KNOWLEDGE SPILLOVERS FROM RESEARCH UNIVERSITIES: EVIDENCE FROM ENDOWMENT VALUE SHOCKS

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Abstract—We estimate the local spillovers from research university activity in a sample of urban counties. Our approach uses the interaction between university endowment values and stock market shocks over time for identification. We find statistically significant local spillover effects from university activity. The effects are significantly larger when local universities are more research intensive or local firms are technologically close to universities. Our results suggest that the longer-term effects that universities have on their local economies may grow over time as the composition of local industries adjusts to take advantage of the heterogeneous knowledge spillovers we identify.

I. Introduction

The geographic concentration of economic activity is a salient feature of modern economies. There are a number of reasons to suspect that the positive externalities associated with the clustering of labor and capital in urban areas accounts for the dramatic economic density we observe. For example, density allows producers to access suppliers more easily and inexpensively, enables them to reach customers more efficiently, and raises the prospects of hiring high-quality workers in a thick labor market. Furthermore, the thick labor market that a city offers mutually benefits workers, who can mitigate their unemployment risk and raise their own chances for a quality employer match. Economists have also devoted significant attention to understanding the importance that knowledge spillovers play in contributing to the increasing returns of geographic density. According to Marshall (1890, p. 332), when productive people locate closely, “The mysteries of the trade become no mysteries; but are as it were in the air… Good work is rightly appreciated, inventions and improvements in machinery, in processes and the general organization of the business have their merits promptly discussed; if one man starts a new idea it is taken up by others and combined with suggestions of their own; and thus becomes the source of yet more new ideas.”

While Marshall seems to have emphasized the organic nature in which knowledge is developed and transferred, in this paper we seek to measure the extent and magnitude of such spillovers from a formal institution whose sole mission is the creation and dissemination of knowledge: the research university. In other words, since research universities exist and are heavily subsidized to “spill knowledge,” it seems natural to look here first to understand the importance that knowledge spillovers can play in agglomeration economies in general. Despite the prominence of high-profile university-industry partnerships in Silicon Valley and along the Route 128 corridor in Massachusetts, there is a relatively small but growing body of empirical research that has attempted to measure the role that universities play in contributing to economic growth at the relatively local level. Following Jaffe (1989; see also Acemoglu, Audretsch, & Feldman 1991), much of the research has explored the spillover effects of academic research on such outcomes as patents, innovations, business start-ups, or employment changes. While the prior research has shown the importance of academic research to the development of specific local industries, such as pharmaceuticals or electrical and electronic equipment, and that the productivity gains from...
academic research tend to be highly localized, we still have little understanding of the causal role that research university activities play in contributing to broad-based regional economic development or the extent to which they facilitate knowledge-based agglomeration.  

This paper seeks to address this question directly. We focus specifically on relatively densely populated counties from 1981 to 1996 and examine how research university activity in these urban counties affected the wages that were paid to workers outside the higher education sector. The main challenge we face is that university activity does not occur randomly. The endogeneity arises because the activities of universities themselves may be directly affected by the presence of highly productive and innovative firms in a region. Highly productive firms may provide the intellectual or physical capital needed for a university-industry partnership to be successful. In addition, if knowledge spillovers are present, then they are likely to flow in both directions. Universities benefit from the presence of highly productive and innovative neighboring firms and workers, much as innovative firms do from the presence of a research university. Furthermore, the presence of highly productive firms may increase the local demand for workers trained in a university setting who transition to local jobs—that is, graduating undergraduate and graduate students, as well as former postdoctoral researchers. Thus, naively examining the cross-sectional correlation between university activity and labor income of workers in the neighboring area may lead one to conclude that universities are the source of productive knowledge spillovers, when in fact the causal link is unclear. Our estimation strategy seeks to isolate the spillover effects of research universities’ activities on their local economies.

To address the endogeneity concern, we develop an instrumental variables strategy based on the fact that universities typically spend a rigid fraction of the market value of their endowments in each year.  

We take advantage of the facts that shocks to stock market returns occur at the national level and that prior levels of university endowments are exogenous to the future economic activity that may occur in their respective counties.  

For example, much of the variation in the size of universities’ endowments across counties is simply a function of when the institutions were founded and how long their endowments have been able to grow. As there is little reason to expect a direct effect of the age of the university (often founded before the twentieth century) on changes in local noneducation sector wages other than through university activity, we regard using prior endowment values as a compelling instrumental variable for contemporaneous university expenditures. As urban counties across the United States had universities with different levels of initial endowments, when interacted with national stock price fluctuations, the instrument will capture variation in university activity that is exogenous to changes in local income. Using this method, we can estimate the causal effect of university activity on local labor income in noneducation sector firms, the parameter of interest.

Our empirical analysis reveals that research university activity results in modest but statistically significant productivity spillovers to other industries. Our IV estimates indicate that a 10% increase in higher education spending in an urban county increases the average worker’s income in the noneducation sector labor income by 0.8%. Put another way, a $1 increase in university spending generates an 89 cent increase in noneducation labor income. We also find that these effects are persistent, at least measured out five years, thus suggesting that an expenditure shock to a university produces something more profound than a simple fiscal multiplier effect.

While the broad spillover effects from universities appear rather modest, we further investigate whether the intensity of university research or closer economic links between universities and local industries magnify the effect, as the prior literature on academic research spillovers would suggest. We first show that the impact of university expenditure on the wages paid by other local firms is nearly three times larger in counties with above-median fractions of graduate students at the local universities than in those with lower levels of graduate students. We then consider three linkage measures. First, we examine whether industries that pool labor markets with the higher education sector receive larger spillovers. Second, we look at how frequently industry patents cite a patent issued by a university to measure industry-specific utilization of higher education knowledge. Finally, we measure the degree to which each indus-

6 Aghion et al. (2009) consider the impact of research university activity on state economies in an endogenous growth framework. Their study finds that exogenous increases in research university activity have a greater impact on economic growth for states close to the technological frontier. Part of the reason for this disproportionate benefit is that potential beneficiaries of such education migrate to the frontier states and away from the distant frontier states. They also find that innovation, in the form of patent activity, increases as a result of the exogenous shocks to higher education. Whalley and Hicks (forthcoming) find that university financial resources increase knowledge production by universities themselves.

7 Recent work by Brown et. al. (2010) analyzing university financial decisions from 1987 to 2008 has demonstrated that universities tend to deviate from their chosen, fixed endowment spending policies when confronted with negative returns to their endowment investments, which were especially salient during the dot-com bust. The authors found no statistical deviation from the chosen spending policy when the returns were positive. While we believe that universities were less likely to adjust their spending policy to stock market shocks during our sample period (1981–1996), we examine the robustness of our results to heterogeneous endowment spending policies.

8 Conceptually, our instrumental variables strategy of using exogenously determined price changes to gain information on local exposure to an economic phenomenon is very similar to that recently used by Black, Daniel, and Sanders (2002) to estimate the effect of local economic activity on disability program participation using the coal boom and bust, and Acemoglu, Finkelstein, and Notowidigdo (2009), who estimate the effect of local income on health spending using oil price shocks.

9 We follow Moretti (2004b), Ellison et al. (2010), and Greenstone, Hombée, and Moretti (2010) in measuring disparate spillover effects based on different measures of economic proximity to higher education.
try employs college graduates, the other primary output of local universities. We find that the impact on labor income in industries that used university knowledge (patents) more intensively, that were more likely to share a labor market with universities, or that hired more college graduates was between 20% and 100% greater than the impact in industries that were technologically more distant from universities.

II. Conceptual Framework

The mechanism by which universities—or any other industry—contribute to knowledge spillovers is a topic of active, ongoing research. On the one hand, we might think that the basic research in which university faculty and staff are engaged has broad applicability that may not accrue locally in any disproportionate manner. Research is produced locally but disseminated in international scholarly outlets and, hence, available for anyone worldwide to adopt. Yet the empirical research has found otherwise. Jaffe, Trajtenberg, and Henderson (1993), for example, show that nearby industrial firms and universities are much more likely to have their patents cited by others who are geographically close. In an analysis of R&D laboratories owned by U.S. firms, Adams (2002) finds that knowledge spillovers from universities are much more localized than industrial spillovers: “Firms go to nearby universities for advice, research, and students. In contrast, industrial interactions take place over a greater distance and occur selectively” (p. 254).10 The localized network effects associated with faculty, research staff, and graduate and undergraduate students, based on recent empirical research, seem to be a critical feature of the relationship between universities and their industrial counterparts that rely on knowledge generation. While highlighting the paradox of the finding that universities, as institutions that are oriented toward generating public knowledge, seem to benefit local private firms disproportionately, Adams (2002, p. 274) suggests that it is the nature of open science that draws firms to locate near academic institutions: Firms “go to local universities to obtain information that is reasonably current and not proprietary…. This increases the localization of academic spillovers.” Yusuf (2008, p. 1173) explains, “The closer one gets to the knowledge frontier, the larger the human factor in the transmission process. Networking and circulation of knowledge workers take on a much greater importance.” Universities, according to Yusuf, often act as hubs that connect the creators and users of path-breaking knowledge that will set the stage for future economic development.

If academic spillovers are indeed highly localized, then what should their impact be on noneducation local labor markets?11 Theoretically, both wages and land rents would be required to estimate the spillover effects of university activity on total factor productivity (see Roback, 1982). However, as Moretti (2004c) and Rosenthal and Strange (2008) point out, nominal income differences across locations are sufficient to estimate the spillover effect on the marginal product of labor. To see why, consider an adaptation of the open-city model from Rosenthal and Strange (2008). The model is based on the concept of spatial equilibrium, where firms and workers are indifferent across locations. In the model, firms and workers make decisions about where to locate. Spatial equilibrium wages and rents are determined by two indifference conditions. First, real wages must adjust so that workers are indifferent across locations with different amenities. Second, nominal wages must adjust so that they are equal to differences in the value of the marginal product of labor across locations.

To understand the effect of the presence of university activity on equilibrium wages and land rents, consider two different locations, one with and one without a university. Suppose that universities enhance local workers’ productivity but do not directly affect workers’ utility.12 In equilibrium, when universities generate knowledge spillovers, firms will expand until the unit cost of production is equalized across locations. As land is an immobile factor, some of the external productivity gains will be capitalized into higher land rents. In this case, the impact of knowledge spillovers on wages is a lower-bound estimate of the overall productivity gains, holding rents constant, even though the impact on nominal wages is an exact measure of the impact on the marginal productivity of labor.13

III. Empirical Approaches

A challenge in estimating the causal effect of university activity on wages, as we have noted, is the endogenous nature of university research activity. We implement two strategies to address the endogeneity concern. Our first strategy is to restrict our analysis to counties with a research university presence and to difference-out time-invariant characteristics of counties and industries, which addresses a wide

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10 For recent corroborating research that industries locate near universities to capture the unique local benefits of their research activities, see Zucker et al. (1998), Woodward et al. (2006), Abramovsky et al. (2007), and Furman and MacGarvie (2007).

11 Our discussion closely follows that in Rosenthal and Strange (2008), who examine evidence for human capital spillovers in nominal wages.

12 Of course, it is also possible that locations with and without a university presence have different levels of amenities that workers value. Shapiro (2006) recently estimated that 60% of the growth rate in employment across metropolitan areas from 1940 to 1990 can be attributed to the agglomeration effects associated with the enhanced productivity of college graduates in a city. The remainder can be attributed to the notion that more highly educated areas experience more rapid growth in quality of life, which contributes to growth in employment, wages, or rents.

13 Arzaghi and Henderson (2008) caution, however, that the benefits of agglomeration may be capitalized into rents more than previous research has realized. In their study of the advertising industry in Manhattan, they show that the information spillovers that occur within a close proximity (occurring within 750 meters) influence rents much more than wages within the industry.
class of potential selection problems. Any permanent differences across counties that are correlated with the scale of university activity such as university quality, the presence of a Silicon Valley, or a highly skilled labor force are factored out in the differencing. Moreover, permanent differences in the location of industries, which may be correlated with university activity, are also effectively controlled. Thus, cross-sectional differences in university activity, or factors associated with universities, across counties do not contribute to the identification. Our results are identified from within-county changes in university activity over time. To allay further concerns that we have not effectively dealt with endogeneity, our second strategy is to adopt an instrumental variables approach.

A. Difference Equation

Our goal is to estimate the responsiveness of changes in labor income to changes in university expenditures in a county using a long-differences specification. We estimate the model as

$$\Delta Y_{ijt} = \alpha_1 \Delta UE_{it} + T + \epsilon_{ijt},$$

where $\Delta Y_{ijt}$ is the long difference in the logarithm of average noneducation sector labor income in county $i$, industry $j$, in year $t$ relative to year $t - x$ ($Y_{ijt} - Y_{ijt-x}$), $\Delta UE_{it}$ is the long difference in per capita total expenditures by universities in county $i$ in year $t$ relative to year $t - x$ ($UE_{it} - UE_{it-x}$), $T$ is a set of year fixed effects, and $\epsilon_{ijt}$ is the error term. Our parameter of interest is $\alpha_1$. The time horizons we examine are three- and five-year long differences.

The long-difference specification in equation (1) effectively addresses concerns that time-invariant county and industry characteristics might bias our estimates of the true impact of university activity. However, a couple of concerns remain. First, many local productivity shocks are unobservable and are likely to affect both local wages and university activity. For example, if a local firm produces an innovation that increases its productivity and also leads to an increase in the demand for collaboration on future research projects with a local university, this unobserved innovation shock would affect both the level of wages and university activity.

The second concern with equation (1) arises because there is likely to be a measurement error in the level of university expenditures in a county. Estimating the model in long differences magnifies any problems that measurement error in university expenditures poses for the estimation of the effect on labor income. If the measurement error in university activity is classical, $\alpha_1$ will be biased toward 0, and we will underestimate the effect of university activity on local labor income. This attenuation effect may well be important, as Rosenthal and Strange (2008) demonstrate in the context of education externalities. Thus, we turn to an instrumental variables estimation strategy to mitigate the concerns that the endogeneity of changes in university activity and measurement error in university expenditure will lead to bias in our estimates of $\alpha_1$. The direction of the bias, we should note, is ambiguous.

B. Instrumental Variable Strategy

Our empirical strategy attempts to identify potentially exogenous sources of variation in university expenditures in a county. We develop our instrument by taking advantage of the fact that many universities follow a rigid spending formula to determine how much of their endowments are spent in a given year. This formula rigidity allows us to instrument for overall university expenditure by exploiting differential impacts of stock price changes across counties where universities had different levels of endowments. In particular, we instrument for $\Delta UE_{it}$ in equation (1) with the first-stage specification,

$$\Delta UE_{it} = \beta_1 (\Delta SM_i \times IE_{it-x-1}) + T + \zeta_{ijt},$$

where $\Delta UE_{it}$ is the long difference in per capita university expenditures in county $i$ in year $t$ relative to year $t - x$, $(\Delta SM_i \times IE_{it-x-1})$ is the long difference in the Standard and Poor’s 500 Stock Index in year $t$ relative to year $t - x$ $(\Delta SM_i)$ interacted with the per capita market value of the endowments of all universities in county $i$ in the year prior to $t - x$ $(IE_{it-x-1})$, $T$ is a set of year fixed effects, and $\zeta_{ijt}$ is the error term. As the year fixed effects flexibly control for any time series variation in $\Delta UE_{it}$, we do not include the main effect of stock market shocks $(\Delta SM_i)$ in the model.

The intuition behind our identification strategy is straightforward. Universities tend to spend a fixed fraction of the market value of their endowments in any year for a number of reasons, including legal constraints on the spending of endowment resources held in trust and constraints placed on them by creditors. As Ehrenberg (2000, 2009) notes, many universities follow a rule of spending 4% to 5% of the market value of their endowments each year. Yoder (2004) finds that the average spending rate for all universities in 1999 was 4.7% of the market value of their endowments, with the most highly endowed spending 4.1% and the least endowed 4.8%. To see why the 4% to 5% spending rule has become a standard among universities, consider that a typical endowment portfolio of 70% stocks and 30% bonds would be expected to yield an average annual return of 9% over the long term. With a historic inflation rate for university costs of 4%, this leaves a real return of 5%. Thus, spending up to 5% of the market value of an endowment ensures the long-term sustainability of its real value. Universities may have different target spending rates depending on the composition of their portfolios, investment returns, preferences for intergenerational equity, or desires to increase the long-term real growth rate of their
endowments, but in practice there is little variation among institutions.14

Universities seek the long-term sustainability of their endowments, so they should not arbitrarily adjust their spending rule to short-term fluctuations in economic conditions, whether unusually favorable or negative. In other words, excess returns would be reinvested in the endowment in a favorable year in order to weather below-normal returns in another. The fixed nature of the spending rule has generated substantial controversy. In the late 1990s and early 2000s especially, the fact that university spending from endowment funds was far below the returns they were able to achieve in financial markets led to congressional hearings on the nature of the spending policies and whether the favorable tax treatment of endowment income should continue. More recently, with the collapse in endowment values due to the 2008 financial crisis, universities have faced pressure from faculty and students to increase the spending rate from the endowment to preserve academic quality. The fact that universities have by and large held firm on their spending policy in the face of significant pressure is largely due to the responsibility they have to protect the principal value of gifts to their endowments on behalf of the long-term sustainability of the institution.15 In fact, Brown et al. (2010) find that it is only during negative market shocks that universities deviate from their established payout policies by reducing payout rates to preserve principal, which has an impact on university expenditures. This finding will not have a material impact on our analysis since we consider three- and five-year changes in variables, and during our sample period the stock market never experienced negative returns over any three- or five-year span.

Since universities generally follow their own stable payout rule and all have different endowment values, then exogenous stock market shocks will lead to variation in the amount of endowment income each university will be able to spend in any one year. As stock market shocks and the level of the initial endowment are exogenous to trends in local economic activity across counties, this variation provides a compelling source to identify the effects of overall university expenditures on local economies.

C. Potential Challenges to the Identification Strategy

Our identifying assumption is that absent stock price changes, labor income in counties with different levels of initial university endowments would have grown at similar rates. This assumption is reasonable since both national stock market prices and the level of initial endowment should not be correlated with subsequent changes in a county’s level of economic activity. Of course, counties with different initial levels of university endowment may differ in other ways that could affect local labor income, such as the skill level of the population, the productivity of local firms, or the availability of valuable amenities. Any such differences that are time invariant will be differenced out in the long-differences model. Only differential trends in income across counties driven by unobservables that are correlated with the level of initial endowment could pose a threat to our identification strategy. While it seems reasonable that our assumption is valid, it is instructive to consider cases where it might be violated.

First, it is possible that stock market shocks affect firms differentially. For example, small firms that are more credit constrained may be more sensitive to cyclical conditions (see Moscarini & Postel-Vinay 2009). If the location of credit-constrained firms is correlated with the initial endowment of universities in a county, then our identification assumption may be undermined. We address this and other potential concerns with firms’ differential exposure to stock market shocks by estimating additional models where we allow for changes in labor income in each industry to be differentially correlated with changes in stock prices.

Second, it is possible that stock market shocks affect universities differentially. For example, higher-quality universities hold a different portfolio of assets in their endowments (see Lerner et al. 2008). If higher-quality institutions hold assets that are less correlated with stock market shocks, this will weaken our first stage for this group of universities. To address this concern, we estimate models where we allow changes in labor income in each county to be differentially correlated with changes in the stock market depending on the average quality of universities in the county and examine models where we allow universities to be differentially exposed to stock market shocks. To measure institutional quality, we use the average of the 1991 U.S. News and World Report (USNWR) quality rankings of the institutions within a county.16

14 While differences across institutions in their target spending rates are small, differences in the rate of return they experience may well be larger. Lerner, Schoar, and Wang (2008) show that the colleges and universities in the top quartile of the SAT admission distribution experienced a 1.4% greater return on their endowments from 1992 to 2005 than those of a median SAT institution. Much of the differences in the rates of return are explained by different portfolio allocations, with asset selection and management differences explaining a smaller portion. One change that has generated much discussion recently is the increasing allocation toward relatively new alternative assets such as hedge funds, private equity, and venture funds. This change is quite recent, and many institutions still have very small holdings in these asset classes. Lerner et al. (2008) note that in 1992, these types of assets accounted for only 1.1% of all assets but grew to 8.1% in 2005. Thus, in our sample period of 1981 to 1996, these alternative assets made up only a small portion of endowment portfolios.

15 See Salem (1992). It is worth noting that while we have discussed endowments as if they were one entity, in practice each separate gift has a separate endowment account. Many endowment gifts are restricted to funding a certain chair, a scholarship, or a building at an institution, and universities are legally bound to disburse the money of the endowment in accordance with the donor’s intent. Whereas many gifts to university endowments have strings attached, endowment disbursements are largely fungible. That is, donors typically provide gifts to support the core activities of the university, such as hiring faculty and offering student aid, so the restrictions that donors place on gifts are unlikely to substantively alter the composition of a university’s expenditures. A university can always decline gifts inconsistent with its mission or strategic plans.

16 As relative institutional quality is very stable over time and the 1991 issue of USNWR was the first to include all national colleges in the rankings algorithm, we treat these data as time-invariant measures of quality.
In sum, while we cannot completely rule out the possibility that some of the effect we report reflects time-varying county-specific changes in unobserved labor productivity within a county, it appears that many sources of spurious correlation are controlled.

D. Other Estimation Considerations

A few other estimation details are worth noting. First, we cluster the standard errors at the county level to address the fact that university expenditure is measured at the county level and the same expenditure is affecting all industries within the county (see Moulton, 1986). This clustering also allows us to address the concern that changes in labor income may be serially correlated within a county-industry cell. Second, we weight all of the industry-county cells by their employment level in 1981. Our estimates, then, represent the effect of university activity on the income of the average worker, not on the average industry-county cell. Third, in measuring the scale of university activity, we use total university spending from all revenue sources, ranging from tuition, state support, and federal grants to endowment income.

Fourth, we estimate alternative versions of equations (1) and (2) where we define the long differences as occurring over a three-year and five-year time horizon. Differences in estimates of \( \tau_1 \) between models with different temporal lags help us to understand whether any spillovers are persistent or only transitory. We examine a five-year change in labor income to better capture potential migration responses to changes in university activity. As 20% of Americans change counties about every five years (Glaeser & Gottlieb, 2009), the lagged responses may better capture those discussed in the spatial equilibrium literature.

Finally, we probe the validity and robustness of our estimates with a number of alternative specifications. For example, we allow stock market shocks to have a differential impact on different industries or types of universities. We also present specifications where the long differences in university expenditures are lagged instead of contemporaneous.

IV. Data

The primary data needed to implement the empirical analysis are overall university expenditures, endowment market values, and local labor income in the noneducation sector. We obtain annual financial data on each university, as well as data on their characteristics, from the U.S. Department of Education’s Higher Education General Information Survey (HEGIS) and the Integrated Postsecondary Education Data System (IPEDS) from 1981 to 1996. The HEGIS/IPEDS data provide a census of all four-year colleges and universities in the United States and report information on revenue, expenditure, enrollment, and institutional characteristics from each institution. HEGIS was replaced with the IPEDS survey in 1984. We end our analysis in 1996 because the U.S. Department of Education has unfortunately not released the institutional financial data from the 1997 to 2000 surveys. In addition, there were significant changes in the accounting methods used to report expenditure and revenue beginning with the 2000 survey, thus making it difficult to compare to the earlier data. In addition, universities began investing in much more complicated financial assets after the end point of our study, so the use of stock market changes should prove to be a more powerful instrument for the period of our study. Nonetheless, we test the robustness of our results by examining whether they are sensitive to constructing our instrument using endowment market value held in equities alone. These portfolio data were collected from the National Association of College and University Business Officers (NACUBO). We construct our measure of equity holding based on the average percentage held in domestic equities over the entire sample period.\(^\text{17}\) Our second central data source is the U.S. Census Bureau’s County Business Patterns (CBP) data set that contains information on annual labor income and employment by industry for each county. We also use baseline demographic information on counties from the U.S. Census Bureau’s 1983 County and City Data Book (CCDB). As a measure of the quality of each institution, we use the USNWR college rankings from 1991. Finally, our instrumental variable uses annual data on the Standard and Poor 500 (S&P 500) stock market index.

We form our analysis sample by first limiting the set of institutions to the leading research colleges and universities. We define the population of research institutions as those classified as Research I, Research II, Doctoral I, or Doctoral II in the 1994 Carnegie Classification of Higher Education Institutions. This initial sample contains 229 institutions. Since we restrict our attention to counties with populations above 250,000 and exclude the District of Columbia, the resulting sample of colleges and universities is 138 institutions. We impose this geographic restriction as we are interested in estimating the effect of research university activity in large, diversified local economies that contain the broadest representation of industries. In addition, to preserve confidentiality, the CBP data mask industry-county cells with a small number of establishments, which are more likely to occur in relatively small counties. This sample restriction results in the loss of a few prominent research universities that are located in small counties, such as Duke University. Further, we drop three institutions that do not report expenditures in at least fifteen years of our sixteen-year sample period.\(^\text{18}\) For fourteen institutions that are missing only one year of expenditure data, we impute the missing value by inflating the institution’s prior year expenditure by the national growth rate in all institutions’ expenditures. The final sample consists of 135 colleges and universities located in 85 counties.

\(^\text{17}\) We use an average over the entire sample period because some universities did not report in the NACUBO data in every year.

\(^\text{18}\) As a result of dropping the three universities with missing expenditure data, we were forced to drop one county that had only the single research university (Rutgers, New Brunswick, in Middlesex County, New Jersey). For the other two universities, their counties remain in the sample.
We aggregate the institution-level data to the county level. We keep all SIC two-digit industries in the CBP data, but drop tobacco manufacturing (2100) because it is a highly geographically concentrated industry. We also drop the education sector (SIC 8200) and agriculture, minerals, and mining (SIC of less than 1500) from the analysis. As there is some entry and exit of small county-industry cells in the CBP data, likely caused by the masking of confidential information, we restrict our analysis to the industries that are reported consistently over time within a county. There are a potential 58 industries, across 85 counties, over fifteen years included in the data set, although not all industries are reported in each county.

We construct our instrument by interacting the endowment market value in each county in the year prior to the three- or five-year period under consideration with the change in the S&P 500 Index over that three- or five-year period. We normalize the S&P 500 Index so that the 1981 value is 1. As university expenditure is reported for the fiscal year from July to June, we use the average value of the S&P Index over the fiscal year so that the timing of stock market shocks lines up with the timing of university expenditures.

Columns 1 and 2 of table 1 show the means and standard deviations of various county characteristics, computed over all large counties (populations greater than 250,000) in the first year of the sample, dividing large counties by whether they have a university. Column 3 presents t-statistics for a test of differences in the means between columns 1 and 2. The comparison yields a number of interesting results. First, nominal labor income in noneducation industries is statistically significantly higher in research university counties than in nonuniversity counties. Second, university counties are much larger, have higher crime rates, and are more racially diverse. There is little difference in the education level of the workforce or housing rents across the sets of counties, however. Third, there are significant differences in the industry distribution of the workforce. University counties have less employment concentrated in retail trade and more employment concentrated in transportation and communications, finance, insurance, real estate services, and other services. Table 1 demonstrates that the differences between university and nonuniversity counties in noneducation sector labor income could be due to a number of observable differences. Because there are also likely significant differences in unobservable determinants of nominal income between university and nonuniversity counties, our central empirical analysis focuses on university counties alone.

Table 2 presents descriptive statistics for the subsample of 85 urban (populations greater than 250,000) counties that have research university activity. Columns 1 and 2 show the means and standard deviations of various county characteristics, dividing the sample counties based on whether their university expenditures in 1981 fell above or below the median value. Columns 4 and 5 divide the counties based on whether their university endowments in 1981 fell above or below the median. Columns 3 and 6 present t-statistics for a test of differences in the means between columns 1 and 2 and between 4 and 5, respectively. The table reveals, perhaps unsurprisingly, that counties with above-median university expenditures have statistically significantly larger endowments, and those counties with larger endowments have relatively larger endowments have relatively higher nominal labor income in noneducation sectors, the same difference does not carry over to counties with above- and below-median university expenditures. Thus, in contrast to table 1, this cursory look would suggest little marginal impact of university activity itself on noneducation labor income.

Table 2 reveals other important connections between university expenditures, endowments, and characteristics and their relationships to county characteristics. The data show that older universities have larger endowments and spend more on current operations. While below-median endowment counties tended to have a greater share of public universities, there was no significant difference when considering expenditures. Further, the data reveal that counties with above-median expenditures and endowments had higher-quality institutions.

There are also significant differences between the groupings of counties in terms of the average skill levels of the populations. Counties with relatively greater university expenditure and endowment levels had more skilled workers, as measured by the percentage of the population with a college degree. As these characteristics are likely to affect county wage levels independent of university spending, and likely correlated with important unobservables, this comparison demonstrates the value of using an IV strategy to achieve a causal estimate of the impact of university activity.

Table 2 also reveals that counties with above- and below-median university activity differ in terms of how their labor forces are distributed across industries. Counties with above-median university expenditures have a larger fraction of the labor force in finance, insurance, and real estate services than those with below-median university expenditures. Similarly, counties with above-median university endowments have a lower fraction of the labor force concentrated in retail trade. This difference suggests, like table 1, that the unobserved characteristics of firms are likely to differ across counties with varying levels of university activity. As the location and scale of high-productivity firms may well determine university activity, this comparison again demonstrates the value of using an IV approach.

V. Regression Results

A. First Stage

Our IV strategy exploits variation in university expenditures across counties arising from the fact that counties had varying levels of initial research university endowments that were all exposed to similar financial market shocks over the three- or five-year time period we consider in our
long-difference analysis. In table 3, we present the results from estimating the first-stage model in equation (2). The estimates in the table show that the coefficient on the interaction between initial endowment and stock market fluctuations results in a strong first stage. The $F$-statistic on the excluded instruments in the first stage is above the threshold level of 10 that has been established as key to reducing potential weak instrument bias (Bound, Jaeger, & Baker, 1995).

The coefficient estimate of the instrument’s impact on the change in university expenditures reported in table 3 column 2 translates into a 9 cent marginal effect from a $1 increase in endowment value, which is higher than the typical endowment spending policy of 4% to 5% reported above. The higher coefficient estimate is likely the result of the fact that our first-stage model is based on endowment value as of the year prior to the three- or five-year period under consideration. Universities, of course, determine their current spending from endowment funds based on the portfolio’s value in the years immediately surrounding the year the decision is made. Our use of the smaller endowment value in the year prior to the time horizon in question will

<table>
<thead>
<tr>
<th>Outcome</th>
<th>University Counties</th>
<th>Nonuniversity Counties</th>
<th>Columns 1–2 t-Statistic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average annual labor income in noneducation sector (1981)</td>
<td>$15,325 ($1,419)</td>
<td>$14,719 ($1,303)</td>
<td>2.97</td>
</tr>
<tr>
<td>University characteristics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>University expenditure (per 000 population 1981)</td>
<td>$0.71 ($1.01)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>University endowment market value (per 000 population 1981)</td>
<td>$0.47 ($1.27)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Percent of endowment in invested in domestic equity</td>
<td>50 (12)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Year of opening</td>
<td>1852 (51)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Fraction public (1981)</td>
<td>0.61 (0.42)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Average quality ranking (1991)</td>
<td>2.22 (1.12)</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Economic and demographic characteristics (1980)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population</td>
<td>940,703 (1,007,882)</td>
<td>440,303 (186,825)</td>
<td>4.73</td>
</tr>
<tr>
<td>% college graduate</td>
<td>16 (4)</td>
<td>15 (5)</td>
<td>1.03</td>
</tr>
<tr>
<td>% black</td>
<td>16 (13)</td>
<td>9 (9)</td>
<td>4.13</td>
</tr>
<tr>
<td>Average rent</td>
<td>$255 ($34)</td>
<td>$258 ($41)</td>
<td>–0.57</td>
</tr>
<tr>
<td>Crime rate (per 000 population)</td>
<td>7,385 (2,477)</td>
<td>5,850 (1,795)</td>
<td>4.78</td>
</tr>
<tr>
<td>% service spending on amusements</td>
<td>12 (18)</td>
<td>8 (12)</td>
<td>1.59</td>
</tr>
<tr>
<td>Population, 1900</td>
<td>225,704 (363,076)</td>
<td>83,120 (73,337)</td>
<td>3.66</td>
</tr>
<tr>
<td>Manufacturing output per capita, 1900</td>
<td>223 (153)</td>
<td>240 (266)</td>
<td>–0.49</td>
</tr>
<tr>
<td>Industry distribution of labor force (1981; %):</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td>0.06 (0.02)</td>
<td>0.06 (0.04)</td>
<td>–0.09</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>0.23 (0.08)</td>
<td>0.26 (0.11)</td>
<td>–1.84</td>
</tr>
<tr>
<td>Transportation and communications</td>
<td>0.07 (0.03)</td>
<td>0.06 (0.02)</td>
<td>2.60</td>
</tr>
<tr>
<td>Wholesale trade</td>
<td>0.07 (0.02)</td>
<td>0.07 (0.03)</td>
<td>1.15</td>
</tr>
<tr>
<td>Retail trade</td>
<td>0.20 (0.04)</td>
<td>0.23 (0.05)</td>
<td>–3.34</td>
</tr>
<tr>
<td>Finance, insurance, and real estate</td>
<td>0.08 (0.03)</td>
<td>0.07 (0.02)</td>
<td>3.53</td>
</tr>
<tr>
<td>Services</td>
<td>0.27 (0.04)</td>
<td>0.25 (0.06)</td>
<td>2.84</td>
</tr>
<tr>
<td>Number of counties</td>
<td>85</td>
<td>94</td>
<td></td>
</tr>
</tbody>
</table>

*Labor income data are from U.S. Census Bureau County Business Patterns; data relating to university expenditures, endowments, and ownership status are from the U.S. Department of Education Higher Education General Information Survey (HEGIS) and the Integrated Postsecondary Educational Data System (IPEDS); and college and university quality data are from U.S. News & World Report (1991). Socioeconomic county characteristics are from the U.S. Census Bureau County and City Data Book (1983), and the industrial distribution of the labor force is from U.S. Census Bureau County Business Patterns. The sample contains one observation for each county. The main entries in columns 1 and 2 are the means of the selected variable. The entries in parentheses in columns 1 and 2 are the standard deviation of the selected variables. Reported $t$-statistics are obtained from a regression of university county indicator on the selected variable. All reported monetary amounts are in nominal dollars.
cause the coefficient estimate to be greater than the actual spending rate.  

If the difference between the parameter that our approach estimates and the typical spending rule is due to the use of an earlier endowment market value, then a similar regression with annual differences in expenditure and endowment values should lead to point estimates closer to the spending rate. (We thank an anonymous referee for this suggestion.) Consistent with this explanation, in an (unreported) analysis, we find an implied spending rate of 2.4% in an annual first-differences model. Measurement error, exacerbated by the first differencing, is likely attenuating the coefficient.

### B. Second-Stage Long-Difference Estimates

Table 4 reports the central results of the paper. The top panel presents the results from estimating long-difference equation (1) considering the three-year time horizon; the bottom panel presents results from the five-year long-difference model. Each column presents the results from one estimation. Column 1 reports OLS estimates of the model and column 2 presents the TSLS estimates.

In column 1 of the top panel of the table, the OLS estimate indicates that a 1 standard deviation increase in univer-
sity activity per thousand residents within a county ($1.01) statistically significantly increases noneducation labor income by 6.5%. In column 1 of the bottom panel, the estimated effect remains statistically significant at the five-year horizon, suggesting that increasing the scale of research university activity in a county has longer-term spillovers to other industries within a county. The evidence we present below on the timing of the expenditure shocks further indicates that these estimated spillovers are persistent and not merely the short-term result of a fiscal multiplier effect.

In column 2 of table 4 we present the TSLS estimates. In the top panel, the estimate indicates that a 1 standard deviation increase in university activity ($1.01) increases noneducation labor income by 11.5%. This estimate is statistically significantly different from 0 at the 1% level. In the lower panel, the five-year long-difference result is very similar to the magnitude of the three-year effect and is statistically significant at the 1% level. The estimated coefficient implies an elasticity of university expenditures with respect to noneducation labor income of 0.08.  

Put differently, a $1 increase in university expenditures would lead to a $0.89 increase in noneducation sector labor income. In other words, the overall multiplier for university activity is roughly 1.9 (the university’s own $1 effect plus the external effect). The implied multiplier is notably lower than the multipliers typically reported by universities.

C. Employment Effects

The final set of core results we present is an analysis of employment effects. As Ciccone and Hall (1996) and Ciccone (2002) point out, the relative strength of the employment-and output-density externalities will depend on such factors as the prevalence of decreasing returns to immovable factors, such as land, or the availability of physical capital. Furthermore, in the textbook spatial equilibrium model, workers will migrate costlessly, thus eliminating any gains from spatial arbitrage and causing nominal wages to equal the marginal revenue product of labor. However, when there are meaningful costs to migration, the wages of local workers can increase by more than the change in their labor productivity would otherwise dictate in a long-run equilibrium. Thus, if there were frictions in the reallocation of labor across space, the effects of research university expenditures on noneducation sector wages would represent an upper bound on the total factor productivity effects of research university activity. Examining the employment effects of university expenditure provides a sense of whether such frictions exist in the mobility of workers across space in the relatively short time periods considered in our analysis.

We analyze the employment effects of university activity by estimating models similar to equations (1) and (2), but we replace changes in wages with changes in employment levels. The results are reported in table 5. We find little evidence of a positive employment response, which can be explained by short-term labor market frictions, physical capital constraints, or decreasing returns to immovable factors such as land.
Table 5.—The Effect of University Activity on Local Employment, 1981–1996

<table>
<thead>
<tr>
<th>Model</th>
<th>Three-Year Differences</th>
<th>Five-Year Differences</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OLS</td>
<td>TSLS</td>
</tr>
<tr>
<td>Δ University Expenditure per Capita</td>
<td>–0.020 (0.061)</td>
<td>–0.123 (0.081)</td>
</tr>
<tr>
<td>F-statistic: Δ Stock Index × Lagged Market Value of Endowment</td>
<td>12.96 [0.0005]</td>
<td></td>
</tr>
<tr>
<td>Number of observations</td>
<td>40,380</td>
<td></td>
</tr>
</tbody>
</table>

See table 1. The estimates presented are for a modified version of model (2) in the text where the long difference in university expenditure is lagged by the length of the long difference. The test statistic value is reported as the main entry, and the p-value of the test is reported in brackets. Significantly different from 0 at *10%, **5%, and ***1%.

Table 6.—The Dynamic Effects of University Activity on Local Labor Income, 1981–1996

<table>
<thead>
<tr>
<th>Model</th>
<th>Differences in log Income</th>
<th>OLS</th>
<th>OLS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Three Year</td>
<td>Five Year</td>
<td></td>
</tr>
<tr>
<td>Δ University Expenditure per Capita (t – 1)</td>
<td>0.057* (0.031)</td>
<td>0.053 (0.038)</td>
<td>0.070** (0.032)</td>
</tr>
<tr>
<td>Δ University Expenditure per Capita (t – 2)</td>
<td>0.070** (0.032)</td>
<td>0.053 (0.036)</td>
<td>0.065** (0.029)</td>
</tr>
<tr>
<td>Δ University Expenditure per Capita (t – 3)</td>
<td>0.065** (0.029)</td>
<td>0.056 (0.038)</td>
<td>0.076** (0.030)</td>
</tr>
<tr>
<td>Δ University Expenditure per Capita (t – 4)</td>
<td>0.076** (0.030)</td>
<td>0.065** (0.038)</td>
<td>0.120*** (0.043)</td>
</tr>
<tr>
<td>Number of observations</td>
<td>40,380</td>
<td>33,650</td>
<td>30,285</td>
</tr>
</tbody>
</table>

See table 1. The estimates presented are for a modified version of model (2) in the text where the long difference in university expenditure is decomposed into a sequence of first differences in university expenditure variables. All estimates are weighted by the level of employment in the industry-county cell in 1981. The main entries in columns 1 and 2 are coefficient estimates. The entries in parentheses in columns 1 and 2 are standard errors. The test statistic value is reported as the main entry, and the p-value of the test is reported in brackets. Significantly different from 0 at *10%, **5%, and ***1%.

VI. The Mechanisms Underlying the Spillover Effects

In this section, we seek to shed light on the mechanisms underlying the spillover effects we have identified. First, we present evidence on the timing and persistence of the measured effect. We suggest that it is not merely driven by a stimulus effect from increased local university expenditures. Next, we analyze how stock market–driven shocks to the endowment market value affected the universities’ spending behavior. These results provide some insight into the source of the spillover effect we measure for the county at large.

A. Timing and Persistence of the Spillover Effect

Table 6 reports results from an OLS regression that seeks to decompose the three- or five-year long difference in noneducation labor income as a function of the yearly first differences in university expenditures over the period in question. While it would be impractical to instrument for each of the first differences, the OLS provides some insights into the dynamics of the spillover effect on labor income. The results from the three-year estimation show that the annual difference in university expenditures from the second and third lags are both statistically significant and contribute to the three-year change in labor income roughly equally. The five-year estimation shows even more clearly the longevity of the spillover effect. While the baseline estimate presented in table 4 would reflect the average of the annual first differences in university expenditures, the results in table 6 indicate that the substantially larger and statistically stronger effects are coming from the fourth and fifth lags. In other words, it does not appear that increases in noneducation labor income result primarily from short-term stimulus–like increases in university expenditures that die off quickly. Instead, the dynamic pattern of the decomposed estimate is consistent with the idea that spillovers from university activity take time to manifest and remain persistent.
ceeding the long-difference period we consider for the changes in labor income. The estimates of both the OLS and TSLS three- and five-year long-difference models are roughly the same as those found in the baseline contemporaneous models, although the power of the instrument falls in the five-year equation. These results demonstrate the persistence of the effect of expanded research university expenditures on nominal wages. The estimated effect seems to be something other than a short-term fiscal stimulus effect.

B. Changes in Other University Outcomes

In table 8 we begin to identify the mechanism by which increased research university activity might spill over to the noneducation sector. The results thus far have shown that the current expenditures of universities in a county have meaningful effects on the wages paid by other firms, but have said little about the potential sources of the research universities’ impact on labor income in other industries. To shed light on this issue, we examine how research universities adjust their spending as a result of changes in endowment income. Table 8 reports OLS estimates of the three- and five-year long-difference models, similar to equation (2), with undergraduate enrollment, graduate enrollment, university donations, building expenditures, and equipment expenditures as outcomes. Interestingly, the strongest impact of a stock market–driven endowment shock comes in the form of expanded graduate student enrollment. Undergraduate enrollment is unaffected. Taken together, these results suggest that increased income from endowment sources translates into an increase in research intensity.

The results here again indicate that our findings represent something more substantive than a simple short-term stimulus effect. We cannot reject the hypothesis that increased endowment income had no effect on university building expenditures over a five-year time period or equipment expenditures under either the three- or five-year period. We do detect a small, statistically significant increase in building expenditures over the three-year horizon, however. The small size of this estimate, coupled with the relatively small size of the higher education sector within a county, implies that an implausibly large multiplier effect would be required for a pure stimulus effect to account for our central findings.

Finally, we find a positive but statistically insignificant effect on changes in donations as a result of relatively greater stock market gains. This finding provides evidence that our instrument satisfies the exclusion restriction. A potential concern with our instrument is that stock market shocks might be differentially correlated with local industries that experienced productivity gains. If this were the case, we might expect to see such gains manifest in greater contributions to local universities, which is not borne out in the data.

C. Heterogeneous Effects across Industries

Some studies of agglomeration spillovers suggest that the magnitude of the effect is related to input and output linkages or the pooling of labor markets (see Moretti, 2004b; Ellison et al. 2010; Greenstone et al., 2010). In addition, as noted earlier, previous research has found that knowledge spillovers from universities seem to be more localized than for other industries. Therefore, to explore more explicitly the sources of the research university spillovers that we

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Table 8.—The Effect of Stock Market Shocks Interacted with the Value of Lagged Endowments on Other University Outcomes, 1981–1996

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Δ University Undergraduate Enrollment per Capita</th>
<th>Δ University Graduate Enrollment per Capita</th>
<th>Δ University Donation Revenue per Capita</th>
<th>Δ University Building Expenditure per Capita</th>
<th>Δ University Equipment Expenditure per Capita</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>OLS</td>
<td>OLS</td>
<td>OLS</td>
<td>OLS</td>
<td>OLS</td>
</tr>
<tr>
<td>Model 1: Three-Year Differences</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ Stock Index × Lagged Market</td>
<td>0.043**</td>
<td>0.163*</td>
<td>0.002</td>
<td>0.007**</td>
<td>0.001</td>
</tr>
<tr>
<td>Value of Endowment</td>
<td>(0.117)</td>
<td>(0.100)</td>
<td>(0.003)</td>
<td>(0.003)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Observations</td>
<td>1,020</td>
<td>850</td>
<td>1,014</td>
<td>561</td>
<td>569</td>
</tr>
<tr>
<td>Model 2: Five-Year Differences</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ Stock Index × Lagged Market</td>
<td>0.014</td>
<td>0.240**</td>
<td>0.001</td>
<td>0.005</td>
<td>0.003*</td>
</tr>
<tr>
<td>value of endowment</td>
<td>(0.146)</td>
<td>(0.098)</td>
<td>(0.001)</td>
<td>(0.004)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Observations</td>
<td>850</td>
<td>765</td>
<td>845</td>
<td>320</td>
<td>322</td>
</tr>
</tbody>
</table>

See table 1. The stock market index is the S&P 500 Stock Index. The estimates presented are for a modified version of model 3 in the text with the indicated university outcome variable replacing university expenditure. The unit of observation is at the county-year level. All estimates are weighted by the level of employment in the county cell in 1981. All university expenditure variables and lagged market value of endowment are measured as the spending rate per county population/1,000. University undergraduate enrollment per capita and university graduate enrollment per capita variables are measured as the enrollment rate per county population × 1,000. The entries in the first and fourth rows of columns 1–5 are coefficient estimates. The entries in parentheses in second and fifth rows of columns 1–5 are standard errors of the coefficient estimates clustered at the county level. Significantly different from 0 at *10%, **5%, and ***1%.

---

24 To see this, we calculate the building expenditure-log(labor income) effect needed to entirely account for our results and compare it to the estimated total expenditure-log(labor income) effect reported in table 4. Consider the effect of a 1 unit change in Δ Stock Index × Lagged Market Value of Endowment. From the three-year results in tables 3 and 4, the total log(labor income) effect is given by

\[ \Delta \text{Building Expenditure} \times \text{Log(labor income)} \]

required to account for a change in log(labor income) of 0.008778 is given by

\[ \Delta \text{Building Expenditure} = \frac{0.008778}{0.008778} \]

which translates into a 0.008778 effect. To translate this back into labor income, we can use the elasticity of labor income with respect to building expenditures. Let \( \beta_l \) be the elasticity of labor income with respect to building expenditures. Then the effect on log(labor income) is given by

\[ \Delta \text{Building Expenditure} \times \beta_l \]

Therefore, the building expenditure effect required to account for our results is

\[ \Delta \text{Building Expenditure} \times \beta_l = \frac{0.008778}{\beta_l} \]

This effect is a measure of the sensitivity of labor income to building expenditures. To see how this compares to the total expenditure effect, we can use the elasticity of building expenditures with respect to labor income, \( \gamma_l \), which is given by

\[ \Delta \text{Building Expenditure} \times \Delta \text{Labor Income} \]

Therefore, the building expenditure effect required to account for our results is

\[ \Delta \text{Building Expenditure} \times \gamma_l \]

To see this, we calculate the building expenditure-log(labor income) effect needed to entirely account for our results and compare it to the estimated total expenditure-log(labor income) effect reported in table 4. Consider the effect of a 1 unit change in Δ Stock Index × Lagged Market Value of Endowment. From the three-year results in tables 3 and 4, the total log(labor income) effect is given by

\[ \Delta \text{Building Expenditure} \times \text{Log(labor income)} \]

required to account for a change in log(labor income) of 0.008778 is given by

\[ \Delta \text{Building Expenditure} = \frac{0.008778}{0.008778} \]

which translates into a 0.008778 effect. To translate this back into labor income, we can use the elasticity of labor income with respect to building expenditures. Let \( \beta_l \) be the elasticity of labor income with respect to building expenditures. Then the effect on log(labor income) is given by

\[ \Delta \text{Building Expenditure} \times \beta_l \]

Therefore, the building expenditure effect required to account for our results is

\[ \Delta \text{Building Expenditure} \times \beta_l = \frac{0.008778}{\beta_l} \]

This finding provides evidence that our instrument satisfies the exclusion restriction. A potential concern with our instrument is that stock market shocks might be differentially correlated with local industries that experienced productivity gains. If this were the case, we might expect to see such gains manifest in greater contributions to local universities, which is not borne out in the data.
have identified, we test for evidence of heterogeneous responses depending on the research intensity of the universities within the county and how technologically close an industry is to the higher education sector.

We first stratify the sample of urban counties based on the fraction of the universities’ students who are graduate students. If the magnitude of the spillover effect varies based on the research intensity of the universities, this will be suggestive of the idea that knowledge spillovers provide a source of the measured beneficial effect on local industries. We next examine whether industries that pool labor markets with the higher education sector receive larger spillovers. This measure is based on workers’ transitions out of (into) higher education and into (out of) their pooling industry counterparts. Our labor market pooling measure is constructed from CPS data on the frequency of transitions of workers between higher education and other industries. We consider two measures of how intensively an industry uses the output of universities. First, we look at how frequently industry patents cite a patent issued by a university to measure industry-specific utilization of higher education knowledge. Second, we measure the intensity of each industry’s employment of college graduates. The measure is based on the fraction of workers in each industry who are college graduates, as calculated from the 1980 IPUMS Census microdata.

In table 9 we present TSLS results where we stratify the sample along these dimensions. Columns 1 and 2 in table 9 show the TSLS results when we stratify the sample based on the graduate education intensity of the county’s universities. The estimated effect of increased university expenditures on noneducation labor income is remarkably higher in relatively research-intensive counties, as measured by above-median graduate education. For example, considering the five-year time horizon, 1 standard deviation increase in university expenditures per thousand residents ($1.01) in the research-intensive county caused a 13.5% increase in labor income in the above-median counties, but only a 4.2% increase in the below-median counties.

Turning next to the industry stratification, we find that industries that pool labor with universities have approximately twice the responsiveness to university activity when compared to the low-pooling intensity industries (see columns 3 and 4). Increases in university activity at the three- and five-year time frames are more likely to benefit workers who are employed in industries that experience a robust two-way labor market relationship with higher education.

In columns 5 and 6 we present the results when we stratify the sample by industry patent citation intensity. There is clearly a difference in the impact of university activity across above-median and below-median patent citation industries. The TSLS estimate for the above-median industries at five years reported in column 5 in the bottom panel are 32% larger than the estimates for the below-median industries in the bottom panel of column 5. This result suggests that larger spillover effects tend to accrue in counties

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25 We construct our industry patent citation measure from the NBER patent database (Hall, Jaffe, & Trajtenberg, 2001). For each industry, we calculate the fraction of citations to other patents that were issued to universities. For this measure, we consider all patents issued by universities, not just the sample of universities located in urban areas that we consider in this paper.

26 Because many industries do not issue patents, the sample size here is necessarily smaller than the full sample used above.
more heavily populated with industries that use university knowledge more intensively in their own innovation processes. Finally, in columns 7 and 8, we present results where we stratify industries based on their employment of college graduates. We find weak evidence that industries that use college-educated labor receive larger spillovers. Industries that employ an above-median fraction of college graduates. We find weak evidence that industries that disproportionately benefit from a research university’s activities will have a greater-than-average presence in technologically closer to universities experience relatively greater spillovers provides a rationale for such industries to colocate near universities.

These stratified results strongly suggest that it is research and technological innovation that spills over from universities, which is then capitalized in higher nominal wages enjoyed by workers in local noneducation industries. Workers in industries that are technologically closer to the knowledge generated from universities disproportionately benefit.

VII. Robustness of the Results

In this section, we explore the robustness of the results as we alter various assumptions of the baseline empirical estimation. We first explore a potential cause for the TSLS estimate exceeding the OLS estimate (see table 4). Such an outcome suggests that measurement error in university activity may be attenuating the OLS long-difference results toward 0. In table 10, columns 1 and 2, we reestimate the models, but trim the sample of observations for which the endogenous university expenditure variable is in the top or bottom fifth percentile. Eliminating these outlying observations causes the OLS estimate to converge significantly toward the TSLS value, which suggests that the IV approach seems to be an important counterbalance to measurement error in the endogenous variable. We further experiment with the same top and bottom fifth percentile trim on the outcome variable (see columns 3 and 4) and find similar (but more precisely estimated) results to our baseline estimation, though the TSLS estimate is somewhat smaller. This analysis suggests that our baseline IV estimates are larger in magnitude than the OLS estimates most likely because of measurement error in the endogenous variable, diminishing the concern about upward simultaneity bias.

We further explore the sensitivity of the baseline results to various assumptions we have imposed on the empirical model. In column 5 of table 10, we cluster the standard errors at the county-year level instead of at the county level. This approach increases the precision of the estimates and dramatically raises the power of the instrument. In column 6, we run the TSLS model unweighted. While statistically significant, the coefficient estimates are smaller and the power of the instrument declines such that the F-statistic falls below 10. Our goal in weighting the regression to account for employment in the industry-county-year cell is to capture the effect of university activity on the average worker within the county, as opposed to the average effect across all industries. The relatively large difference between the weighted and unweighted regressions suggests that industries that disproportionately benefit from university activities will have a greater-than-average presence in such university counties. The evidence that industries that are technologically closer to universities experience relatively greater spillovers provides a rationale for such industries to colocate near universities.

Finally, because our university expenditure and endowment data are measured at the county-year level, which is then tied to all industries in the county-year cell, we reestimate the equation considering the average noneducation labor income at the county-year level as well. Column 7 shows that the estimated coefficient is about half the magnitude as our baseline regression using individual industry observations. Again, this finding suggests that industries that disproportionately benefit from a research university’s
presence are generating heterogeneous effects, which in turn dampens the county-aggregate effect.27

### A. Alternative University Endowment Specifications

We further examine whether our results are robust to important changes in our instrument strategy. We begin by testing whether the results are robust to allowing stock market shocks to have differential impacts on university expenditures, as the findings in Brown et al. (2010) indicate. We do this in two ways. First, we construct a measure of the extent to which university endowments within a county were invested in domestic equities instead of using the overall market value of the endowment. We are then able to examine whether accounting for differences in observable portfolio allocations affects the robustness of our results. The results of this analysis are presented in table 11 column 1. The results demonstrate that the positive and statistically significant effect of university expenditure on noneducation labor income remains in both the three- and five-year differences. Adding more precision to our measure of the domestic equity exposure within endowments does not seem to affect the results in a dramatic way.

Our second strategy is to allow expenditures by universities with different time-invariant characteristics to be differentially sensitive to stock market shocks. To do so, we allow the sensitivity of expenditures to stock market shocks to depend on university quality and the fraction of graduate students within the county. The first-stage results in table A3 in the online appendix demonstrate that university expenditures at higher-quality universities are indeed positively responsive to stock market shocks but negatively responsive at universities with a higher proportion of graduate students. We see in table 11, column 2 that incorporating the heterogeneous responses leads to positive and statistically significant estimates of the effect of university expenditures on noneducation labor income, with slightly larger magnitudes than the baseline estimates above. In addition, the incorporation of heterogeneous responses significantly strengthens the first stage, leading to $F$-statistics of 74 and 59 in the three- and five-year models, respectively.

As a further robustness check, we examine whether our TSLS results are sensitive to the precise specification of the endowment variable. In column 3 of the table we use the initial endowment value in 1981 to construct our instrument, and in column 4, we use the logarithm of the lagged endowment value. We find that the positive and statistically significant effect remains, though the magnitudes of the estimate vary slightly depending on the specification. Thus, the results in the first four columns of table 11 indicate that our findings are robust to allowing universities of various

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27 In table A1 in the online appendix, we present the results of the heterogeneous effects analysis, comparable to table 9, but using data that aggregate above- and below-median observations to the county level.
types to be differentially responsive to stock market shocks and are not sensitive to the precise construction of the endowment market value variable.

B. Alternative Stock Market Exposure Controls

Next, we examine the robustness to allowing labor income in different industries and counties to be differentially correlated with stock market shocks. If, for example, industries that are more sensitive to cyclical financial conditions are located in counties with relatively higher levels of university endowments, then our IV strategy would be weakened. To test for these possibilities, we first estimate various versions of the models in equations (1) and (2), where we allow stock market shocks to affect labor income through other time-invariant characteristics of universities, industries, and counties. We allow for different flexible time trends in noneducation sector wages across industries, states, and counties with higher-quality colleges by including year fixed-effect interactions. Specifically, we extend models (1) and (2) as

\[ \Delta Y_{ijt} = \alpha_1 \Delta U E_{it} + T + \alpha_2 C_{ij} + \alpha_3 (T \times C_{ij}) + \varepsilon_{ijt}. \]  

(3)

The first stage for the IV model above becomes,

\[ \Delta U E_{it} = \beta_1 (\Delta S M_t \times I E_{a-t-1}) + T + \beta_2 C_{ij} + \beta_3 (T \times C_{ij}) + \xi_{it}, \]  

(4)

where \( \Delta U E_{it} \) is the long-difference change in per capita university expenditures in county \( i \) over the three- or five-year time period under consideration, \( \Delta S M_t \) is the long-difference change in the S&P stock index over the time period, \( C_{ij} \) represents the additional initial characteristics of county \( i \) or industry \( j \), \( T \) is a set of year fixed effects, and \( \varepsilon_{ijt} \) and \( \xi_{it} \) are the error terms.

We consider five measures of relevant differences across industries, universities, and counties. The first measure of \( C_{ij} \) is a set of state dummy variables. This approach allows each state to be differentially affected by stock market shocks. While this method does not seek to explain why labor income in some states is more or less correlated with stock market shocks, it is very flexible. The second measure of \( C_{ij} \) is a set of industry dummy variables. Similarly, this approach allows each industry to be differentially affected by stock market shocks. If stock market shocks affect labor income differentially across states or industries, then including the additional controls should significantly alter our estimate of \( \alpha_1 \). Third, we consider the average quality of the universities within the county, measured in 1991. If universities of different quality levels were disparately affected by stock market shocks, perhaps because of different donor or student characteristics, then this would undermine our identification. This specification allows for counties with higher-quality universities to be differentially correlated with stock market shocks for reasons other than university endowment spending policies because the difference nature of our estimation would factor that out. Our fourth measure of \( C_{ij} \) is the level of housing rent within the county in 1980. If counties with varying degrees of unobserved amenities, as manifest in rental prices, were differentially affected by stock market shocks, then our identification strategy would be weakened. Finally, we allow for county-specific time trends based on characteristics of the county in 1900. Specifically, we include year interactions with both 1900 population and manufacturing output per capita in 1900. If historical characteristics of counties, which may be correlated with the size of the modern endowment, have a differential impact from stock market shocks, our instrument may be threatened.

The results for models with these additional stock market shock interactions are shown in table 11, columns 5 to 8. There are a number of notable findings in the table. First, the results in columns 5 and 6 demonstrate that the inclusion of state and industry-specific flexible time trends has little effect on the statistical significance of the main results, though the magnitude of the effect is somewhat smaller than in table 4. For instance, allowing industries to be differentially affected by stock market shocks (table 11, column 6), the TSLS estimate of the five-year long-difference effect is 78% of the size of the estimate in table 4. Thus, while allowing changes in labor income in each state or industry to be differentially correlated with stock market shocks does not change conclusions about the sign of the relationship, it does weaken the response somewhat.

We show the results for the university quality interaction in column 7. We see that allowing income in counties with different levels of college quality to be differentially correlated with stock market shocks does little to alter the main results. This finding is important given the potential concern that universities and firms in research university counties might be differentially exposed to stock market shocks depending on university quality, independent of the levels of university endowment in the local economies. Moreover, the magnitudes of the estimates are quite similar to their counterparts in table 4, though the power of the instrument is somewhat weakened. Column 8 shows that allowing for a rough proxy for amenities, that is, housing rents, to be differentially correlated with stock market shocks has little bearing on the results. Finally, accounting for historical differences across counties that might be correlated with endowment size has little bearing on the results.

VIII. Conclusion

In this paper we demonstrate that university activity generates persistent spillovers to local firms and workers. The estimates indicate that a 1% increase in university expenditures in a county increases local labor income in other sectors by 0.08%. We find evidence that the spillovers are larger when local universities are more intensively focused on
research and when research universities are technologically closer to local firms, in the sense that they share a labor market with higher education and are more likely to cite university patents. In our models estimating the spillover effect over five years, we found that firms in these technologically closer industries enjoy a spillover that is double that of the typical firm that is not close. Our findings tend to confirm previous research that knowledge spillovers from universities tend to be concentrated on particular local industries, such as pharmaceuticals or electronics, and are not broad based.

While our empirical results indicate a causal link between university research activities and productivity gains in neighboring firms, future work would benefit from a careful analysis of the mechanism that generates such productivity gains. Understanding how industries that are closely related to higher education in terms of innovation and shared labor markets respond to the presence of nearby university activity would help to shed light on the pathways through which university activity affects its neighbors and help to address fundamental public policy questions with respect to public support for research universities. The findings provide a rationale for place-based university policies so long as they focus on industry fundamentals. Our results also suggest that the longer-term effects that universities have on their local economies may grow over time as the composition of local industries evolves to take advantage of the knowledge spillovers we identify.

REFERENCES


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