Wage Trickle Down vs. Rent Trickle Down:

How does increase in college graduates affect wages and rents?

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Abstract

We extend the Rosen-Roback spatial equilibrium model to show that increasing city-level college share affects the welfare distribution by changing both wages and housing costs across individuals with different education levels. Using the PSID from 1980 to 2013, we confirm that high skilled workers gain greater benefits from living in cities with a rising college share, as the increase in their wage premiums outweighs their rent growth. However, the earnings increases of the unskilled is completely offset by higher housing rents. In cities with influxes of college graduates, housing wealth also increases significantly more for the incumbent college graduates, further widening the welfare gap.

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I. Introduction

This study investigates how rising shares of college graduates affects welfare distribution across individuals with different education attainment by examining changes to both wages and and housing costs. Extant research finds evidence of increasing skill divergence across US cities (Berry and Glaeser, 2005; Glaeser, Saiz, Burtless and Strange, 2004). Since the 1980s, cities with initially higher schooling levels have attracted greater shares of adults with college degrees. While prior studies have largely focused on the impact of the human capital externality on wages, they have overlooked the impact of this externality on the cost of living, which is a significant element of individual welfare. Not only does this study examine how rising college share simultaneously affects wages and rental costs, and thus provide a broader implication for welfare, we more convincingly demonstrate he causal linkages between wages and college share by exploiting the nature of household level panel data. Specifically, we are the first paper that takes into account individual fixed effects for each educational attainment group in order to draw inferences about educational spillovers on people belonging to such groups.

Despite widespread evidence that individuals in cities with higher shares of skilled population receive higher wages, there are disagreements about who receives greater benefits from the increase of human capital. For example, Moretti (2004a) finds that wage increases are higher for the less skilled population in highly skilled cities, while Berry and Glaeser (2005) find an opposite result. Data limitations lead to identification challenges for past studies that examine the external effects of increasing human capital. Both Moretti (2004a)4 and Berry and Glaeser (2005) use Census data to test whether the size of the college share effect on wages differs by

[4] Morretti (2004a) uses the NLSY (National Longitudinal Survey of Youth) to control for individual's unobserved ability and sorting. As sample is small with only individuals below age 37, Morretti uses Census data when examining whether the human capital externality effects differ by the level of education.

individuals' educational attainment. Although the Census has sufficient numbers of observations to externally validate the results, the data only allows cross-city, cross-sectional comparisons. Therefore, prior studies were not able to document what happened to individuals residing within the same cities over time. Because the Census does not follow individuals, researchers using Census data cannot fully control for individuals' unobserved ability or their sorting behavior. Unobserved individual characteristics, such as ability, are likely to be correlated with both wages and college share. If the return for unobserved ability is higher in cities with higher college shares, then high quality workers without college degrees may sort into cities with higher college shares. Furthermore, in the long run, individuals can adjust to the externally driven changes in their wages and rental costs by moving to a new location. For example, if housing costs increase more in cities where shares of college graduates increase, then low skilled workers may eventually decide to move to cities where housing is cheaper. These types of sorting will bias cross-sectional coefficients on the external impact of human capital.

We address these problems by using the Panel Study of Income Dynamics (PSID). Although the sample size is much smaller than the Census, the major advantage of using the PSID is that it tracks individuals over time. Thus, we are able to control for both the differences in the level of unobserved ability across individuals, and the differences in returns to unobserved ability across cities. We can also observe those who move within and out of the city. As moving involves cost, it might take time for individuals to react to the wage/price impacts of changing shares of highly educated populations. By tracking individuals annually (biannually from 1997), we are able to identify what happens to the earnings of those who stay in the same city.

Household welfare not only depends on income, but also on the cost of living. Thus, studies that focus only on wages provide incomplete pictures of welfare changes arising from human capital externalities. Housing, by far, accounts for the greatest proportion of living cost, so we examine how an influx of college graduate simulataneously affects wages and rents. As the PSID dataset contains information about monthly rental payments, we test how the increase of college share affects the residual wages (income minus rent) of individuals living and estimate how the net benefits from human capital externalities are allocated across individuals in different education groups. While high skilled and low skilled workers likely compete in different labor markets, the boundaries in the housing market are likely less rigid. If so, it is possible that an income trickle down from an influx of high skilled workers could be lower than a rent trickle down.

Our results confirm prior studies that show individuals earn higher wages in cities with higher shares of college graduates and also in cities where the shares of college graduates are increasing. Even after controlling for sorting and unobserved ability, we find that a 1 % increase in the share of college graduates leads to a 1.4 % increase in wages. However, the size of the human capital externality on wages differs across education groups. Our results agree with Berry and Glaeser (2005); we find the greatest increase in the wage premium goes to college graduates working in cities that experience greater increases in the supply of college graduates. In fact, our results show that the wage premium increase of those without a high school diploma is less than a half of that for college graduates, in line with the theories of knowledge spillover and skill-bias technological change (SBTC). Additionally, we find rental prices also increase more in cities with greater influxes of college graduates. Along with getting higher wage premiums, college graduates pay higher rent premiums in cities with increasing shares of college educated people.

Considering wage and rent growth simultaneously, we demonstrate that increases in rent offset the increases in wage growth in cities where shares of high skilled workers are growing.

On average, the influx of college graduates increases rent to income ratios while residual earnings remain unchanged. However, there are significant discrepancies in the growth rate of rent to income ratios across education groups. While rent to income ratio increases about 3.4 % on average, those with the highest educational attainment experience the smallest increase of rent relative to income. The residual earnings of these people also increases the most in response to increasing college share. In contrast, residual earnings of renters with at most a high school degree show no increase in cities that are attracting high skilled workers. Overall, college graduates receive greater gains from the influx of high skilled workers. In fact, on average, less educated people are no better off in these cities, as the increase of rent cost completely offsets the increase in wages. Additionally, we find evidence that the home equity value of high skilled homeowners increases more than low skilled homeowners as college share increases, further widening the welfare gap across individuals with different educational attainment. We perform a series of robustness checks and find that our results remain strong and significant.5

One important element that is not considered in either our theoretical or empirical model is changing amenities. Diamond (2016) finds amenities improve more in cities with larger shares of

[5] We first directly control for changes in city-specific productivity shocks in the wages regression and find our main results remain unchanged. We also investigate whether our results change significantly if we use the presence of a land grant university to instrument the share of college graduates. As the instrumental variable is a dummy, we can only do a cross-city comparison and cannot observe how the impact of college share differs by education groups. Confirming our previous results, we find evidence that higher share of college degree holders leads to higher wages and rents. These results show that both wages and rents are causally associated with the share of college graduates. Furthermore, the size of the coefficient for monthly rent is greater than that for wages, in line with our OLS results. As individuals can adjust for changes in rental costs by moving within a city, we also run our regressions that drop observations where particular individuals at particular times have moved within the city. We find that all our results remain robust. Finally, we examine whether our results are driven by cities where elasticity of housing supply is low. In cities where housing supply elasticity is high, residents may not face increases in rental costs as new housing units can be built easily. We use Saiz's (2010) housing supply elasticity index to run regressions separately in cities with high and low housing supply elasticities. As expected, we find the degree of increase in rent to income ratio and decrease in residual income is greater inelastic cities. While increases in rent offset increases in wages in cities with high housing supply elasticities, rent increases more than income in cities with low housing supply elasticities.

college graduates. If, for some reason, less skilled workers receive higher utility from the improvement in urban amenities, these individuals may also be relatively better off from living in cities with rising college shares. We conduct some (albeit limited) empirical analysis using two variables: (1) households' amount spent eating out and (2) child's school enrollment. First, we find that only skilled people spend more money eating out as cities become more skilled, suggesting that the highly educated are getting more enjoyment from the increasing numbers of restaurants. We also find no evidence that a child of households headed by a less educated parent is more likely to be enrolled in school in cities that experience growth in college share. While it is possible that less skilled workers are benefitting from other amenity improvements in skilled cities, overall, our results suggest that skilled workers are gaining greater benefits from the college share externality.

We finally discuss our findings by examining whether occupation and housing subsidies can mitigate the widening welfare distribution in cities attracting skilled workers. In line with existing studies, we find that the response of wages on college share is positively higher for those low skilled workers in service jobs than in other sectors. Also, those who are living in government subsidized housing experience smaller increases in rent burdens and smaller decreases in net income. However, these two slightly better outcomes are limited to the fairly small share of people who either receive subsidies or work in the service sector.

The next section provides theoretical bases for why the inflow of high skilled human capital may have different influences on different groups of people in the city; this is followed by a spatial equilibrium model in Section 3. Section 4 describes the data and the methods we use to test the theories, and Section 5 presents main results followed by robustness checks in section 6.

Section 7 examines how changes in amenities explain our results, and the final two sections discuss our findings and conclude.

II. Human Capital Externality and Residual Wages

Why would increases in the share of college graduates have different impacts on the welfare for skilled and unskilled individuals living in the same city? From prior studies, we examine what happens in both labor market and housing market in response to the influx of skilled laborers.

Existing theories provide different explanations about how the increase in the share of college graduates can have different impacts on the wages for different groups living in the same city. First, differences in the adoption of skilled biased technology explains why high skilled workers may have larger returns to skill in places with greater shares of college graduates. Skilled biased technological change (SBTC) – especially the development and the diffusion of computers –is one of the most prominent theories for explaining growing inequality in the labor market (Katz and Murphy, 1992; Autor, Katz and Krueger, 1998, Goldin and Katz, 2001; Acemoglu, 2002). This theory suggests that the computer revolution has increased the productivity of high skilled workers while displacing low skilled workers performing routine tasks (Autor and Dorn, 2013). The reason why SBTC results in higher wage gains for cities with abundant and increasing shares of college graduates is related to the differences in the time and the speed of computer adoption and diffusion across cities. Between 1980 and 2000, Beaudry, Doms, and Lewis (2010) show that cities with greater shares of skilled workers adopted PCs most intensively. These cities have also experienced the greatest increases in the return to skills. These changes occurred mostly during the period when cities with higher initial schooling levels attracted more college graduates (Berry and Glaeser, 2005). Therefore, the influx of college graduates may have further stimulated the adoption of technology that favors skilled workers, creating an endogenous loop between increasing college share and increasing return to skill.

Knowledge spillover also explains why workers can be more productive in cities with greater shares of college graduates. For a long time, scholars have suggested that the interaction with high skilled workers enhances individual productivity (Marshall, 1890; Jacob, 1969; Porter; 1990), which leads to higher wages. Enrico Moretti finds direct evidence that supports this theory. In his two papers published in 2004, Moretti finds that productivity of plants rises more in cities that experience larger increases in the share of college graduates (Moretti, 2004b) and also finds that individual wage increases are greater in these cities (Moretti, 2004a). However, it is uncertain who benefits more from the knowledge spillover effect– high skilled or low skilled. If the interaction and learning between individuals with similar skill levels is greater than between those with different skill levels, then the benefit from knowledge spillovers will be greater for high skilled workers. On the other hand, if low skilled workers gain greater productivity directly from interacting with high skilled workers, or indirectly from a working at a firm managed more efficiently and effectively by the high skilled workers, then the spillover effect on wages will be greater for low skilled workers than high skilled workers.

More recently, the increase of consumption demand by high skilled workers has received greater attention (Manning, 2004; Kaplanis, 2010; and Mazzolari and Ragusa, 2011). As opportunity cost of time is higher for high skilled workers, these people spend a larger fraction of their budget in time intensive services, such as cooking, cleaning and childcare. Opposite to the SBTC, this theory predicts that low skilled workers obtain greater increases in wage due to increases in high skilled labor force. As the demand for home production substitutes increases more in places with greater inflows of high skilled workers, low skilled workers who are providing these services experience greater wage increase.

Finally, researchers (e.g. Katz and Murphy, 1992; Moretti, 2001b; Ciccone and Peri, 2006) also suggest imperfect substitution results in differences in the impact of college shares on wages for individuals with different level of educational attainment. This theory also explains why low skilled workers gain higher wages in cities with greater shares of college graduates Not only do low skilled workers benefit from the productivity gains, but they also obtain higher wage as these workers are relatively scarcer in MSAs with greater shares of college graduates. On the other hand, while college graduates also benefit from the increased productivity, greater competition among college graduates may reduce the spillover benefit.

These four theories are not mutually exclusive and can coexist. The strength of these four competing and complementary theoretical explanations will affect the relative size of the wage gains for different education groups. So far, empirical evidence on spillovers is mixed. Moretti (2004a) shows that the gains from increasing college shares is greater for low skilled workers than high skilled workers. Berry and Glaeser (2005), however, find the opposite result. Both studies have used Census data, which cannot identify what happens to the same individual over time. In the long run, people can adjust to the changing environment by moving to a new location or by acquiring additional skills. Using the PSID, we examine how the increase of college share changes the wage of workers by tracking individuals and their location of residence annually or biannually.

Influxes of college graduates can also affect the cost of housing. In separate studies, both Glaeser et al. (2001) and Moretti (2013) highlight the importance of considering changes in cost of living when considering changes in wages. Glaeser et al. (2001) finds that since the 1970s, rents have gone up more quickly than wages in cities with greater shares of college graduates. The study claims this stylized fact implies that the quality of life increased more in these cities and thus people are willing to pay higher rental prices that more than offset their wage increases. Moretti (2013) shows that the real wage differences between high skilled and low skilled workers decreases if changes in housing costs are incorporated as college graduates sort to live in more expensive cities.

Both studies however, do not consider the changes in the distribution of housing costs within a single city. If housing markets are less segmented than labor markets, the increase of high skilled workers in a city may have different levels of impact on changes in the wages and rents for different subgroups of the population. It is likely that high skilled and low skilled workers compete in substantially different labor markets; the distinction between "low-skill" and "high-skill" housing markets in which the two groups compete may not be so clear. If so, an increase of college graduates may have varying impact on wage and rent distributions. Furthermore, since prior studies (Ganong and Shoag, 2017) find that low skilled workers are less mobile than their high skilled counterparts, it may take time for low skilled workers to re-adjust to rising housing costs by moving to a new location. Finally, a series of studies (e.g., Haurin 1991) shows that the income elasticity of demand for housing is well under one, suggesting that if low income people are spending a greater share of income on housing as incomes rise, it is not because they are choosing to do so. Our study compares how the increase in college graduates simultaneously affects the wages and rents of individuals, and thereby directly compares costs and benefits for different groups of city residents.[6]

[6] Our study only examines housing cost for renters and do not examine housing costs for homeowners. While the increase of college share can affect the initial cost of buying home, once the house is bought, homeowner's annual housing cost is largely fixed. In this case, earlier buyers are likely to obtain greater welfare gain the first time home

III. Theoretical Model

Our general equilibrium model builds on Rosen-Roback spatial equilibrium framework (Rosen, 1979; Roback, 1982) but relax some adjustments to better reflect reality. In Rosen-Roback world, all workers are identical and indifferent between locations. When a city experiences a local demand or supply shock of labor, the impact of the shock is fully capitalized in the price of land. Therefore, shocks to the local economy do not affect workers' welfare, as changes in housing costs fully offset changes in wages.

Following Moretti (2011), we assume that workers have idiosyncratic preferences for location, which affect their mobility. Housing supply is not necessarily fixed. In other words, local labor supply is not infinite and housing supply elasticity is not zero. In this context, local labor market shocks are not fully capitalized into land prices, and can have different impacts across workers. In equilibrium, only the marginal worker is indifferent between locations, while the inframarginal workers either can benefit or lose from the changes in the local labor market.

As Moretti, we also allow for heterogeneity in skills, assuming there are skilled and unskilled workers. Within a city, workers with different level of skills compete in different labor markets but compete in a single housing market. Each city-specific productivity is an endogenous function of the relative size of skilled workers in the city, thus incorporating agglomeration externalities that can occur from endogenous improvements in skilled bias technology or knowledge spillover. Our model takes a step further than Moretti, in that we *simultaneously* allow for heterogeneity of skills and agglomeration externalities.

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buyers in the later period as influx of college graduates are likely to have increased the sales price. Comparing the welfare gains for homeowners is an interesting research question but is beyond the scope of this study.

III.1. Model Environment

Utility of Workers Consider an economy with two cities, a and b. In each city, there are two types of workers with different skill levels, labeled as the skilled (H) and the unskilled (L). It is assumed that in each period τ, indirect unity of worker i with skill level $S \in \{H, L\}$ living in city $c \in \{a, b\}$ depends on her wage ($w_{Sc,\tau}$), rent ($r_{c,\tau}$), value of amenity ($A_{Sc,\tau}$), and idiosyncratic preference for the city of residence ($e_{Sic,\tau}$),

$$U_{Hic,\tau} = w_{Hc,\tau} - r_{c,\tau} + A_{Hc,\tau} + e_{Hic,\tau}, \ c \in \{a, b\}, \tau \in \{t-1, t\} \qquad (1)$$

$$U_{Lic,\tau} = w_{Lc,\tau} - r_{c,\tau} + A_{Lc,\tau} + e_{Lic,\tau}, \ c \in \{a, b\}, \tau \in \{t-1, t\}, \qquad (2)$$

where $U_{Sic,\tau}$ denotes the indirect utility for $S \in \{H, L\}$. Note that because we assume that skilled and unskilled workers compete in a same housing market in this economy, the rents in the utility functions (1) and (2) are identical for the two skill levels.

Now suppose the idiosyncratic preference of worker i for city a over b is[7]

$$e_{Hia,\tau} - e_{Hib,\tau} \sim \text{logit}(0, s_H) \qquad (3)$$

$$e_{Lia,\tau} - e_{Hib,\tau} \sim \text{logit}(0, s_L) \qquad (4)$$

where N_{Hc} and N_{Lc} are log of number of high- and low- skilled workers in city c, respectively. Let $N_H = N_{Ha,\tau} + N_{Hb,\tau}$ and $N_L = N_{La,\tau} + N_{Lb,\tau}$, both of which are assumed to be fixed. We further assume that[8] $N = N_H = N_L$. The magnitudes of s_H and s_L determine the mobility of workers for each skill level. If $s_H = 0$, for instance, skilled workers have no

[7] Note that if a random variable x follows $\text{logit}(\mu, s)$, the cdf of x is

$$\frac{1}{1 + \exp\left(-\frac{x - \mu}{s}\right)}$$

[8] We can allow different value of N_H and N_L. However, this generalization does not affect to implication of our model, while making the derivations more complex.

personal attachment to a city and they are perfectly mobile. On the other hand, if $s_L = \infty$, unskilled workers are perfectly immobile.

Technology of Firms We assume that skilled and unskilled workers compete in different labor markets - there are two different types of firms hiring skilled and unskilled workers, respectively. The technology of each firm is assumed be Cobb-Douglas:

$$\ln(y_{Hc,\tau}) = X_{Hc,\tau} + hN_{Hc,\tau} + (1-h)K_{Hc,\tau}, \; c \in \{a,b\}, \tau \in \{t-1,t\} \quad (5)$$

$$\ln(y_{Lc,\tau}) = X_{Hc,\tau} + hN_{Lc,\tau} + (1-h)K_{Lc,\tau}, \; c \in \{a,b\}, \tau \in \{t-1,t\} \quad (6)$$

Where $y_{Sc,\tau}$, $K_{Sc,\tau}$ and $X_{Sc,\tau}$ denote output, capital input and technology level of the firms hiring workers with skill level S. We further assume that there exists externality in technology:

$$X_{Hc,\tau} = x_{Hc,\tau} + \delta_H N_{Hc,\tau}, \; c \in \{a,b\}, \tau \in \{t-1,t\} \quad (7)$$

$$X_{Lc,\tau} = x_{Lc,\tau} + \delta_L N_{Hc,\tau}, \; c \in \{a,b\}, \tau \in \{t-1,t\} \quad (8)$$

where $x_{Hc,\tau}$ and $x_{Lc,\tau}$ exogenously switches productivity of high- and low- skilled workers, respectively. In equations (7) and (8), it is assumed that productivity of firms hiring high skilled workers and low-skilled workers depends on N_{Hc}. Since the sum of $N_{Ha,\tau} + N_{Hb,\tau}$ and $N_{La,\tau} + N_{Lb,\tau}$ are constant, this assumption also indicate that productivity of a city depends on share of high-skilled workers.

Our specifications of the externality in productivity in (7) and (8) relate the values of δ_H and δ_L to strength of agglomeration effect of relative share of high-skilled worker in a specific city. According to the theory of knowledge spillover, the relative size of δ_H and δ_L depends on the relative size of the benefit that skilled and unskilled workers receive from interacting with skilled workers: if skilled workers gain greater benefit, then δ_H will be greater than δ_L, and vice versa. On the other hand, the SBTC always predicts that δ_H is greater than δ_L.

Local Housing Market Following Moretti (2011), we assume that one worker demands one house. Unlike the conventional Rosen-Roback model, we assume that housing supply is not fixed. For simplicity, we assume that the two cities have the same housing supply function:

$$r_{c,\tau} = z + k * (N_{Hc,\tau} + N_{Lc,\tau}), \quad c \in \{a, b\} \qquad (9)$$

Equation (9) implies that high- and low- skilled workers compete in a same housing market in each city. For both skill levels, elasticity of housing supply is identical.

Local Capital Demand For simplicity, interest rate i is assumed to be fixed internationally. Then the capital demand in each type of firm is given as:

$$K_{Hc,\tau} = \frac{1}{h}\left[-\ln i + \ln(1-h) + hN_{Hc,\tau} + X_{Hc,\tau}\right], \; c \in \{a, b\}, \tau \in \{t-1, t\} \quad (10)$$

$$K_{Lc,\tau} = \frac{1}{h}\left[-\ln i + \ln(1-h) + hN_{Lc,\tau} + X_{Lc,\tau}\right], \; c \in \{a, b\}, \tau \in \{t-1, t\} \quad (11)$$

where as in equations (5) and (6) , $K_{Sc,\tau}$ denotes capital input of the firms hiring workers with skill level S.

III.2. Local labor market

Local Labor Supply A marginal high-skilled worker i^* in period τ satisfies:

$$e_{Hi^*a,\tau} - e_{Hi^*b,\tau} = (w_{Ha,\tau} - w_{Hb,\tau}) - (r_{a,\tau} - r_{b,\tau}) + (A_{Ha,\tau} - A_{Hb,\tau}) \quad (12)$$

Let $m^*_{H,\tau} = e_{Hi^*a,\tau} - e_{Hi^*b,\tau}$. If $e_{Hia,\tau} - e_{Hib,\tau} \leq m^*_{H,\tau}$, high-skilled worker i chooses city b over a. From (3), we have

$$m^*_{H,\tau} = s_H(N_{Hb,\tau} - N_{Ha,\tau}) \qquad (13)$$

From (12) and (13), we have following labor supply of skilled workers:

$$w_{Hb,\tau} = w_{Ha,\tau} + (r_{b,\tau} - r_{a,\tau}) + (A_{Ha,\tau} - A_{Hb,\tau}) + s_H(N_{Hb,\tau} - N_{Ha,\tau}) \quad (14)$$

Similarly, labor supply of unskilled workers is given as below:

$$w_{Lb,\tau} = w_{La,\tau} + (r_{b,\tau} - r_{a,\tau}) + (A_{La,\tau} - A_{Lb,\tau}) + s_L(N_{Lb,\tau} - N_{La,\tau}) \quad (15)$$

As each worker demands one house, the local housing demand of each worker in each skill level is just a rearrangement of local labor supply. Thus, Eq. (14) and (15) can be transformed to:

$$r_{b,\tau} = \frac{s_L(w_{Hb,\tau}-w_{Ha,\tau})+s_H(w_{Lb,\tau}-w_{La,\tau})}{s_L+s_H} + \frac{s_L(A_{Hb,\tau}-A_{Ha,\tau})+s_H(A_{Lb,\tau}-A_{La,\tau})}{s_L+s_H} - \frac{s_Ls_H(N_{Hb,\tau}-N_{Ha,\tau})}{s_L+s_H} - \frac{s_Ls_H(N_{Lb,\tau}-N_{La,\tau})}{s_L+s_H} + r_{a,\tau} \quad (16)$$

Equation (16) implies that the rent differences across city a and city b is determined by (1) the wage gap $(w_{Sb,\tau} - w_{Sa,\tau})$, (3) the differences in amenities $(A_{Sb,\tau} - A_{Sa,\tau},)$ and (3) the differences in the number of workers $(N_{Sb,\tau} - N_{Sa,\tau})$, for individuals in different skill groups, $S \in \{H, L\})$ across the two cities. The equation shows that as the relative wage of workers in city b increases, their incentive to stay in city b also goes up, increasing the willingness to pay for housing services in city b. Likewise, if the quality of amenities in is relatively higher in city b, workers will pay higher rent to live in city b. Finally, if the number of high and low skilled workers increases in city b, presumably due to an external shock, both housing demand and rent will increase in city b.

Local Labor Demand Perfect competition in the two types of local labor markets implies that each wage is equal to its corresponding marginal productivity of labor. From the production function (5) to (8), labor demand in each labor market is as follows:

$$w_{Hc,\tau} = \frac{1}{h}X_{Hc,\tau} = \frac{1}{h}(x_{Hc,\tau} + \delta_H N_{Hc,\tau}), \quad c \in \{a, b\}, \tau \in \{t-1, t\} \quad (17)$$

$$w_{Lc,\tau} = \frac{1}{h}X_{Lc,\tau} = \frac{1}{h}(x_{Lc,\tau} + \delta_L N_{Hc,\tau}), \quad c \in \{a, b\}, \tau \in \{t-1, t\} \quad (18)$$

If there were no externality in productivity, wages are determined by exogenously given productivities of each type of workers, $x_{Hc,\tau}$ and $x_{Lc,\tau}$. In this economy, however, the wage also depends on the relative size of skilled workers. This specification implies that the wage gap between skilled and unskilled workers depends δ_H and δ_L.

III. 3. Event: an increase in productivity of skilled-workers

Equilibrium of our model is determined by equations (9), (10), (11), (14), (15), (16), (17) and (18). In this subsection, we illustrate the relationship between the shares of skilled workers, and residual income (wage net housing cost). Specifically, we focus on a case when there is a positive shock on productivity of skilled workers.[9] In this case, we can show the larger the share of skilled workers, the greater the increase in wage and residual income inequality in response to the shock, given plausible values of parameters. In order to isolate the effect of change in productivity, we assume that amenities are fixed across time and the same across the cities.

Change in Share of Skilled Workers Suppose the productivity of high-skilled workers in city b increases exogenously (for example due to the invention of new technology) by

$$\Delta x_{Hb,t} \equiv x_{Hb,t} - x_{Hb,t-1} = \epsilon, \qquad \epsilon > 0 \quad (19)$$

In response to the increase in the productivity, both the population of skilled and unskilled workers in city b change by $\Delta N_{Hb,t}$ and $\Delta N_{Lb,t}$. From the equilibrium condition, we can derive the following equation that shows that changes in the total population in city b.

$$\Delta N_{Hb,t} + \Delta N_{Lb,t} = \frac{s_L\epsilon + 2(s_L\delta_H + s_H\delta_L)\Delta N_{Hb,t}}{2(s_L + s_H)hk + 2s_Ls_Hh} \quad (20)$$

While, $\Delta N_{Hb,t}$ is positive due to the positive productivity shock of high skilled workers, it is unclear whether $N_{Lb,t}$ will increase or decrease. However, since all parameters in equation

[9] Note that we are not identifying the source of the local labor market shock, but examining how the increase of college share (which itself is a result of the local market supply or the demand shock) affects welfare distribution across different skill groups.

(20) are positive, the increase in total population in city b will push up the rent, regardless of the direction of change in the number of unskilled workers.[10]

Change in Workers' Welfare Finally, we derive changes in welfare of skilled and unskilled workers. From the labor demand equation, the wage growth of skilled workers in city b is

$$\Delta w_{Hb,t} = \epsilon + \frac{\delta_H}{h} \Delta N_{Hb,t} \qquad (21)$$

Rent growth in city b can be derived from the housing supply function (9):

$$\Delta r_{b,\tau} = k * (\Delta N_{Hb,\tau} + \Delta N_{Lb,\tau}), \text{where } k > 0 \; (22)$$

As an exogenous increase in skilled workers' productivity in city b leads to a higher share of skilled workers in that city. Under these circumstances, equation (21) shows that the wage of skilled workers increases in city b. If all other factors are fixed, higher income generally implies higher welfare. However, since changes in skilled workers' productivity affects equilibrium in the housing market, the overall welfare changes depend on changes of both wages and rents. In other words, the welfare of skilled workers depends on the change in residual income shown in the following equation:

$$\Delta w_{Hb,t} - \Delta r_{b,t} = \epsilon + \left(\frac{\delta_H}{h} - k\right) \Delta N_{Hb,t} - k\Delta N_{Lb,t} \qquad (23)$$

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[10] Equation (20) further implies

$$\frac{\partial \Delta N_{Lb,t}}{\partial \Delta N_{Hb,t}} = \frac{2(s_L \delta_H + s_H \delta_L)}{2(s_L + s_H)hk + 2 s_L s_H h} - 1$$

which shows that depending on the degree of externality, $N_{Lb,t}$ can increase or decrease when $\Delta N_{Hb,t} > 0$. If δ_L is low enough, i.e. share of skilled workers has weak effect on productivity of unskilled workers, the number of unskilled workers may decrease as x_{Ht} increases. . Because skilled and unskilled workers compete in the same housing market, an increase in the relative size of skilled workers due to higher $x_{Hb,t}$ causes higher rent in city b. Labor supply equation (15) shows that the higher rent lowers unskilled labor supply in city b.

From (20) we can show that, $\Delta w_{Hb,t} - \Delta r_{b,t} > 0$ if either ϵ is large enough or $\delta_L < hk < \delta_H$. The ϵ is large when the increase in skilled-workers' productivity shock in city b is substantial. The condition $\delta_L < hk < \delta_H$ holds when income gains from the agglomeration effect for skilled workers (δ_H/h) is larger than the increase of housing cost arising from an increase in the number of skilled workers

As for unskilled workers, their income growth in response to the exogenous shock on skilled worker productivity is: $\Delta w_{Lb,t} = \frac{\delta_L}{h} \Delta N_{Hb,t}$ (24)

Because rent growth for the unskilled is identical to that of the skilled (22), the overall welfare change of an unskilled worker is

$$\Delta w_{Lb,t} - \Delta r_{b,t} = \left(\frac{\delta_L}{h} - k\right) \Delta N_{Hb,t} - k\Delta N_{Lb,t} \quad (25)$$

Equation (26) implies that skilled workers can be worse off if $\delta_L < hk$. In other words, if the spillover effect of technology for low skilled workers is weak, then increases in skilled workers' productivity can harm unskilled workers. The intuition behind of this is that if an increase in skilled workers' productivity in city b does not affect unskilled workers' productivity, labor income of unskilled workers in city b cannot increase enough to compensate for the increase in rent in that city.

Our model thus implies that, depending on the degree of agglomeration effects, or spillover effects, of skilled workers' productivity shocks, it is possible that advances in technologies for skilled workers leads to distributional changes of welfare between skilled and unskilled workers, resulting in unskilled to become relatively worse off than the skilled.

IV. Data & Method

Data This study uses the Panel Study of Income Dynamics (PSID) from 1980 to 2013. The PSID has followed a sample of individuals and households in the US since 1968. Between 1968 and 1997, surveys were conducted annually; after 1997 there were conducted biannually. The major advantage of the PSID is that it contains extensive information on each individual's demographic and socioeconomic characteristics, including wages and rental costs. We also have access to the restricted geo-coded data which we use to merge the Decennial Census data to the PSID.

The dependent variables come from the household level data. The PSID asks the hourly wage only for heads and wives.[11] Thus, our analysis does not include household members who are neither the head or a wife of the head. We include all head and wives between ages 16 and 65 who are not enrolled in school. On average, the annual number of observations in our sample is slightly over 10,500 individuals. The city level data comes from the Decennial Census 1980, 1990, 2000, 2010 and the American Community Survey (ACS) 2008-2012. Our definition of city includes metropolitan and micropolitan statistical area[12] which covers all urban labor markets. The key variable of interest is the share of college graduates for the adult population age 25 and over.[13] We download this variable from the Decennial Census and the American Community Survey at the census tract level and use the crosswalk file from Logan et al. (2014) to adjust 1980, 1990 and 2000 to match 2010 city boundaries. We then match the city level variables to the geocoded PSID. We interpolated these variables in the years for which Census figures are not available. For years 2011 and 2013, we used Census 2010 data.

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[11] Since the PSID asks about earnings in the previous year, we lead the earnings variable to match it with the current data.

[12] The boundaries of metropolitan and micropolitan statistical areas are defined by the office of Management and Budget. According to the US Census, metro area contains a core urban area of 50,000 or more population, and a micro area contains an urban core with a population at least 10,000 but less than 50,000. Each metro or micro area consists of at least one county including the urban core, and also any adjacent counties that have a high degree of social and economic integration (as measured by commuting to work) with the core urban area.

[13] Other city level variables include total population and share of black and Hispanic. These variables are collected from Census 1980, 1990, 2000 and 2010.

Table I presents the summary statistics for both individual and city level variables. The inflation adjusted average hourly wage (2013 US dollars) is 22.83 dollars and the inflation adjusted average monthly rent is around 630 dollars. Average inflation adjusted home equity, calculated by subtracting the remaining mortgage principal from the self-reported house value, is approximately 105,000 dollars. Slightly less than a quarter of the sample received 4 years of college education, and about the same number of individuals received at least some level of college education. Almost 40 percent of those in the sample are high school graduates and the remaining did not receive a high school diploma. In the city level data, our key variable of interest is the percent of college graduate. On average, 16 percent of adults age 25 and above are college graduates, ranging from 4.7 percent in Ashtabula, Ohio in 1980 to 40.3 percent in Boulder, Colorado in 2000.[14]

As the PSID started its survey in 1968 and intentionally focused more on low-income households, the proportion of blacks is significantly higher than the national average, while Hispanics account for less than 1 percent of the sample. To adjust for the overrepresentation of blacks, the PSID provides weights for individuals. However, as weights of individuals are only available for about a half of our sample, we do not use weights in our analysis in order to gain greater statistical power. Since the purpose of this study is to examine whether the size of the human capital externality differs across groups of individuals who received different level of education having sufficient sample size for these groups is critical.[15]

[14] Note that the percent with a 4-year college degree in the PSID sample is higher the average share of college graduates in the city level data. This is because we exclude those who are over 65 year olds in the PSID sample. The group who, on average, received less education than the younger generation. The fact that we only have data for heads and wives and not other individuals in the households is also likely to have increased the percent of college graduates in the PSID sample.

[15] We also ran individual weight adjusted regressions and our main results do not show considerable changes from what we present. These results can be provided upon request.

Method. To measure the causal impact of college share on wages and rental costs, we need to control for two omitted variables: each individual's (1) unobserved ability and (2) sorting behavior. First, it is likely that individuals living in cities with increasing levels of human capital are more likely to have greater unobserved ability. Moretti (2004a) points out that cities that have a particular industrial structure may have greater demand for high skilled workers and also offer more compensation for unobserved ability. Thus, high wages for individuals living in these cities may merely reflect the heterogeneity of individuals' productivity due to unobserved skills. Furthermore, individuals' will migrate to cities where their unobserved ability have greater value. This sorting behavior will increase the wage gaps between those living in a city with greater demand for high skilled workers from those who are living in cities with less demand for the highly educated. Our empirical models deal with this issue by using both individual and city fixed effects and the multiplication of both. The following two equation forms are the two baseline models that we use:

$$Log(Y_{ict}) = \alpha_{ct}X_{it} + \beta CS_{ct} + \gamma CS_{ct} \times EDUC_i + \delta Z_{ct} + \pi_t + \mu_c + \theta_i + \varepsilon_{ict} \quad (1)$$

$$Log(Y_{ict}) = \alpha_{ct}X_{it} + \beta CS_{ct} + \gamma CS_{ct} \times EDUC_i + \delta Z_{ct} + \pi_t + \mu_c\theta_i + \varepsilon_{ict} \quad (2)$$

In both models, Y_{ict} represents three dependent variables, (1) individual hourly wage, (2) monthly rent, or (3) annual labor income relative to annual rent cost. X_{it} is a vector of individual level characteristics, such as age, race and ethnicity; CS_{ct} represents the share of college educated individuals in city c at year t; $EDUC_i$ represents dummy variables for the level of education (without high school diploma, high school, received less than four years of college education, college graduates); Z_{ct} is a vector of city characteristics that may be correlated with

CS_{ct} including MSA population[16]; π_t is the year fixed effects and ε_{ict} is the error term. The coefficients of interest are β and γ, which show whether college share affect wages and rents, and whether the size of this effect differs across groups of people in different education categories.

The above models differ in assumptions of how cities value unobserved ability. The first model assumes that unobserved skills are equally valued in every city while the second model assumes that returns to unobserved ability vary across cities. Model (1) assumes that the impact of college share on wages does not differ between movers and stayers, when controlling for observed and unobserved characteristics. On the other hand, model (2) assumes that returns for unobservable skills differ across cities and affects sorting behavior. To control for sorting, the model includes individual × city dummies which absorb the variations that occurs from the movers. Thus, in model (2) the coefficient shows how the changing college share affects an individual who stayed in the same city. If, for example, individuals move to cities where they gain greater return for unobserved skills, than β and γ in the wage regression will be higher in model (1) than model (2).

V. Main Results

Hourly Earnings Table II presents the relationship between the share of college graduates and wages. The dependent variable is the log hourly earnings. Column (1) shows that individuals living in cities with higher shares of college graduates have higher wages, even after controlling for individual and city level variables, including individuals' educational attainment. When the share of college graduates increases by 1 percentage point, hourly earnings go up by 1.26%,

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[16] As we control for the share of population, the impact of share of college graduates on our dependent variables are showing the impact of changes in composition of population.

which is similar to Moretti's (2004a) finding of a 1.31% increase in hourly earnings. In column (2), we include city fixed effect and find that the external return conditional on city fixed effect drops to 0.60%.[17] This shows that in cities where the college share is growing, individuals' wages are also going up. This specification, however, does not control for individuals' unobserved ability or sorting behavior.

Next, we add individual fixed effects. Individual fixed effects capture any unobserved characteristics such as ability or family background. When the permanent individual characteristics are controlled for, the estimated effect of human capital externality increases back to 1.32%. This shows that the differences in the unobservables do not explain why individuals have higher earnings in cities that attract college graduates. However, there is still a possibility that these results are due to sorting. In reality, individuals do not randomly select places to live but make a choice correlated with their expected return. For example, if return to ability differs across cities and individuals move to places that offer greatest return, then β will be biased upward. In column (4), we include individual×city fixed effect to control for unobserved heterogeneity in the return to ability across city. In this regression, β indicates the size of the human capital externality on hourly wages for those who do not move. The size of the β in column (4) is not significantly different from column (3), suggesting that the movers and the stayers are gaining similar wage premiums from the increase in college share.

[17] Using National Longitudinal Survey of Youth data, Moretti finds that the estimated private return to education conditional on city fixed effects is 1.13% which is almost double of what we find. This may be related to difference in the sample as Moretti examines only population between ages 23 to 37. If we run the same regression for population under 38 our coefficient increases to 0.98%. The difference in the result may also be related to the period of estimation. The size of our coefficient also increases if we only include years before 1995. This suggests that the effect of human capital externality also differs by age groups and time periods. In this study, however, we focus on how the effect differs across the level of education. Using Census data, Morretti finds that a 1 percentage point increase in college share raises average wages by 0.6 to 1.2%, which is similar to the range found in our study.

We next examine whether the size of the human capital eternality on wages differs across four education groups: (1) without high school diploma, (2) high school graduate, (3) received some level of college education, (4) with a bachelor degree. The reference group is those without high school diplomas. The first column in Table III shows that wages are higher in cities with greater share of college graduates for all for groups with different level of educational attainment. Among the four groups, the size of the coefficient for those with a bachelor degree is significantly higher than the remaining three groups. Column (2) shows when share of college graduates increase within the same city, the wage growth increases with the level of educational attainment.

While this linear pattern changes once the individual fixed effects are included, we still find that bachelor degree holders benefit the most from the increase in college share (Columns (3)). The result shows that those with a high school degree or less gain about 0.56% to 0.66% increases in hourly wages in response to a 1 percentage point increase in the share of college graduates. Compared to the least educated individuals, those with some level of college education gain a 0.34 percentage point higher increase in hourly earnings from the increases in the level of human capital, while college graduates receive a 1.12 percentage point higher increase in hourly earnings. We find similar results, when controlling for sorting by including individual x city fixed effects: we find that the less educated group gains no wage benefits from the increase in the share of college graduates. Again, college graduates receive the greatest wage benefits (1.732%=0.698%+1.034%) from a 1 percentage point increase in college graduates, and high school drop outs receive the smallest benefit (0.698%).

Overall, our results are in line with two theoretical explanations. First, knowledge spillover exists. Moreover, the benefit of knowledge spillover increases by the level of education. Second, cities where college share is higher and where the share increases also adopt skill-biased technology more intensively, which as a result increases the wages of skilled workers relative to unskilled workers. (Beaudy, Doms and Lewis, 2010; Autor and Dorn, 2013).[18] Our findings show that highly educated workers experience greater wage gains is consistent Berry and Glaser (2005).

Monthly Rents Next, we investigate how rent costs are changing in response to increases in college share. Because we focus on renters only, our sample size becomes smaller. Also instead of including both heads and wives we only include heads since including wives will double count same households. The PSID provides information about the house value and monthly mortgage payment. However, since the house value is decided when the property is first bought, the impact of changing house value due to increase in college share will differ across existing homeowners and new buyers. For this reason, we only focus on renters, who are more likely to experience concurrent changes in housing cost in response to increasing numbers of college graduates. In section VIII, we discuss how an increase of college graduates affects the welfare distribution of homeowners.

In Table IV and onwards, we only present the results using either model (1) which include both individual and city fixed effects (Columns (1) & (3)) and model (2) which includes individual $\times$ city fixed effect (Columns (2) & (4)). We do so as the results without the fixed effects or with only the city fixed effects do not show significant differences from the presented two results

[18] Although not presented in the paper, we find that the size of the human capital effect on wages was larger during the period before the year 2000s, when the adoption of the skill-bias technology was high. Once the technology diffuses across the cities the coefficient size for the share of college graduates decreases significantly.

The first two columns in Table IV show that the increase of college share is associated with an increase in monthly rent. The coefficient size of the human capital effect on rent is 2.36% and 2.46% in column (1) and column (2), respectively. Columns (3) and (4) show that rent price increases are greater for those with higher educational attainment. In both regressions, the rental costs of college graduates increase by approximately 3% in response to a 1 percentage point increase of share of college graduates, which is approximately 1.1 percentage point higher than the rent increases of high school dropouts.

Although this study does not directly examine why there are differences in rent growth for different educational groups, we speculate that it reflects neighborhood sorting *within* cities (we only examine sorting across cities). Numerous studies, including Massey et al. (2009), find that segregation by socioeconomic status has increased over the last three decades, even though segregation by race has declined during this period. Our finding is also in line with the gentrification story: college educated workers gentrify low income neighborhoods, which in turn increases the rent for less skilled workers. Nevertheless, college graduates likely prefer high amenity, affluent neighborhoods, which explains why their rents appear to rise faster than non-college graduates.

Rent Increase vs. Earnings Increase To directly compare the cost and benefits of human capital externalities across groups with different educational attainment, we examine how the increase of college graduates affect rents relative to earnings. We use two dependent variables to investigate the changes in rent and earning: (1) annual rent over annual labor income and (2) annual labor income minus annual rent. The first is a proxy for rent burden. If the growth rate of rent exceeds the growth rent of income, households will pay higher rent relative to income. However, even when the rent growth is higher than income growth, residual earnings (income minus rent) could increase if the absolute increase of income is higher than the absolute increase of rent. Our second dependent variables show how the remaining income after paying for the rent changes due to changes in the share of college graduates. We include both heads and wives in our regression but adjust for rental cost depending on the employment status. If both heads and wives are working, we assume that they are paying equal amounts of rent of their income and allocate half of the monthly income to each individual. This method adjusts for the double counting of monthly rents and also accounts for the fact that both spouses are more likely to work in high cost cities.[19]

Table V presents the results where the dependent variable is the log value of rent over income. The first column shows that if the share of college graduates increases by 1 percentage point, the rent burden for renters increases by 3.42% in column (1) and 3.44% in column (2). The fact that rent burdens increase for stayers (at a similar degree as movers) as college graduate share rises implies that a mechanism other than sorting also explains the changes in rent burden. The next two columns show that higher college graduate shares lead to rent burden increases for all education groups. Compared to the less educated, however, the increase of rent burden is significantly lower for those who received a college degree. Although rental cost growth is lower for less skill workers compared to high skilled workers in cities where college share is increasing, the wages of less skilled workers are growing at an even lower rate. As a result, rent burden increases more for those who received less education living in cities where college share

[19] We also run all our regressions in Tables V and VI with only the heads in the sample. Additionally, we combine the labor income of heads and wives and recalculated the rent to income ratio and residual income and re-run the regressions. Overall, the results do not differ significantly from what is shown in Table V and VI. However, we do find that residual income increases in cities where the college graduates are increasing when we use the combine the labor income of head and wives. These results can be provided upon request.

is growing. This provide some evidence that the housing market is less segmented than the labor market.

Table VI examines how increasing college shares affect residual income, measured by the log value of income minus rent. On average, we do not find any statistical changes in the residual income in response to the increasing share of college graduates. However, columns (3) and (4) show that changes in residual income in response to the increasing college share differs by educational group. The two columns show that the residual income growth is higher for those who receive more education. In fact, the college graduates who do not move experience a positive increase in residual income in cities that attract college graduates. Meanwhile, column (3) suggests that that the less educated who move to cities with higher shares of college graduates experience a decrease in residual income, as cost of housing increases outweigh the wage gains. This results accords with Ganong and Shoag (2017), who find that unskilled individuals have become less likely to move to cities with high costs of living, as these cities have become more and more unaffordable over time. Interestingly, those who move from a low skilled city to a high skilled city have a smaller increase in residual income that stayers who remain in a city where educational attainment rises. If the increase of college graduates further improves the amenity quality, as suggested by Diamond (2016), our results indicate that college graduate stayers benefit the most from the increase of high skilled workers.

Homeowner's Equity Value Our main analysis focuses on changes in housing cost for renters, as housing cash flow costs for owners tend to stay fixed after purchase[20]. Not only is the

[20] The exception to this is property tax costs, which can rise (or fall) after purchase, and maintenance costs, which tend to move with inflation.

cost of housing relatively stable for owners compared to renters (Sinai & Souleles, 2005), homeowners can also build home equity from living in places where house prices are rising.

The homeownership rate rises with skills. In our sample, homeownership rates for each level of educational attainment are: (1) high school dropouts: 38 % (2) high school graduates: 47%, (3) those who received some college education: 52% and (4) college graduates: 68%. Thus, if house values increase more in cities where college share is rising, than the welfare gap between high and low skilled workers will further increase in these cities, as owners, who are more likely to be college graduates, gain greater housing wealth.

Table VII shows that homeowners in cities where college share increases do experience an increase of housing wealth.[21] In fact, a 1 percentage point increase in college share leads to greater than a 4 percent increase in home equity. Within a city, neighborhoods with greater shares of high skilled people are more likely to attracted high skilled workers. Thus, house prices can rise more in these neighborhoods, further benefitting the highly skilled. Columns (3) and (4) show that college graduates, indeed, experience a greater increase in home equity compared to less educated households. These findings are in line with our findings that show college graduates gain greater welfare from increasing numbers of college graduates. College graduate renters receive higher wage growth than rent growth. College graduate owners also experience an increase in their housing wealth, as home prices rises in response to the rising college share. The less skilled, on the other hand, are not only less likely to be owners, but even when they do own, they also experience smaller increase in home equity from living in cities where college share is rising.

[21] To control for the impact from moving within the city, we control for inner city moves using a dummy variable. As with monthly rent regressions, the unit of analysis is households.

VI. Robustness Check

This section provides three additional results that confirm the robustness of our results. We regress our data including local labor demand shifts, using IV method, and also run our regressions for different subsamples. Overall, the results remain largely similar to the previous section.

Local Demand Shifts While city fixed effect captures unobserved city level fixed characteristics, we cannot fully rule out the possibility that our results are driven from the changes in industry-specific labor demand which is correlated with both the increase in the share of college graduates and the increase in wages. We follow Katz and Murphy (1992) and Moretti (2004a), which use Bartik shock to control for exogenous shifts in relative demand for different education groups. For example, a national increase in the demand for skilled workers in a certain industry, will lead to a greater positive labor demand shock of skilled workers in cities that employs a larger share of the labor force in that industry. The index is based on nationwide employment growth for each industry, weighted by the city-specific employment share in those industries. Using Decennial Census 1980, 1990, 2000 and ACS 2008-12 and ACS 2011-15[22], we create the following Bartik index for both college graduates and for those who received high school or less education:

$$\text{Bartik}_{\text{jc}}=\sum_{s=1}^{66} \theta_{sc}\, \Delta E_{js}$$

where $\text{Bartik}_{\text{jc}}$ predicts employment change for workers in educational group j in city c; θ_{sc} is the share of total hours worked in industry s (two digit sic-code) in the 1980, 1990, 2000 and 2010; ΔE_{js} is the change in the log of total hours of employers in education group j who worked in industry in s between 1980, 1990, 2000, 2010 and the following years (1990, 2000, 2010,

[22] ACS 2008-12 data represents year 2010 and ACS 2011-15 represents year 2013.

2013). As we did with other city level data from the Census and the ACS, we merge the two Bartik shocks to the PSID data and interpolate the data in the years for which data is missing.

Table VIII shows the wage regression which includes the two Bartik shocks. In line with our expectation, we find that an increase in local demand for college graduates increases the average wages while an increase in local demand for those who received high school education at most decreases average wages. However, incorporating the local demand shifts does not significantly change the relationship between college share and wages for all education groups. Again, we find that the more educated individuals receive greater wage benefit from increasing college graduates.

Land Grant University While we control for individual's unobserved ability and sorting using fixed effects, we cannot claim causality due to the possibility of an omitted variable that may cause spurious results. In addition to local demand shifts, it is still feasible that there is a variable that simultaneously affects both the increase in college graduates and the increase in wages. To address this issue we use the presence of land-grant universities as an instrumental variable, as it is highly correlated to the present share of college graduates but is unlikely to be influenced by the current employment environment (Moretti, 2004a).

Since the passage of the Morrill Acts in 1862 and 1890, 73 land-grant universities have been established. All 50 states have a minimum of one land-grant school. These institutions were created to strengthen higher education, with focuses on engineering, agriculture and military science. To be a valid instrument, the existence of a land-grant university should not be correlated the unobserved quality of workers with the same level of education. Moretti (2004a) points out several factors that justifies using the land-grant university as an instrument: (1) land-grant university were established more than 100 years ago, (2) the program was implemented at the federal level, (3) the universities were often established in rural areas (4) and the location did not depend on natural resources or other factors that could make the region wealthier. Other studies also suggest that the geographical location of land-grant universities were randomly selected (Nervis, 1962; Williams, 1991).

The first stage regression results in column (1) of Table IX show that the presence of a land-grant university is significantly associated with the share of college graduates. Both F and t-statistics confirm that the instrument is valid. Next four columns present the results where the dependent variables are 1) log (monthly wages), 2) log (monthly rent), 3) log (annual rent/annual labor income) and 4) log (annual labor income-annual rent). As land grand university variable is a dummy we cannot include city fixed effects. Furthermore, using the instrumental variable, we are only able to conduct cross-city comparison and cannot compare between different educational groups using interaction terms. Columns (2) and (3) shows that individuals in cities with higher college share does have higher wages and higher rent. The size of the coefficient is larger in columns (3) than columns (2), which accords with our previous findings. This suggests that college share does have a positive effect on both wages and rents. However, these individuals do not face higher rent burden or lower residual income than those living in cities with lower share of college graduates, indicating that in the long run individuals sort into cities to adjust for the wage and income changes.

Non-Movers If individuals face increases in their rent due to influx of college graduates but have high preference for current location, they can also move within the same city to make their housing more affordable. The sorting within the city can also affect our results, although it is more likely to cause a downward bias in the college share on monthly rent coefficient. In order to eliminate the effect of moving within the same city, we excluded the observation when households move within a city and rental prices change due to the moving. Appendix Table A1 to A4 presents four results that run the same regressions of the main four dependent variables – (1) hourly earnings, (2) month rent, (3) rent to income ratio, and (4) residual earnings – after excluding the effect of moving within a city. The coefficients in the Tables A1-A4 do show significant differences across the four education groups from those in our main results, although the percent of rent increase, in particular, do become slightly smaller. This suggests that some residents do self-select to move into more affordable housing in response to the rising college share, but this *within* city sorting behavior does not alter our results significantly.

Housing Supply Elasticity Finally, we test if our results are driven by cities with low housing supply elasticity. Since the housing supply is more likely to be less responsive to changes in the demand in these cities, housing cost may rise faster in places. According to Gyourko et al (2013), cities with inelastic housing supply and greater preference for the location experienced greater increases in house prices over the past 50 years. These places also experience a greater increase in the share of high income households.

We spilt our sample into groups and test whether rent burden and residual income response to the changes in college share in cities differs between cities with high and low housing supply. The housing supply elasticity data comes from Saiz (2010). This index incorporates information of land availability and local regulations and creates a single measure of how difficult it is to build new housing in a city.

The results in Appendix Tables A5 and A6 compare changes in rent to income ratio and changes in residual income between two groups of cities. As expected, rent burden increases more significantly in cities where housing supply is less elastic. In fact, in cities with high housing supply elasticity, we find that rent burden do not increase. The net residual income also decreases only in cities where housing supply elasticity is lower. The results suggest that our finding is mainly driven by cities where housing supply is inelastic, as housing supply does not respond quickly to the increases in housing demand, including increases arising from rising college share. Meanwhile, both tables present similar patterns between the two groups of cities: High skilled workers experience a relatively small increase in rent burden and large increase in residual wages compared to the low skilled workers. Again, this suggests there are significant differences in the welfare gains across groups with different educational attainment in response to the rising college share.

VII. Amenities

While our theoretical model assumes amenities to be fixed, Diamond (2016) points out the share of college graduates has an endogenous effect on urban amenities. Her study shows that amenities improve more in cities with higher proportion of college graduates. While residual income of low skilled worker does not increase in these cities, they may gain utility from improved urban amenities which arise in the presence of college graduates. While studies have suggested that urban amenities are normal goods (Costa & Kahn, 2000; Diamonds, 2016), there is little empirical evidence that support this argument. While it is unclear why low skilled workers would gain greater benefit from the improvement in urban amenities than the high skilled workers, we partially address this issue by examining two of the major amenities in urban life, restaurants and schools. Diamond's work shows that eating and drinking places increased significantly with the increase in college share. Government spending per K-12 students also increased more in cities with greater share of college graduates.

As the PSID provides information on how much households spend monthly for eating out, we first use the variable to examine whether there are changes in the households' spending on eating out in cities where the share of college graduates is increasing. Table X shows that, on average, increasing in college graduates do not affect households' amount spent eating out. However, columns (3) and (4) show that eating out increases for only high skilled workers in cities where college graduates are growing in share. This is in line with the results in Table VI, which shows only high skilled workers had residual income increases in cities where college share rises. With no increase in income to spend, the low skilled workers are not likely to adjust their consumption in restaurants, and hence do not benefit from having more restaurants.

While less educated populations are not enjoying the improvement in their dining options, they may still be receiving greater utility gains from other amenity improvement. For example, the children of low skilled parents gain greater long term benefits in future employment and higher wages from enrolling in better schools. While it is not possible to investigate this long term outcome, we do examine whether living in cities with increasing share of college graduates have positive impact on children school enrollment. To examine this hypothesis, we link children data in the PSID to the parent data and test whether children between ages 16 and 24 are more likely to be enrolled in school if they reside in cities where the share of college graduates are rising. Since there is little time variation of whether an individual between 16 and 24 is enrolled in school, we do not include individual or individual by city fixed effects. However, to control for the age effect on school enrollment, we include child's age in all our regressions. We also include with a dummy variable that controls for the level of education for heads as well as black and Hispanic dummies.

Column (5) and (6) in Table X presents the results of the likelihood of child's school enrollment using a logit regression, where the dependent variable equals 1 if the child is enrolled in school. Column (5) shows that children living in cities that attract college graduates do not have higher likelihood of being enrolled in school. Furthermore, column (6) shows that the likelihood of school enrollment in response to higher college share is insignificant, regardless of parent's educational level. While we show that the less educated do not benefit from amenity improvements two contexts, our findings may arise from having small samples, especially in the examination of children's school enrollment. Furthermore, we cannot completely rule out the possibility that skilled and unskilled workers are gaining different benefits from other forms of urban amenities. As our study have limited evidence to prove this statement, further research is required to identify who benefits the most from the changing amenities.

VIII. Discussion

Our main results show that the increase in the share of college graduates has significantly different welfare impacts across educational groups. We find that unskilled workers, especially those without a high school diploma, do not benefit in terms of residual income in response to inflows of college graduates. This section goes a step further, and examines whether those in services occupations and those receiving housing subsidies are affected differently from the broader population in the face of changing college graduate share. We also discuss how the increase of college graduates affects homeowners' home equity, which may have additional distributional effects.

Service Workers The impact of increasing college graduate share on wages may differ by occupation, even for those with similar educational attainment. Due to growing opportunity cost, college graduates may increase consumption in home-based production of household services in response to rising returns to skill (Manning 2004, Mazzolari and Ragusa, 2013). Also, in cities that adopt technology more quickly, and where the skilled workers are abundant (Beaudry, Doms, and Lewis, 2010), technology displaces workers engaging in routine work, leading to increases in service employment (Autor and Dorn, 2013).[23] Autor and Dorn (2013) also find that the wages of service workers increases more in high skill cities.[24]

To test this hypothesis, we examine whether low skilled service workers have greater gains in earnings compared to low skilled workers working in other sectors, owing to increasing shares of college graduates. The variable that indicates whether an individual is working in the service sector is not entirely accurate, because the PSID periodically changes occupation classifications.[25] As the categorization of service workers changed in the survey, there may be some noise in our results.

To pick up the relative benefits to service workers, we include three additional interaction terms in our regression model: (1) % BA+ $\times$ High School; (2) % BA+ $\times$ Service; and (3) %BA+ $\times$ High School $\times$ Service. Service is a dummy variable which equals one if the individual is a service worker. High School is a dummy variable that indicates those who received a high school diploma or less education. In this model, the reference group is non-service workers, who received at least some level of college education. Our main interest is in comparing the second and fourth interaction terms in Table XI. In cities with increasing shares of college graduates, we find that low skilled service workers experience greater increases in hourly earnings than low skilled non-service workers. In both columns (1) and (2), we find that the

[23] This happens when the elasticity of substitution in production between computer capital and routine labor is higher than the elasticity of substitution in consumption between goods and services, and thus those performing low-skilled routine tasks move to service industries.

[24] The two authors explain that this is because the elasticity of substitution in consumption between goods and services are less than one.

[25] From 1970 to 1996 the PSID provides a 1 digit code for occupation categorization. For wives, the 1 digit code is only available for 1976 and 1985. From 1997 to 2001 the PSID provides 3 digit 1970 census occupation code and from 2003 it provides 3 digit 2000 census code. Both head and wife occupation data is available since 1986. In the 1 digit code, laborers and service workers, farm laborers are classified into the same category. In 1970 census code, we classify those working in codes between 901 and 965 (Service Workers, except Private Household) as service worker. In 2000 census code, we classify those working in codes 400-416 (Food Preparation and Serving Occupations), 420-425 (Building and Grounds Cleaning and Maintenance Occupations and 430-465 (Personal Care and Service Occupations) as service workers.

coefficient of the triple interaction term is positive. This is consistent with previous studies, and also the consumption theory presented in section II.

While we find that low skilled service workers receive greater wage benefits than those working in non-service sectors, recent studies (e.g. Frey and Osborne (2017)) suggest that low skill service jobs face high risks of disappearing in the near future as automation accelerates. The relative wage gains of service workers may not continue for long.

Housing Subsidies In order to make rental housing more affordable to low income population, the US government provides housing subsidies. Since 1986, the PSID has asked households whether they live in public housing or whether they receive financial support from the government when making their rent payments.[26] We use this information to investigate whether those receiving rent subsidies experience lower rent increases arising from influxes of college graduates and thereby obtain a net gain from such an influx. About 16.6 percent of renters in our sample receive housing subsidy. Also, 78.8 percent of those who receive housing subsidies have received no more than a high school education.

Table XII shows the wage regression results for renters only. The first two columns show that renters do not experience an increase in wages as college graduates increase in the city. As renters, on average, are less educated than homeowners, these findings are consistent with our findings that wages of those who do not receive more than a high school education do not increase in response to the growing share of higher educated population. Meanwhile, monthly rents increased less for those living in subsidized housing (column (3) & (4)).

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[26] For those who do not move, we use the information in 1986 to determine whether the household received housing subsidy.

The next four columns show that those who received a housing subsidy experience smaller increases in rent burdens and net increases in residual earnings. The findings in Table XI suggest that housing subsidies do help lower the housing cost burden of the low skilled that occurs from influxes of college graduates. However, the impact of housing subsidies on distributional outcomes is small, as only about 28 percent of those eligible for housing subsidies receive such subsidies (Getsinger et al, 2015)

IX. Conclusion

By extending the Rosen-Roback framework, we show that increases in college share can lead to different distributional impact within a city. In agreement with our theoretical model, this paper shows that costs and benefits arising from human capital externalities differ across different subsets of the population. For highly educated people, living in cities that attract college graduates raises wages more than rents, although the percent increase in rental cost is slightly higher than the percent increase in wages. For those without college degrees, not only does higher levels of college graduates in a city produces rent increases that are greater than wage increases in percentages, the rent increases completely offset wage increases. Our results show that, in percentage terms, the rent trickle down from an increase in college graduates is higher than the wage trickle down. In other words, rent spillovers from college share rise, is faster than wage spillovers.

Overall, our study finds that the increasing college share favors high skilled over low skilled workers. In addition to the changes in wages, when we take into account the changes in housing cost and housing wealth, the welfare gap between the skilled and the unskilled further widens in cities with rising college share. While both the high and the low skilled gain wage premiums from living in high skilled cities, because of increasing housing cost, high skilled cities may become less affordable for low skilled. In the long term, this could further increase inequality across different educational groups.

Our findings suggest that policy makers need to systematically address the distributional consequences arising from human capital externalities. Policies need to simultaneously consider changes occurring both in the labor and the housing market from the rising college share. Our study offers an important contribution to housing policy and urban studies research by revealing that that the increase in college the benefits of living in a city with a growing share of educated residents share disproportionately favors the more educated residents—a result that has important implications for urban inequality over the less.

References

Acemoglu, D. (2002). Technical Change, Inequality, and the Labor Market. *Journal of Economic Literature*, *40*(1), 7–72.

Autor, D. H., & Dorn, D. (2013). The Growth of Low-Skill Service Jobs and the Polarization of the US Labor Market. *American Economic Review*, *103*(5), 1553–1597.

Autor, D. H., Katz, L. F., & Krueger, A. B. (1998). Computing Inequality: Have Computers Changed the Labor Market? *The Quarterly Journal of Economics*, *113*(4), 1169–1213.

Beaudry, P., Doms, M., & Lewis, E. (2010). Should the Personal Computer Be Considered a Technological Revolution? Evidence from U.S. Metropolitan Areas. *Journal of Political Economy*, *118*(5), 988–1036.

Berry, C. R., & Glaeser, E. L. (2005). The divergence of human capital levels across cities. *Regional Science*, *84*(3), 407–444.

Ciccone, A., & Peri, G. (2006). Identifying Human-Capital Externalities: Theory with Applications. *The Review of Economic Studies*, *73*(2), 381–412.

Costa, D. L., & Kahn, M. E. (2000). Power couples: changes in the locational choice of the college educated, 1940–1990. *The Quarterly Journal of Economics*, *115*(4), 1287–1315.

Diamond, R. (2016). The Determinants and Welfare Implications of US Workers' Diverging Location Choices by Skill: 1980–2000. *American Economic Review*, *106*(3), 479–524.

Ganong, P., & Shoag, D. (2017). Why Has Regional Income Convergence in the US Declined? NBER Working Paper.

Glaeser, E. L., Kolko, J., & Saiz, A. (2001). Consumer city. *Journal of Economic Geography*, *1*(1), 27–50.

Glaeser, E. L., Saiz, A., Burtless, G., & Strange, W. C. (2004). The Rise of the Skilled City.

Brookings-Wharton Papers on Urban Affairs, 47–105.

Goldin C, Katz LF. (2001). Decreasing (and then Increasing) Inequality in America: A Tale of Two Half Centuries. F. Welch (Ed.) The Causes and Consequences of Increasing Inequality Chicago: University of Chicago Press, pp. 37-82.

Gyourko, J., Mayer, C., & Sinai, T. (2013). Superstar Cities. *American Economic Journal: Economic Policy*, *5*(4), 167–199.

Haurin, D.R. (1991). Income Variability, Homeownership, and Housing Demand. *Journal of Housing Economics*, 1(1), 60-74

Hout, M. (2012). Social and Economic Returns to College Education in the United States. *Annual Review of Sociology*, *38*(1), 379–400.

Jacob, J. (1969) The Economy of Cities. New York: Vintage.

Katz, L. F., & Murphy, K. M. (1992). Changes in Relative Wages, 1963–1987: Supply and Demand Factors. *The Quarterly Journal of Economics*, *107*(1), 35–78.

Leopold, J., Getsinger, L., Blumenthal, P., Abazajian, K., & Jordan, R. (2010). *The Housing Affordability Gap for Extremely Low-Income Renters in 2013*. Urban Institute.

Logan, John R., Zengwang Xu, and Brian Stults. (2014) Interpolating US Decennial Census Tract Data from as Early as 1970 to 2010: A Longitudinal Tract Database *The Professional Geographer 66(3): 412–42*

Manning, A. (2004). We Can Work It Out: The Impact of Technological Change on the Demand for Low-Skill Workers. *Scottish Journal of Political Economy*, *51*(5), 581–608.

Marshall, A. (1890) Principles of Economics. London: Macmillan.

Mazzolari, F., & Ragusa, G. (2013). Spillovers from High-Skill Consumption to Low-Skill Labor Markets. *Review of Economics and Statistics*, *95*(1), 74–86.

McCall, L. (2001). Sources of Racial Wage Inequality in Metropolitan Labor Markets: Racial, Ethnic, and Gender Differences. *American Sociological Review*, *66*(4), 520–541.

Moretti, E. (2004a). Estimating the social return to higher education: evidence from longitudinal and repeated cross-sectional data. *Journal of Econometrics*, *121*(1–2), 175–212.

Moretti, E. (2004b). Workers' Education, Spillovers, and Productivity: Evidence from Plant-Level Production Functions. *The American Economic Review*, *94*(3), 656–690.

Moretti, E. (2011). Chapter 14 - Local Labor Markets*. In D. C. and O. Ashenfelter (Ed.), *Handbook of Labor Economics* (Vol. 4, Part B, pp. 1237–1313). Elsevier.

Moretti, E. (2013). Real Wage Inequality. *American Economic Journal: Applied Economics*, *5*(1), 65–103.

Nervis, A. (1962). The State Universities and Democracy. University of Illinois Press, Champaign, IL.

Ngai, L. R., & Pissarides, C. A. (2007). Structural change in a multisector model of growth. *The American Economic Review*, *97*(1), 429–443.

Porter, M.S. (1990) The Competitive Advantage of Nations. New York: Free Press.

Sinai, T. & Souleles, N.R. (2005) Owner-Occupied Housing as a Hedge Against Rent Risk. The Quarterly Journal of Economics, 120(2), 763-789

Williams, R. L. (1991). The Origins of Federal Support for Higher Education. The Pennsylvania State University Press, Pennsylvania.

Tables & Figures

[Table I] Summary Statistics

Variable	Mean	Std. Dev.
Individual Level		
Hourly Wage	22.83	24.89
Monthly Rent	629.59	432.22
Home Equity	104986.8	160454.7
High School	0.38	0.48
Some College	0.24	0.43
College (BA+)	0.23	0.42
Black	0.31	0.46
Hispanic	0.09	0.29
Experienced (Years Work)	12.18	9.25
Age	38.18	11.16
Head	0.67	0.47
Female	0.50	0.50
Never Married	0.14	0.34
Divorced/Separated	0.13	0.33
Widowed	0.02	0.13
City Level		
% BA+	0.16	0.05
% Black	0.16	0.11
% Hispanic	0.09	0.11
Population	2962010	4047682
Observation	175,023	

[Table II] Effect of Changes in Share of College Graduates on Log Hourly Wage

VARIABLES	(1)	(2)	(3)	(4)
% BA+	1.264***	0.598**	1.320***	1.381***
	(0.077)	(0.293)	(0.243)	(0.255)
High School	-0.180***	-0.185***		
	(0.005)	(0.010)		
Some College	-0.155***	-0.150***		
	(0.011)	(0.016)		
College	0.270***	0.258***		
	(0.006)	(0.011)		
Black	0.433***	0.415***		
	(0.007)	(0.012)		
Hispanic	0.733***	0.715***		
	(0.007)	(0.014)		
Head	0.046***	0.046***	0.043***	0.044***
	(0.002)	(0.002)	(0.004)	(0.004)
Female	-0.001***	-0.001***	-0.001***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
Single	0.011***	0.011***	-0.002**	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Div/Separated	-0.000***	-0.000***	0.000	0.000
	(0.000)	(0.000	(0.000)	(0.000)
Widowed	0.200***	0.199***		
	(0.008)	(0.015)		
Age	-0.157***	-0.160***		
	(0.008)	(0.013)		
Age sq./100	-0.232***	-0.235***		
	(0.008)	(0.014)		
Experience	-0.208***	-0.201***		
	(0.008)	(0.014)		
Experience sq./100	-0.252***	-0.248***		
	(0.017)	(0.031)		
% Black	-0.074**	0.056	0.489	0.667**
	(0.029)	(0.351)	(0.302)	(0.320)
% Hispanic	0.0384	0.156	0.467***	0.506***
	(0.029)	(0.174)	(0.162)	(0.177)
Log (Population)	0.061***	0.052	-0.025	-0.068*
	(0.003)	(0.038)	(0.036)	(0.039)
Constant	-0.429***	-0.412	0.826*	1.621***
	(0.046)	(0.443)	(0.478)	(0.544)
Individual FE			Y	
City FE		Y	Y	
Individual×City FE				Y
Year FE	Y	Y	Y	Y
Observations	146,331	146,331	146,331	146,331
R-squared	0.398	0.411	0.279	0.252
Number of cbsaid				25,631
Number of id			21,082	

Note: Dependent variable is log value of hourly wage. Robust standard errors, corrected for city year clustering, are in parentheses. (*** p<0.01, ** p<0.05, * p<0.1).

[Table III] Effect of Changes in Share of College Graduates on Log Hourly Wage by Education Level

VARIABLES	(1)	(2)	(3)	(4)
% BA+	0.890***	-0.146	0.561**	0.698**
	(0.134)	(0.253)	(0.263)	(0.273)
% BA+ * High School	0.197	0.331***	0.0994	0.087
	(0.126)	(0.125)	(0.082)	(0.084)
% BA * Some College	0.339**	0.589***	0.335***	0.349***
	(0.134)	(0.133)	(0.092)	(0.095)
% BA * College (BA+)	0.728***	0.866***	1.120***	1.034***
	(0.145)	(0.145)	(0.111)	(0.114)
Individual Control	Y	Y	Y	Y
City Control	Y	Y	Y	Y
Individual FE			Y	
City FE		Y	Y	
Individual×City FE				Y
Year FE	Y	Y	Y	Y
Observations	146,331	146,331	146,331	146,331
R-squared	0.398	0.412	0.280	0.253
Number of cbsaid				25,631
Number of id			21,082	

Note: Dependent variable is log value of hourly wage. Robust standard errors, corrected for city year clustering, are in parentheses. (*** p<0.01, ** p<0.05, * p<0.1).

[Table IV] Effect of Changes in Share of College Graduates on Log Monthly Rent

VARIABLES	(1)	(2)	(3)	(4)
% BA+	2.355***	2.462***	1.794***	1.929***
	(0.428)	(0.512)	(0.435)	(0.519)
% BA+ * High School			0.422***	0.427***
			(0.095)	(0.102)
% BA * Some College			0.585***	0.530***
			(0.106)	(0.116)
% BA * College (BA+)			1.127***	1.084***
			(0.121)	(0.136)
Individual Control	Y	Y	Y	Y
City Control	Y	Y	Y	Y
Individual FE	Y		Y	
City FE	Y		Y	
Individual×City FE		Y		Y
Year FE	Y	Y	Y	Y
Observations	56,296	56,296	56,296	56,296
R-squared	0.251	0.211	0.252	0.212
Number of id	13,930		13,930	
Number of cbsaid		16,312		16,312

Note: Dependent variable is log value of monthly rent. Robust standard errors, corrected for city year clustering, are in parentheses. (*** p<0.01, ** p<0.05, * p<0.1).

[Table V] Effect of Changes in Share of College Graduates on Log Rent-Income Ratio

VARIABLES	(1)	(2)	(3)	(4)
% BA+	3.420***	3.441***	3.562***	3.622***
	(0.742)	(0.851)	(0.753)	(0.860)
% BA+ * High School			0.065	0.057
			(0.168)	(0.178)
% BA * Some College			-0.067	-0.276
			(0.202)	(0.215)
% BA * College (BA+)			-0.516**	-0.526**
			(0.229)	(0.251)
Individual Control	Y	Y	Y	Y
City Control	Y	Y	Y	Y
Individual FE	Y		Y	
City FE	Y		Y	
Individual×City FE		Y		Y
Year FE	Y	Y	Y	Y
Observations	51,023	51,023	51,023	51,023
R-squared	0.027	0.013	0.028	0.013
Number of id	13,748		13,748	
Number of cbsaid		16,157		16,157

Note: Dependent variable is log value of rent to income ratio. Robust standard errors, corrected for city year clustering, are in parentheses. (*** p<0.01, ** p<0.05, * p<0.1).

[Table VI] Effect of Changes in Share of College Graduates on Log Residual Income

VARIABLES	(1)	(2)	(3)	(4)
% BA+	-0.779	-0.309	-1.273*	-0.866
	(0.691)	(0.798)	(0.710)	(0.816)
% BA+ * High School			0.001	0.095
			(0.166)	(0.168)
% BA * Some College			0.385**	0.589***
			(0.186)	(0.190)
% BA * College (BA+)			1.395***	1.459***
			(0.231)	(0.246)
Individual Control	Y	Y	Y	Y
City Control	Y	Y	Y	Y
Individual FE	Y		Y	
City FE	Y		Y	
Individual×City FE		Y		Y
Year FE	Y	Y	Y	Y
Observations	54,285	54,285	54,285	54,285
R-squared	0.157	0.136	0.159	0.137
Number of id	14,092		14,092	
Number of cbsaid		16,751		16,751

Note: Dependent variable is log value of income minus rent. Robust standard errors, corrected for city year clustering, are in parentheses. (*** p<0.01, ** p<0.05, * p<0.1).

[Table VII] Effect of Changes in Share of College Graduates on Home Equity – Home Owners

VARIABLES	(1)	(2)	(3)	(4)
% BA+	4.903***	5.206***	4.192***	4.497***
	(0.713)	(0.725)	(0.742)	(0.754)
% BA+ * High School			0.026	0.0101
			(0.181)	(0.185)
% BA+ * Some College			0.146	0.194
			(0.196)	(0.199)
% BA+ * College (BA+)			0.892***	0.912***
			(0.197)	(0.200)
Individual Control	Y	Y	Y	Y
City Control	Y	Y	Y	Y
Individual FE	Y		Y	
City FE	Y		Y	
Individual × City FE		Y		Y
Year FE	Y	Y	Y	Y
Observations	63,611	63,611	63,611	63,611
R-squared	0.348	0.324	0.349	0.325
Number of id	10,071		10,071	
Number of cbsaid		11,058		11,058

Note: Dependent variable is log value of income minus rent. Robust standard errors, corrected for city year clustering, are in parentheses. (*** p<0.01, ** p<0.05, * p<0.1).

[Table VIII] Effect of Changes in Share of College Graduates on Log Hourly Wage: Bartik Shock

VARIABLES	(1)	(2)	(3)	(4)
% BA+	1.293***	1.544***	0.790***	1.030***
	(0.293)	(0.311)	(0.304)	(0.323)
% BA+ * High School			-0.069	-0.009
			(0.073)	(0.075)
% BA * Some College			0.140*	0.239***
			(0.083)	(0.0849)
% BA * College (BA+)			0.852***	0.846***
			(0.094)	(0.097)
Bartik_BA	3.051**	2.648	3.582**	3.197**
	(1.531)	(1.627)	(1.528)	(1.629)
Bartik_HS	-1.971	-2.359	-2.450	-2.790
	(1.608)	(1.697)	(1.606)	(1.699)
Individual Control	Y	Y	Y	Y
City Control	Y	Y	Y	Y
Individual FE	Y		Y	
City FE	Y		Y	
Individual×City FE		Y		Y
Year FE	Y	Y	Y	Y
Observations	126,412	126,412	126,412	126,412
R-squared	0.271	0.247	0.273	0.248
Number of id	19,539		19,539	
Number of cbsaid		23,153		23,153

Note: Dependent variable is log value of hourly wage. Robust standard errors, corrected for city year clustering, are in parentheses. (*** p<0.01, ** p<0.05, * p<0.1).

[Table IX] Effect of Changes in Share of College Graduates: IV Results

VARIABLES	(1) % BA	(2) Log (Hourly Wage)	(3) Log (Monthly Rent)	(4) Log (Rent/Income)	(5) Log (Income-Rent)
Land Grant Univ.	0.0400***				
	(0.002)				
% BA+		1.316***	2.408***	0.350	1.151
		(0.482)	(0.585)	(0.887)	(0.911)
City Control	Y	Y	Y	Y	Y
Individual FE	Y	Y	Y	Y	Y
Year FE	Y	Y	Y	Y	Y
F Stat	635.49				
Number of cbsaid	131,248	131,248	51,091	50,550	48,981
Number of id	19,474	19,474	12,787	13,542	12,886

Note: Robust standard errors, corrected for city year clustering, are in parentheses.
(*** p<0.01, ** p<0.05, * p<0.1).

[Table X] Effect of Changes in Share of College Graduates on Eating out & School Enrollment

	Monthly Eating Out				School Enrollment Children 16-24	
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
% BA+	0.105	0.548	-0.290	0.144	2.451	3.248
	(0.373)	(0.404)	(0.386)	(0.420)	(4.107)	(4.488)
% BA+ * High School			-0.149	-0.150		-4.190**
			(0.092)	(0.096)		(1.704)
% BA+* Some College			0.170*	0.293***		1.512
			(0.101)	(0.107)		(2.272)
% BA+ * College (BA+)			0.724***	0.735***		2.261
			(0.122)	(0.135)		(2.475)
Individual Control	Y	Y	Y	Y	Y	Y
City Control	Y	Y	Y	Y	Y	Y
Individual FE	Y		Y		Y	
City FE	Y		Y		Y	
Individual × City FE		Y		Y		Y
Year FE	Y	Y	Y	Y	Y	Y
Observations	112,609	112,609	112,609	112,609	33,518	32,398
R-squared	0.141	0.135	0.141	0.135		
Number of cbsaid	18,562		18,562			
Number of id		22,328		22,328		

Note: Dependent variable is log monthly amount spend eating out. Robust standard errors, corrected for city year clustering, are in parentheses. (*** p<0.01, ** p<0.05, * p<0.1).

[Table XI] Effect of Changes in Share of College Graduates for Service Workers

VARIABLES	(1)	(2)
% BA+	1.378***	1.496***
	(0.241)	(0.255)
% BA+ * Highschool	-0.424***	-0.401***
	(0.048)	(0.050)
% BA+*Service	-0.295***	-0.256***
	(0.055)	(0.057)
% BA+*Highschool*Service	0.384***	0.342***
	(0.076)	(0.077)
Individual Control	Y	Y
City Control	Y	Y
Individual FE	Y	
City FE	Y	
Individual × City FE		Y
Year FE	Y	Y
Observations	148,812	148,812
R-squared	0.278	0.251
Number of id	21,388	
Number of cbsaid		26,087

Note: Dependent variable is log value of hourly wage. Robust standard errors, corrected for city year clustering, are in parentheses. (*** p<0.01, ** p<0.05, * p<0.1).

[Table XII] Effect of Changes in Share of College Graduates for Housing Subsidy Receivers

	Log(Hourly Wage)		Log(Monthly Rent)		Log(Rent/Income)		Log(Income-Rent)	
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
% BA+	0.065	0.903	1.615***	1.535**	3.213***	3.237***	-0.926	-0.468
	(0.569)	(0.637)	(0.530)	(0.605)	(0.969)	(1.084)	(0.833)	(0.921)
% BA+ * Subsidy	-0.092**	-0.075*	-0.233***	-0.216***	0.026	0.066	-0.194***	-0.170***
	(0.040)	(0.042)	(0.050)	(0.050)	(0.077)	(0.079)	(0.058)	(0.057)
Housing Subsidy	0.420*	0.324	-0.489*	-0.587**	-1.417***	-1.610***	1.113***	0.972***
	(0.220)	(0.225)	(0.282)	(0.285)	(0.442)	(0.454)	(0.314)	(0.305)
Individual Control	Y	Y	Y	Y	Y	Y	Y	Y
City Control	Y	Y	Y	Y	Y	Y	Y	Y
Individual FE	Y		Y		Y		Y	
City FE	Y		Y		Y		Y	
Individual × City FE		Y		Y		Y		Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Observations	43,161	43,161	32,433	32,433	42,160	42,160	44,277	44,277
R-squared	0.187	0.164	0.280	0.240	0.035	0.019	0.142	0.123
Number of id	12,507		9,588		12,240		12,471	
Number of cbsaid		14,601		10,982		14,149		14,553

Note: Robust standard errors, corrected for city year clustering, are in parentheses. (*** p<0.01, ** p<0.05, * p<0.1).

Appendix I

[Table A1] Effect of Changes in Share of College Graduates on Log Hourly Wage: Within City Moves Excluded

VARIABLES	(1)	(2)	(3)	(4)
% BA+	1.342***	1.461***	0.858***	0.981***
	(0.253)	(0.270)	(0.267)	(0.284)
% BA+ * High School			-0.079	-0.045
			(0.079)	(0.081)
% BA * Some College			0.082	0.142
			(0.087)	(0.087)
% BA * College (BA+)			0.813***	0.798***
			(0.101)	(0.103)
Individual Control	Y	Y	Y	Y
City Control	Y	Y	Y	Y
Individual FE	Y		Y	
City FE	Y		Y	
Individual × City FE		Y		Y
Year FE	Y	Y	Y	Y
Observations	123,539	123,539	123,539	123,539
R-squared	0.287	0.264	0.289	0.265
Number of cbsaid	21,133		21,133	
Number of id		25,738		25,738

Note: Dependent variable is log value of monthly wages. Robust standard errors, corrected for city year clustering, are in parentheses. (*** p<0.01, ** p<0.05, * p<0.1).

[Table A2] Effect of Changes in Share of College Graduates on Log Monthly Rents: Within City Moves Excluded

VARIABLES	(1)	(2)	(3)	(4)
% BA+	2.790***	2.953***	2.241***	2.472***
	(0.458)	(0.567)	(0.470)	(0.580)
% BA+ * High School			0.365***	0.362**
			(0.132)	(0.146)
% BA * Some College			0.526***	0.399**
			(0.140)	(0.157)
% BA * College			1.153***	1.023***
			(0.153)	(0.180)
Individual Control	Y	Y	Y	Y
City Control	Y	Y	Y	Y
Individual FE	Y		Y	
City FE	Y		Y	
Individual × City FE		Y		Y
Year FE	Y	Y	Y	Y
Observations	40,371	40,371	40,371	40,371
R-squared	0.285	0.239	0.286	0.240
Number of cbsaid	12,919		12,919	
Number of id		15,097		15,097

Note: Dependent variable is log value of monthly rent Robust standard errors, corrected for city year clustering, are in parentheses. (*** p<0.01, ** p<0.05, * p<0.1).

[Table A3] Effect of Changes in Share of College Graduates on Log Rent-Income Ratio: Within City Moves Excluded

VARIABLES	(1)	(2)	(3)	(4)
% BA+	2.430***	2.195**	2.573***	2.471**
	(0.850)	(0.988)	(0.869)	(1.010)
% BA+ * High School			0.059	-0.029
			(0.205)	(0.220)
% BA * Some College			-0.185	-0.476*
			(0.249)	(0.269)
% BA * College			-0.364	-0.507
			(0.279)	(0.315)
Individual Control	Y	Y	Y	Y
City Control	Y	Y	Y	Y
Individual FE	Y		Y	
City FE	Y		Y	
Individual × City FE		Y		Y
Year FE	Y	Y	Y	Y
Observations	37,278	37,278	37,278	37,278
R-squared	0.037	0.017	0.037	0.017
Number of cbsaid	12,939		12,939	
Number of id		15,123		15,123

Note: Depending variable is log value rent to income. Robust standard errors, corrected for city year clustering, are in parentheses. (*** p<0.01, ** p<0.05, * p<0.1).

[Table A4] Effect of Changes in Share of College Graduates on Log Residual Income: Within City Moves Excluded

VARIABLES	(1)	(2)	(3)	(4)
% BA+	-0.271	0.671	-0.731	0.093
	(0.766)	(0.907)	(0.798)	(0.939)
% BA+ * High School			0.051	0.190
			(0.211)	(0.216)
% BA * Some College			0.300	0.597**
			(0.243)	(0.251)
% BA * College			1.252***	1.381***
			(0.288)	(0.317)
Individual Control	Y	Y	Y	Y
City Control	Y	Y	Y	Y
Individual FE	Y		Y	
City FE	Y		Y	
Individual × City FE		Y		Y
Year FE	Y	Y	Y	Y
Observations	39,493	39,493	39,493	39,493
R-squared	0.177	0.154	0.178	0.155
Number of cbsaid	13,301		13,301	
Number of id		15,777		15,777

Note: Dependent variable is log value of income minus rent. Robust standard errors, corrected for city year clustering, are in parentheses. (*** p<0.01, ** p<0.05, * p<0.1).

[Table A5] Effect of Changes in Share of College Graduates on Log Rent-Income Ratio
Cities with High or Low Housing Supply Elasticity

	High Housing Supply Elasticity				Low Housing Supply Elasticity			
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
% BA+	1.160	1.891	1.153	1.786	5.884***	5.752***	6.173***	6.185***
	(1.428)	(1.555)	(1.456)	(1.591)	(1.383)	(1.490)	(1.407)	(1.515)
% BA+ * High School			0.256	0.356			-0.0895	-0.241
			(0.298)	(0.311)			(0.223)	(0.226)
% BA * Some College			0.316	0.406			-0.512*	-0.794***
			(0.328)	(0.347)			(0.284)	(0.293)
% BA * College (BA+)			-0.619	-0.377			-0.592*	-0.641*
			(0.391)	(0.421)			(0.335)	(0.355)
Individual Control	Y	Y	Y	Y	Y	Y	Y	Y
City Control	Y	Y	Y	Y	Y	Y	Y	Y
Individual FE	Y		Y		Y		Y	
City FE	Y		Y		Y		Y	
Individual×City FE		Y		Y		Y		Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Observations	22,730	22,730	22,730	22,730	23,211	23,211	23,211	23,211
R-squared	0.031	0.013	0.032	0.014	0.021	0.017	0.022	0.017
Number of cbsaid	6,672		6,672		6,544		6,544	
Number of id		7,343		7,343		7,046		7,046

Note: Dependent variable is log value rent to income. Robust standard errors, corrected for city year clustering, are in parentheses. (*** p<0.01, ** p<0.05, * p<0.1).

[Table A6] Effect of Changes in Share of College Graduates on Log Residual Income
Cities with High or Low Housing Supply Elasticity

	High Housing Supply Elasticity				Low Housing Supply Elasticity			
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
% BA+	-0.165	-1.073	-0.627	-1.432	-2.568*	-1.777	-2.974**	-2.401
	(1.321)	(1.441)	(1.352)	(1.475)	(1.380)	(1.479)	(1.397)	(1.496)
% BA+ * High School			-0.026	-0.08`			0.099	0.299
			(0.263)	(0.266)			(0.235)	(0.234)
% BA * Some College			0.239	0.194			0.565**	1.024***
			(0.278)	(0.287)			(0.268)	(0.269)
% BA * College (BA+)			1.572***	1.185***			1.390***	1.862***
			(0.355)	(0.352)			(0.358)	(0.372)
Individual Control	Y	Y	Y	Y	Y	Y	Y	Y
City Control	Y	Y	Y	Y	Y	Y	Y	Y
Individual FE	Y		Y		Y		Y	
City FE	Y		Y		Y		Y	
Individual × City FE		Y		Y		Y		Y
Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Observations	24,429	24,429	24,429	24,429	24,170	24,170	24,170	24,170
R-squared	0.160	0.141	0.161	0.142	0.139	0.133	0.141	0.135
Number of cbsaid	6,907		6,907		6,679		6,679	
Number of id		7,643		7,643		7,224		7,224

Note: Dependent variable is log value of income minus rent. Robust standard errors, corrected for city year clustering, are in parentheses. (*** p<0.01, ** p<0.05, * p<0.1).