R)\right)$,

where $\gamma > 0$ allows a research hour to affect effort differentially from a teaching hour. The two first-order conditions are now

(B2) $F_U \equiv \frac{\partial v}{\partial T^U} = V_C w^U - V_L\left(1 + t + e'(T^U + \gamma T^R)\right) = 0$, and
(B3) $F_R \equiv \frac{\partial v}{\partial T^R} = V_C B'(T^R) - V_L\left(1 + \gamma e'(T^U + \gamma T^R)\right) = 0$.

Equation (B2) says that the marginal utility of consumption from an extra undergraduate "class hour" equals the foregone marginal utility of leisure including the effect of fatigue and commute time. Equation (B3) says that the marginal utility from an extra hour of research time equals the foregone utility of leisure including the effect of fatigue.

A local maximum requires that the Hessian be negative definite

(B4) $\frac{\partial F_U}{\partial T_U} < 0$, and
(B5) $|Hessian| = \frac{\partial F_U}{\partial T^U}\frac{\partial F_R}{\partial T^R} - \frac{\partial F_U}{\partial T^R}\frac{\partial F_R}{\partial T^U} > 0$.

Combining Equations (B2) and (B3) the optimally chosen work times fulfill

(B6) $\frac{w^U}{B'(T^R)} = \frac{1+t+e'(T^U+\gamma T^R)}{1+\gamma e'(T^U+\gamma T^R)}$.

The teacher equates the ratio of the marginal return to undergraduate teaching (the wage) and research (the marginal increase in annual bonus) to the ratio of the foregone marginal utility of leisure due to undergraduate teaching and research time. To see how time spent on undergraduate teaching and research depends on the commute time we apply the implicit function theorem and totally differentiate Equations (B2) and (B3) letting undergraduate teaching and research time adjust to a change in commute time

(B7a) $\frac{dT^U}{dt} = \frac{\begin{vmatrix} \frac{-\partial F_U}{\partial t} & \frac{\partial F_U}{\partial T^R} \\ \frac{-\partial F_R}{\partial t} & \frac{\partial F_R}{\partial T^R} \end{vmatrix}}{|Hessian|}$,
(B7b) $\frac{dT^R}{dt} = \frac{\begin{vmatrix} \frac{\partial F_U}{\partial T^U} & \frac{-\partial F_U}{\partial t} \\ \frac{\partial F_R}{\partial T^U} & \frac{-\partial F_R}{\partial t} \end{vmatrix}}{|Hessian|}$.

Now

(B8a) $\frac{\partial F_{\mathrm{U}}}{\partial t} = -V_{CL}T^U w^U + V_{LL}T^U[1 + t + e'(T^U + \gamma T^R)] - V_L < 0$,
(B8b) $\frac{\partial F_{\mathrm{R}}}{\partial t} = -V_{CL}T^U B'(T^R) + V_{LL}T^U[1 + \gamma e'(T^U + \gamma T^R)] < 0$.

And

(B9a) $\frac{\partial F_U}{\partial T^U} = V_{CC}(w^U)^2 - 2V_{LC}w^U[1+t+e'] + V_{LL}[1+t+e']^2 - V_L e'' < 0,$
(B9b) $\frac{\partial F_R}{\partial T^R} = V_{CC}(B')^2 - 2V_{LC}B'[1+\gamma e'] + V_{LL}[1+\gamma e']^2 + V_C B'' - V_L \gamma^2 e'' < 0,$
(B9c) $\frac{\partial F_U}{\partial T^R} = \frac{\partial F_R}{\partial T^U} = V_{CC}w^U B' - V_{LC}B'[1+t+e'] - V_{LC}w^U[1+\gamma e'] + V_{LL}[1+\gamma e'][1+t+e'] - V_L \gamma e'' < 0,$

where we suppress the arguments of e and B for clarity. We now consider two cases of the model to illustrate that even though undergraduate teaching time decreases in commute time it is possible for research time to either increase (Case 1) or decrease (Case 2) depending on the relative effect of research and undergraduate teaching time on effort (*i.e.*, the magnitude of γ).

Case 1: Suppose $V_{CL} = 0$, $V_{CC} \approx 0$ (close to zero), $B''(T^R) = 0$, and $\gamma > 1$ then

(B10a) $\frac{\partial F_U}{\partial t} \approx V_{LL}T^U\big(1+t+e'(T^U+\gamma T^R)\big) - V_L,$
(B10b) $\frac{\partial F_R}{\partial t} \approx V_{LL}T^U\big(1+\gamma e'(T^U)\big).$

And

(B11a) $\frac{\partial F_U}{\partial T^U} \approx V_{LL}\big(1+t+e'(T^U+\gamma T^R)\big)^2 - V_L e''(T^U+\gamma T^R),$
(B11b) $\frac{\partial F_R}{\partial T^R} \approx V_{LL}\big(1+\gamma e'(T^U+\gamma T^R)\big)^2 - V_L \gamma^2 e''(T^U+\gamma T^R),$
(B11c) $\frac{\partial F_R}{\partial T^U} = \frac{\partial F_U}{\partial T^R} \approx V_{LL}\big(1+\gamma e'(T^U+\gamma T^R)\big)\big(1+t+e'(T^U+\gamma T^R)\big) - V_L \gamma e''(T^U+\gamma T^R).$

It can be verified that parameter values exist for which the second-order condition is met. Now

(B12a) $\frac{dT^U}{dt} \approx \frac{V_L V_{LL} T^U \gamma e''(T^U+\gamma T^R)(\gamma-1+\gamma t) + V_L V_{LL}\big(1+\gamma e'(T^U+\gamma T^R)\big)^2 - (V_L)^2\gamma^2 e''(T^U+\gamma T^R)}{|Hessian|} < 0,$
(B12b) $\frac{dT^R}{dt} \approx \frac{V_L V_{LL} T^U e''(T^U+\gamma T^R)(1-\gamma-\gamma t) - V_L V_{LL}\big(1+\gamma e'(T^U+\gamma T^R)\big)\big(1+t+e'(T^U+\gamma T^R)\big) + (V^L)^2 \gamma e''(T^U+\gamma T^R)}{|Hessian|} > 0.$

The second and third terms in the numerator of Equation (B12a) are negative. Given that $\gamma > 1$ the first term in the numerator is also negative and undergraduate teaching time decreases with commute time. The second and third terms in the numerator of Equation (B12b) are positive. Given that $\gamma > 1$ the first term in the numerator is also positive and research time increases in commute time. Therefore, undergraduate teaching time decreases with commute time, while research time increases with commute time. Relatively little time is spent on research because research effort costs are high and highly convex ($\gamma > 1$). This implies a relatively large amount of leisure time. Therefore, as commute time causes the teacher to scale back undergraduate teaching time some of this is replaced with research time.

Case 2: Suppose $V_{CL} = 0$, $V_{CC} \approx 0$ (close to zero), $B''(T^R) = 0$, and $\gamma \approx 0$ (close to zero) then

(B13a) $\frac{\partial F_U}{\partial t} \approx V_{LL}T^U\big(1+t+e'(T^U)\big) - V_L,$
(B13b) $\frac{\partial F_R}{\partial t} \approx V_{LL}T^U.$

And

(B14a) $\frac{\partial F_U}{\partial T^U} \approx V_{LL}\big(1+t+e'(T^U)\big)^2 - V_L e''(T^U),$
(B14b) $\frac{\partial F_R}{\partial T^R} \approx V_{LL},$

(B14c) $\frac{\partial F_R}{\partial T^U} = \frac{\partial F_U}{\partial T^R} \approx V_{LL}\left(1 + t + e'(T^U)\right)$.

It can be verified that the second-order condition is met for all parameter values. Now

(B15a) $\frac{dT^U}{dt} \approx \frac{V_L V_{LL}}{|Hessian|} < 0$,
(B15b) $\frac{dT^R}{dt} \approx \frac{V_L V_{LL}\left(T^U e''(T^U) - 1 - t - e'(T^U)\right)}{|Hessian|}$.

If $e''(T^U)$ is sufficiently large relative to t/T^U and $e'(T^U)/T^U$ then research time decreases with commute time. In this case, undergraduate teaching time and research time both decrease with commute time. Significant time is spent on research because research effort costs are low and increase slowly ($\gamma \approx 0$). This implies a relatively small amount of available leisure time. Therefore, as commute time increases the leisure time of the teacher is further squeezed. Since the marginal returns to research are so low it is optimal to free up leisure time by decreasing research time.

A Model with Undergraduate and Graduate Teaching Time

A model with undergraduate and graduate teaching time is isomorphic to a model with undergraduate teaching and research time. This can be seen by making the following substitutions in the above model

$T^R = T^G$ and
$B(T^G) = w^G T^G$;

where T^G is the time spent on graduate teaching, w^G is the wage for graduate teaching, and γ now allows for different levels of effort for graduate relative to undergraduate teaching. Note that we have eliminated the dependence of the annual salary on research output.

Since $B'(T^G) = w^G > 0$ and $B''(T^G) = 0 \leq 0$ the results from the model above all follow. Also since $w^G = 1.5w^U$, Equation (B6) implies

(B16) $\gamma = 1.5 + \frac{0.5+1.5t}{e'(T^U+\gamma T^G)} > 1.5$.

Therefore this corresponds to Case 1 above and undergraduate teaching declines in commute time while graduate teaching increases.

Online Appendix C Econometric Model with Heterogeneous Teachers

Consider a model with teacher-specific commute cost sensitivity:

(C1) $Y_{it} = \alpha_i + \delta_t + \tilde{\beta}_i Tr_t * CD_{it} + X_{it} + \tilde{\varepsilon}_{it}$.

$\tilde{\beta}_i$ captures the effect of increased commute time on teaching time for teacher i. $\tilde{\varepsilon}_{it} \sim N(0, \sigma_\varepsilon^2)$ is an error distributed independently across teachers and years. Assume that commute-cost sensitivity across teachers is $\tilde{\beta}_i = \tilde{\beta} + \sigma_{i\beta}$ with $\sigma_{i\beta} \sim N\left(0, \sigma_\beta^2\right)$ independently across teachers and independent of $\tilde{\varepsilon}_{it}$. This heterogeneity occurs because teachers have different schedules for non-teaching activities or family situations such as number of dependents. The covariance structure in Equation (C1) can be accommodated by clustering standard errors by teacher-pre/post transition and allowing for heteroskedasticity:

(C2a) $E[\tilde{\varepsilon}_{it} | CD_{it}] = 0$,
(C2b) $E[\tilde{\varepsilon}_{it}^2 | CD_{it}] = (Tr_t CD_{it})^2 \sigma_\beta^2 + 2\sigma_\varepsilon^2$
(C2c) $E[\tilde{\varepsilon}_{it} \tilde{\varepsilon}_{is} | CD_{it}, CD_{is}] = (Tr_t Tr_s CD_{it} CD_{is}) \sigma_\beta^2$, $t \neq s$
(C2d) $E\left[\tilde{\varepsilon}_{it} \tilde{\varepsilon}_{js} \middle| CD_{it}, CD_{js}\right] = 0, i \neq j, \forall s, t$.

Online Appendix D Model with Effort as Function of Class Size and Daily Undergraduate "Class Hours"

Suppose effort is a function of both daily undergraduate "class hours" and class size: $e(H, S)$. Further, assume that effort is increasing and convex in both class size and daily "class hours" and that teaching a larger class increases marginal fatigue from daily "class hours." That is

(E1) $\frac{\partial e}{\partial H} > 0, \frac{\partial^2 e}{\partial H^2} > 0, \frac{\partial e}{\partial S} > 0, \frac{\partial^2 e}{\partial S^2} > 0$, and $\frac{\partial^2 e}{\partial H \partial S} > 0$.

A simple effort function that satisfies these conditions is: $e(H, S) = a + bSH + cS^2H^2$.

Using Equation (4) in the text we can solve for daily "class hours:"

(E2) $H = \frac{1}{S}\left(\frac{t+a}{c}\right)^{1/2}$. Note that:

(E3) $\frac{\partial H}{\partial S} = -\frac{1}{S^2}\left(\frac{t+a}{c}\right)^{1/2} < 0$.

Thus, if the university unilaterally adjusts class size upward as it transitions to the satellite campus this will decrease undergraduate teaching time irrespective of the increase in commute time. This is absorbed by the academic-year fixed effects in the DD estimates although they would confound the before-after estimates.

Moreover, those with larger class sizes will reduce their daily undergraduate "class hours" by more in response to an increase in commute time:

(E4) $\frac{\partial^2 H}{\partial t \partial S} = -\frac{1}{2cS^2}\left(\frac{t+a}{c}\right)^{-1/2} < 0$.

Since this would confound the DD estimates if the effects are significant we control for class size in Column 6 of Table 7.

Online Appendix E Quantifying University's Response to Decreased Undergraduate Teaching Time

Taking differentials of the supply and demand of undergraduate student "class hours" (Equations (7a) and (7b) in the main text):

(F1a) $\Delta\, Demand =$
$$\Delta\,(Number\ of\ Students) * \overline{(Student\ "Class\ Hours"/Student)} + \overline{(Number\ of\ Students)} * \Delta\,(Student\ "Class\ Hours"/Student),$$

(F1b) $\Delta\, Supply = \Delta\,(Number\ of\ Teachers) * \overline{(Teacher\ "Class\ Hours"/Teacher)} * \overline{(Class\ Size)} +$
$$\overline{(Number\ of\ Teachers)} * \Delta\,(Teacher\ "Class\ Hours"/Teacher) * \overline{(Class\ Size)} + \overline{(Number\ of\ Teachers} * \overline{(Teacher\ "Class\ Hours"/Teacher)} * \Delta\,(Class\ Size),$$

where bars indicate averages of values in 2003 and 2007. We can approximate the adjustment margins on the demand side using Equation (F1a) and the data in Table 2. The number of students increased 4,923 between 2003 and 2007.[1] Multiplying by the average student "class hours" per student (674.6) implies annual demand for teaching time increased by 3.32 million student "class hours." Student "class hours" per student declined from 692 in 2003 to 657 in 2007. Multiplying by the average number of students (13,827.5), demand decreased by 0.49 million student "class hours" annually. The net increase in demand between 2003 and 2007 was therefore 2.83 million student "class hours" annually.

We can similarly approximate the adjustment margins on the supply side using Equation (F1b) and the data in Table 2. The number of teachers increased 183 between 2003 and 2007. Multiplying by the average teacher "class hours" per teacher (188.9) and average class size (85.9), this increased annual supply of teaching time by 2.97 million student "class hours." Teacher "class hours" per faculty member declined by 111.7. This decreased supply by 6.02 million student "class hours" given the average number of teachers (627.5) and average class size (85.9). Therefore, without accounting for class size changes, supply decreased by 3.05 million student "class hours" and demand exceeded supply by 5.88 million student "class hours." This excess was met by a dramatic increase in class size. The university increased average class size by 51.9 students per class between 2003 and 2007. This increased supply by 6.15 million student "class hours" given the average number of teachers (627.5) and average teacher "class hours" per teacher (188.9).[2]

[1] Table 2 assumes that student attrition rates are zero. While we do not have annual attrition data, it appears to be quite low. For example, 2,598 students were admitted in academic year 2000 and 2,586 graduated four years later implying an attrition rate of 0.5%. Similarly, 2,750 students were admitted in academic year 2001 and 2,718 graduated four years later implying an attrition rate of 1.2%.
[2] This is 0.27 million student "class hours" higher than the shortfall because the differentials involve large changes and we approximate the change point by the average value before versus after the change.

Online Appendix F **Descriptive Statistics for 1,057 Teachers Involved in Undergraduate Teaching before or after the Transition (2000 – 2003; 2007 – 2009)**

Variable	N	Mean	Std. Dev.	Min	Max
Annual "Class Hours"	4,226	233.81	169.68	2.00	1,088.00
Annual Teaching Days[1]	4,199	65.49	38.68	3.00	196.00
Daily "Class Hours"[1]	4,199	3.51	1.48	0.21	9.95

An observation is a teacher-year combination. Includes data for any faculty who teach at least one undergraduate class either before or after the transition. [1] Number of observations for annual teaching days and daily "class hours" is less than 4,226 because some observations are missing day-of-week information.

Online Appendix G **"Before-After" Estimates (2000 – 2003; 2007 – 2009) of Effect of Campus Transition on Work Time Measures**

	1 Annual Undergraduate "Class Hours"	2 Annual Undergraduate Teaching Days	3 Daily Undergraduate "Class Hours"
After Transition	-20.26 ***	-26.79 ***	0.91 ***
	(7.18)	(1.48)	(0.06)
Number of Teachers	192	190	190
Teacher Fixed Effects	Yes	Yes	Yes
Asymmetric Aggregate Time Trends	Yes	Yes	Yes
N	1,344	1,330	1,330
R^2	0.605	0.501	0.537

Dependent variable is: annual undergraduate "class hours" in Columns 1 and 2, annual undergraduate teaching days in Columns 3 and 4, and daily undergraduate "class hours" (conditional on teaching that day) in Columns 5 and 6. Standard errors in parentheses. Standard errors allow for clustering within teacher-transition cell and general heteroskedasticity in all regressions. * = 10% significance, ** = 5% significance, *** = 1% significance. Columns 1, 3, and 5 include teachers present in at least one year either before or after the transition. Columns 2, 4, and 6 include teachers present in all years before and after the transition. All regressions include teacher fixed effects and asymmetric linear time trends. Number of observations lower for annual teaching days and daily "class hours" due to missing day of week information.