Online Appendices for:

Estimating Who Benefits From Productivity Growth: Local and Distant Effects of City Productivity Growth on Wages, Rents, and Inequality

Richard Hornbeck

(University of Chicago and NBER)

Enrico Moretti

(Berkeley and NBER)

April 2022

Appendix A: Estimation of Revenue Total Factor Productivity (TFPR)

To measure city-level revenue total factor productivity (TFPR), we use confidential plant-level data from the Census of Manufactures (CMF) in 1977, 1987, and 1997. We adopt an econometric approach similar to that used in our previous work based on the same data from the Census of Manufactures (Greenstone, Hornbeck and Moretti, 2010). We assume each plant p in year t uses the following Cobb-Douglas technology:

$$S_{pt} = A_{pt} L_{pt}^{\beta_1} K_{pt}^{\beta_2} M_{pt}^{\beta_3}, \tag{4}$$

where S is total value of shipments minus changes in inventories, A is TFPR, L is total labor input, K is book value of capital stock, and M is value of material inputs. An important issue is that worker quality is likely to differ across establishments in systematic ways. Failure to account for differences in worker quality would cause measured TFPR to reflect differences in labor inputs. We define total labor input in plant p and year t as the weighted sum of hours worked by production workers (H_{pt}^{P}) and non-production workers (H_{pt}^{NP}), with non-production worker hours weighted by their relative hourly wage: $L_{pt} = H_{pt}^{P} + (w_{pt}^{NP}/w_{pt}^{P}) H_{pt}^{NP}$. This procedure assumes that the relative productivity of production and non-production workers is equal to their relative wage. Capital values are defined as the average total book value of capital stock at the beginning and end of the year, plus the total value of rentals.[44] Material inputs are defined as the total value of materials purchased minus changes in inventories.[45]

Using the confidential plant-level data, we regress log output on log labor, log capital, log materials, and city fixed effects for each year separately. The regressions are weighted by plant output. The estimated 193 city fixed effects reflect average TFPR in each city and year, which also satisfy confidentiality restrictions on Census plant-level data. To interpret

[44] We are unable to use the permanent inventory method because annual investment data are unavailable for all plants in the Census of Manufacturers.

[45] The real quantity of material inputs will be mis-measured if local TFPR growth increases local prices of non-traded materials, which would understate local TFPR growth, but the instrumented change in local TFPR would not reflect local changes in prices.

the magnitudes, we normalize our estimates of nominal TFPR changes to the average real change estimated in the NBER Productivity Database. This normalization of mean changes does not affect the coefficients estimated in our empirical specifications, but benchmarks the reported magnitudes associated with real TFPR growth from 1980 to 1990.

There are well-known challenges in estimating TFPR. An important concern is that establishments may adjust their input choices in response to unobserved shocks, causing bias in the estimated coefficients on inputs (see, e.g., Griliches and Mairesse (1995)). This has been a topic of considerable research, and three points are worth considering in this regard. First, we have explored potential sources of bias on these data and found limited evidence of significant bias in the production function β's (Greenstone, Hornbeck and Moretti, 2010). In particular, we found the production function coefficients to be consistent with cost-share methods of estimating TFPR as well as other standard methods to deal with input endogeneity, including: controlling for flexible functions of investment, capital, materials, and labor; and instrumenting for current inputs with lagged changes in inputs (Olley and Pakes, 1996; Blundell and Bond, 1998; Levinsohn and Petrin, 2003; Syverson, 2004*a*,*b*; Van Biesebroeck, 2007; Ackerberg, Caves and Frazer, 2015). Indeed, our regression-based measure is equivalent to a residual-based measure with particular calibrated shares.[46]

Second, the main parameters of interest in our context are not the β's in the production function; rather, the parameters of interest are the effects of TFPR on local labor market outcomes and local housing market outcomes, which we estimate using instrumental variables. This means that, in our context, any bias in the estimation of TFPR stemming from endogenous input choices will only be a concern to the extent that this bias is systematically

[46]We pool all manufacturing industries when estimating industry-year residuals, fixing the coefficient on inputs across industries within manufacturing, and weighting establishments by revenue to estimate an average effect for all manufacturing. The estimated input coefficients are: 0.578 for materials in 1977, 0.257 for labor in 1977, 0.161 for capital in 1977, 0.565 for materials in 1987, 0.254 for labor in 1987, 0.181 for capital in 1987, 0.661 for materials in 1997, 0.210 for labor in 1997, 0.137 for capital in 1997. We fix those estimated coefficients as input shares when calculating industry-year TFPR, subtract the contribution of industry activity within a particular MSA, and calculate that MSA's predicted change in TFPR based on that adjusted industry-level change in TFPR along with the baseline industry revenue shares in that MSA.

correlated with our instruments.[47]

Third, a substantial separate problem arises in that estimated changes in TFPR are likely to contain substantial measurement error. This problem also motivates our use of instrumental variables.

[47]For example, while factor mobility may contribute to endogenous changes in input usage across cities due to productivity growth, our instrumental variables approach will estimate nationwide industry-level changes in TFPR and assign these nationwide increases in TFPR to particular cities according to their initial industry concentrations.

Appendix B: Theoretical Framework

This Appendix presents a simple spatial equilibrium model of the labor market and housing market, which is useful for considering both the direct effects of local TFPR growth in that city and indirect effects on other cities. The goals are twofold. First, we aim to clarify what influences who benefits from local TFPR growth. Local TFPR growth increases local labor demand, which results in higher nominal wages and also higher cost of housing. The model clarifies how the local gains from TFPR growth are split between workers and landowners. We show that incidence depends on relative elasticities, and which of the two factors (labor or housing) is supplied more elastically. The second goal is to clarify how a local shock to one city might indirectly affect other cities through worker mobility.

We adopt the standard assumptions of Rosen-Roback spatial equilibrium models, with specific functional form assumptions similar to those in Moretti (2011). For brevity, we focus on the simplest version of the model with intuitive closed-form solutions (see Moretti, 2011; Kline and Moretti, 2014, for extensions).

Setup

There are two cities, a and b. Each city is a competitive economy, producing a single output good Y that is traded on the international market at a fixed price normalized to 1. The production function in city c is: $\ln Y_c = A_c + (1 - h)n_c$, where A_c is city-specific log TFPR; n_c is the log of the share of employment in city c; and $0 < h < 1$. Workers are paid their marginal product, and labor demand is derived from the usual first order conditions.[48] We assume a fixed number of workers in the economy.

Indirect utility of worker i in city c is given by: $v_{ic} = w_c - \beta r_c + x_c + e_{ic}$, where w_c is the log of nominal wage, r_c is the log of cost of housing, x_c is the log value of amenities, and β measures the importance of housing consumption in utility and equals the budget share spent on housing. Since people do not spend their entire budget on housing, the effect of a 1% increase in rent is smaller than the effect from a 1% decrease in wage.

[48] We abstract from labor supply decisions and assume each worker supplies one unit of labor.

The random variable e_{ic} is an idiosyncratic location preference, for which a large draw of e_{ic} means that worker i particularly likes city c aside from real wages and amenities. We assume that worker i's relative preference for city b over city a $(e_{ib} - e_{ia})$ is distributed uniformly $U[-s, s]$. The assumption of a uniform distribution is analytically convenient, allowing us to derive closed-form expressions for the endogenous variables in equilibrium. The comparative statics are unchanged in an extended version of this model that assumes the e_{ic}'s are distributed according to a type I Extreme Value distribution.

Workers locate wherever utility is maximized. Worker i chooses city b, rather than city a, if and only if the strength of location preferences exceeds any real wage premium and higher amenity value: $e_{ib} - e_{ia} > (w_a - \beta r_a) - (w_b - \beta r_b) + (x_a - x_b)$. In equilibrium, there is a marginal worker who is indifferent between city a and b.

The parameter s governs the strength of idiosyncratic preferences for location and, therefore, the degree of labor mobility and the city's elasticity of local labor supply. If s is large, many workers will require large differences in real wages or amenities to be compelled to move, and the local labor supply curve is less elastic. If s is small, most workers are not particularly attached to one city and will be willing to move in response to small differences in real wages or amenities, and cities face a more elastic local labor supply curve. In the extreme case where s is zero, there are no idiosyncratic preferences for location and there is perfect labor mobility. In this case, workers will arbitrage any differences in real wages adjusted for amenities and local labor supply is infinitely elastic.

We characterize the elasticity of housing supply by assuming the log price of housing is governed by: $r_c = k_c n_c$. This is a reduced-form relationship between the log cost of housing and the log number of residents in city c.[49] The parameter k_c reflects differences in the elasticity of housing supply, which varies across cities due to differences in geographic constraints and local regulations on land development (Glaeser and Gyourko, 2005; Glaeser,

[49] The model assumes that housing is of constant quality, such that housing supply costs increase only with the number of residents. Our focus is on changes in real housing costs, holding quality fixed, and in the empirical analysis we also present estimates that control for potential changes in housing quality.

Gyourko and Saks, 2006; Gyourko, 2009; Saiz, 2010). In cities where the geography and regulatory structure make it relatively easy to build new housing, k_c is relatively smaller. In the extreme case where there are no constraints on building housing, k_c is zero and the supply curve is horizontal. In the extreme case where it is impossible to build new housing, k_c is infinite and the supply curve is vertical.[50]

Direct Effects of Local TFPR Growth

We now explore how local TFPR growth in city b directly affects equilibrium wages, housing rents, and employment in that city. We assume the two cities are initially identical and that TFPR increases in city b by an amount Δ. If A_{b1} is initial TFPR, the TFPR gain is $A_{b2} - A_{b1} = \Delta$. TFPR in city a does not change.

Increased TFPR in city b shifts the local labor demand curve to the right, resulting in higher employment and higher nominal wages. Higher employment leads to higher housing costs. Assuming an interior solution, the changes in equilibrium employment, nominal wage, and housing rent in city b are:

$$n_{b2} - n_{b1} = \frac{1}{\beta(k_a + k_b) + 2h + s}\Delta > 0, \tag{5}$$

$$w_{b2} - w_{b1} = \frac{\beta(k_a + k_b) + h + s}{\beta(k_a + k_b) + 2h + s}\Delta > 0, \tag{6}$$

$$r_{b2} - r_{b1} = \frac{k_b}{\beta(k_a + k_b) + 2h + s}\Delta > 0. \tag{7}$$

The magnitudes of these effects depend on the elasticities of labor supply and housing supply. Employment increases more when the elasticity of labor supply is higher (s is smaller) and the elasticity of housing supply in b is higher (k_b is smaller). A smaller s means workers have less idiosyncratic preference for locations, so workers are more mobile in response to differences in wages. A smaller k_b means that city b can add more housing units to accommodate

[50] For simplicity, we are ignoring durability of the housing stock and the asymmetry between positive and negative shocks uncovered by Glaeser and Gyourko (2005).

in-migration with less increase in housing cost. Nominal wages increase more when the elasticity of labor supply is lower (s is larger), and housing costs increase more when the elasticity of housing supply in b is lower (k_b is larger).[51]

The increase in real wages, or purchasing power, in city b reflects the increase in nominal wage minus the budget-share weighted increase in housing cost:

$$(8) \qquad (w_{b2} - w_{b1}) - \beta(r_{b2} - r_{b1}) = \frac{\beta k_a + h + s}{\beta(k_a + k_b) + 2h + s}\Delta > 0.$$

Equation 8 shows how the benefits from TFPR growth are split between workers and landowners, with the relative incidence depending on which of the two factors (labor or land) is supplied more elastically at the local level. Intuitively, inelastically supplied factors should bear more incidence.

For a given elasticity of housing supply, a lower local elasticity of labor supply (larger s) implies that a larger fraction of the TFPR shock in city b accrues to workers in city b and that a smaller fraction accrues to landowners in city b. When workers are less mobile, they capture more of the economic gains from local TFPR growth. In the extreme case, if labor is completely immobile ($s = \infty$), then equation 8 becomes: $(w_{b2} - w_{b1}) - \beta(r_{b2} - r_{b1}) = \Delta$. The real wage (or purchasing power) in city b then increases by the full amount of the TFPR shock, such that the benefit of the shock accrues entirely to workers in city b. That is, when labor is a fixed factor, workers in the city directly impacted by the TFPR shock will capture the full economic gain generated by the shock.

For a given elasticity of labor supply, a lower elasticity of housing supply in city b (larger k_b) implies more of the TFPR shock in city b accrues to landowners in city b and less accrues

[51] To obtain equations 5, 6, and 7, we equate local labor demand to local labor supply in each city and equate local housing demand to local housing supply in each city. From the spatial equilibrium condition, the (inverse of) the *local* labor supply to city b in period t is: $w_{bt} = w_{at} + \beta(r_{bt} - r_{at}) + (x_{at} - x_{bt}) + 2s(N_{bt} - 1)$, where N_{bt} is the share of employment in city b. Since N_{bt} is in levels, rather than logs, to obtain closed-form solutions in equations 5, 6, and 7, we use a linear approximation around 1/2: $n_{bt} = \ln N_{bt} \approx \ln(1/2) + 2N_{bt} - 1$, so that we can assign $N_{bt} \approx (1/2)(n_{bt} - \ln(1/2) + 1)$ in the above equation for the (inverse of) the *local* labor supply to city b in period t. We approximate around 1/2 because of the assumption that the two cities are initially identical, which implies that their employment share is initially 1/2. We assume that local housing demand is proportional to city population.

to workers in city b. When housing supply is more inelastic, the quantity of housing increases less in city b and housing prices increase more following the local TFPR shock. In the extreme case, if housing supply in city b is fixed ($k_b = \infty$), the entire TFPR increase is capitalized into land values in city b and worker purchasing power is unchanged.

Motivated by equations 5 to 8, the empirical analysis explores who benefits from local TFPR shocks. The model has assumed that workers are renters, though in the empirical estimates we also allow for some workers to be homeowners. The model has also assumed that people consume only housing and a traded good with fixed price. In our analysis of real wages, or purchasing power, we will also allow for the consumption of non-housing non-traded goods whose prices vary across cities.

Indirect Effects of Local TFPR Growth

We now consider indirect effects on city a from TFPR growth in city b. While city a does not experience any *direct* effect, city a receives *indirect* effects from the TFPR shock in city b. Labor mobility is the mechanism through which city a is indirectly affected by the TFPR shock in city b.

In particular, TFPR growth in city b causes some workers to leave city a for city b. As workers leave, city a experiences an increase in equilibrium wage and a decrease in equilibrium rent. The wage increases in city a because labor demand is downward sloping; the rent decreases in city a because housing supply is upward sloping. This process continues until spatial equilibrium is restored, and the marginal worker is indifferent between city a and city b.[52]

In equilibrium, real wages increase in city a by:

$$(w_{a2} - w_{a1}) - \beta(r_{a2} - r_{a1}) = \frac{\beta k_a + h}{\beta(k_a + k_b) + 2h + s}\Delta > 0. \tag{9}$$

[52]The decrease in employment in city a is equal to the increase in city b, since we have assumed that there is a fixed number of workers in the economy and city a and city b are initially of the same size. We rule out international migration, estimating incidence within the United States, though in principle these cities could be in different countries.

Thus, real wages increase in city a despite TFPR being unchanged in city a. Comparing equations 9 and 8, the increase in city a is smaller than the increase in city b. Real wages increase more in city b, which is the city directly hit by the TFPR shock. Only in the special case of perfect labor mobility, i.e., in the absence of location preferences ($s = 0$), would the increase in real wages be the same in city a and city b.

In this model, with only two cities, the indirect effects on city a are concentrated and large. In our data, however, migrants to city b have many possible origins and the indirect effects on each other city are diffused and small. Though the indirect effects on each other city are small, their sum across all cities is potentially large.

Appendix C: Measuring Changes in Local Purchasing Power

An increase in local TFPR increases both local labor demand and local housing demand, which raises earnings and cost of living. We are interested in quantifying the net effect on worker "purchasing power" in a city, defined as the increase in local earnings net of the increase in local cost of living. This Appendix motivates and derives our measurement of changes in purchasing power.

Renters. For renters, the calculation of changes in "purchasing power" is conceptually more straightforward: it is the percent change in earnings, minus the properly-weighted percent change in housing rent, minus the properly-weighted percent change in cost of non-housing non-tradable goods.

Consider a worker who consumes a traded good (T), housing (H), and a non-housing non-traded good (NT). The price of T is fixed nationally, and is therefore independent of local demand and supply. The rental price of housing (p_H) and the price of the non-housing non-tradable good (p_{NT}) are set locally. We assume Cobb-Douglas utility with fixed consumption shares ($\beta_T + \beta_H + \beta_{NT} = 1$):

$$U = T^{\beta_T} H^{\beta_H} N^{\beta_{NT}}, \tag{10}$$

which implies that worker indirect utility is:

$$\ln V = \ln w - \beta_T \ln p_T - \beta_H \ln p_H - \beta_{NT} \ln p_{NT}. \tag{11}$$

The increase in local purchasing power of renters, from an increase in local TFP, is then given by:

$$\Delta \ln V = \Delta \ln w - \beta_H \Delta \ln p_H - \beta_{NT} \Delta \ln p_{NT}. \tag{12}$$

This definition reflects the percent increase in earnings minus the properly-weighted percent increase in housing rent and cost of non-housing non-tradables. The weights correspond to the share of total expenditures that is spent on housing and non-housing non-tradables, respectively. Intuitively, if housing expenditures make up roughly 33% of total expenditures (U.S. Bureau of Labor Statistics, 2000), then a 1% increase in housing rent would reduce purchasing power by 0.33%.

This is the definition of changes in "real wages" used by Moretti (2013). Note that this definition is based on how the BLS measures the official CPI. The official CPI is the weighted average of the price changes of each good, with weights that correspond to the share of total expenditures spent on that good. The key difference is that, unlike the official CPI that measures average price changes for the entire country, our measure varies at the local level.

We estimate the impact of local TFPR increases on local earnings and the local rental price of housing, but the important data limitation is that changes in local prices of non-housing non-tradable goods are not available for most cities in our period. To overcome this limitation, we follow the approach adopted by Moretti (2013) to impute the systematic component of p_N that varies with housing prices.

Moretti (2013) uses a local consumer price index, released by the BLS for 23 large cities (U.S. Bureau of Labor Statistics, 2000), to estimate the relationship between local prices of non-housing goods and the local cost of housing. This local CPI is normalized to 1 in a given year, which precludes cross-sectional comparisons, but it can be used to infer how local non-housing prices increase along with increases in the cost of housing. Moretti estimates that, from 1980 to 2000, a 1% increase in the local rental price of housing is associated with a 0.35% increase in the local prices of all non-housing goods. Moretti uses this estimate to predict changes in the prices of non-tradable goods, as a function of changes in housing costs, in those cities for which the BLS does not report a local CPI. Moretti (2013) also uses data on non-housing prices from the Accra dataset, collected by the Council for Community and Economic Research, and shows that the imputed local prices are highly correlated with the local CPI based on the Accra data.

Using the above notation, the estimates from Moretti (2013) imply that:

$$\frac{\beta_T}{\beta_T + \beta_{NT}} \times \Delta \ln p_T + \frac{\beta_{NT}}{\beta_T + \beta_{NT}} \times \Delta \ln p_{NT} = 0.35 \times \Delta \ln p_H. \tag{13}$$

Given this relationship between prices, and a housing share of total expenditures equal to 0.33 (U.S. Bureau of Labor Statistics, 2000), we calculate that:

$$\beta_{NT} \Delta \ln p_{NT} = 0.35 \times (1 - \beta_H) \times \Delta \ln p_H = 0.23 \times \Delta \ln p_H. \tag{14}$$

This equation captures how the properly-weighted change in cost of non-housing non-traded goods varies with the estimated change in housing rents. Inserting this into equation 12, we calculate the estimated impact on renters' purchasing power as the estimated increase in log earnings minus 0.56 times log rent, where 0.56 includes both increases in housing cost (0.33) and increases in cost of non-housing non-tradable goods (0.23).

Homeowners. For homeowners, the calculation of changes in "purchasing power" is more complicated conceptually. We focus on homeowners who purchased their home prior to the TFPR shock and the associated increase in housing prices, whereas a homeowner who purchased their home after the TFPR shock is affected similarly as the renter discussed above. Following an increase in local TFPR, the homeowner receives an equity gain and an increase in the user cost of housing. The total impact on homeowner purchasing power is difficult to characterize exactly because it depends on particular homeowner characteristics, such as their expected lifespan and prospects of moving. Instead, we consider two bounds on the changes in homeowners' purchasing power.

As one extreme case (Case A), we consider an infinitely-lived and immobile homeowner. This homeowner does not move after the TFPR shock, and is infinitely-lived in the sense that the homeowner plans to pass on the home to heirs that will continue to live in that city. The homeowner receives an increase in home value, which generates income equal to the increased annual rental return on the home, but the homeowner pays an equivalently higher opportunity cost for living in the home. The homeowner's purchasing power is effectively insulated from increases in local housing costs, though the homeowner does face increased local prices for other non-housing goods. In this Case A, the homeowner's change in purchasing power is defined as:

$$\Delta \ln V = \Delta \ln w - \beta_{NT} \Delta \ln p_{NT}. \tag{15}$$

As above, for renters, we calculate the properly-weighted increase in cost of non-housing non-traded goods. We then calculate the estimated impact on homeowner's purchasing power (Case A) as the estimated increase in log earnings minus 0.23 times log rent, which reflects the increase in cost of non-housing non-tradable goods.

As another extreme case (Case B), we consider a homeowner who is able to consume the income stream associated with the increase in home value. This homeowner anticipates moving to another city, or leaving a bequest to heirs that will live in another city, whose housing prices have not increased. This Case B assumes that homeowners can consume in perpetuity the annual return associated with increased housing rents in their city, which increases their earnings by the percent increase in housing rents multiplied by the expenditure share on housing. That is, homeowners can consume the increase in housing rents that would have been faced by renters of their home.[53] The homeowner still faces increased local prices for other non-housing goods. In this Case B, the homeowner's change in purchasing power is defined as:

$$\Delta \ln V = \Delta \ln(w) + \beta_H \Delta \ln p_H - \beta_{NT} \Delta \ln p_{NT}. \tag{16}$$

In practice, we then calculate the estimated impact on homeowners' purchasing power (Case B) as the estimated increase in log earnings plus 0.10 times log rent (where 0.10 = 0.33 - 0.23), which includes both income received from housing rents (0.33) and an increase in cost of non-housing non-tradable goods (0.23).

Note that we consider impacts on the purchasing power of workers, renters or homeowners, who do not own other assets. Some workers may be shareholders in firms whose profits increase with productivity growth, or some workers may be invested in real estate in cities

[53] Because homeowners' annual housing rents are unobserved, we assume homeowners and renters in the same city spend the same share of consumption on housing.

whose housing rents increase with local productivity.

In summary, we consider changes in "purchasing power" following an increase in local TFPR that both increases earnings and local cost of living. Renters and homeowners both face the same increased cost of non-housing non-tradable goods, but changes in housing costs have different effects on renters and homeowners:

1. Renters must pay increased housing costs, equal to the estimated increase in local rents. Their change in purchasing power, including increased costs for housing and other non-tradables, is defined in equation 12.

2. Homeowners (Case A) are insulated from increases in local housing costs, but must pay higher prices for non-housing non-traded goods. Their change in purchasing power is defined in equation 15.

3. Homeowners (Case B) are insulated from increases in local housing costs, and receive even greater benefits from increases in the value of their home. In this extreme case, they can consume the annual rental return associated with the increased home value, but must pay higher prices for non-housing non-traded goods. Their change in purchasing power is defined in equation 16.

Appendix D: Estimated Indirect Effects: Three Examples

We illustrate our approach to calculating indirect effects with the examples of Houston, San Jose, and Cincinnati. We calculate that real TFPR growth from 1980 to 1990 in these cities was 2.4%, 16.4%, and 2.0%, respectively.

For Houston, we calculate that this TFPR increase alone would be associated with an increase in employment of 86,031 workers in Houston between 1980 and 2000. Panel A of Appendix Figure 5 shows our estimates of where these workers would come from, and which other labor markets and housing markets would be more affected indirectly. For example, 4,551 workers come from Dallas (0.5% of its initial employment), 3,218 from Austin (3.1% of its initial employment), and 2,617 from San Antonio (1.5% of its initial employment). These estimated declines in employment reflect share of migrants to Houston that come from each other city in the 1975 to 1980 period. The map shows that geographic distance has an important influence, with cities further from Houston experiencing a smaller employment decline following increases in Houston TFPR. For example, the employment declines in Portland (OR), Boston, and Madison are 33, 374, and 33, respectively. Panels B and C show the implied indirect effect on per-capita earnings and per-capita housing costs in each city, based on the elasticity of labor demand and the elasticity of housing supply in that city.

Appendix Figure 6 shows the corresponding impacts for San Jose. We estimate that San Jose would experience an increase in city-level employment of 361,765 due to substantial increases in TFPR from 1980 to 1990. Panel A shows that other West Coast cities were most closely linked to San Jose through migration flows, though San Jose would also attract new workers from cities on the East Coast and upper Midwest. Panels B and C show the associated impacts on earnings and housing costs in those other cities, as a consequence of the worker flows. Appendix Figure 7 shows the corresponding impacts for Cincinnati.

Appendix Table 14 reports the direct effects and indirect effects of TFPR growth in Houston (Panel A), San Jose (Panel B), and Cincinnati (Panel C).[54] Column 1 reports the

[54] The standard errors on the indirect effects follow from the variance-covariance structure of the previous estimates.

direct effects as a reference: in Houston, TFPR growth from 1980 to 1990 caused employment to increase by 86,031 workers in the period 1980-2000, earnings to increase by $1,490 per worker, and housing costs to increase by $501 per worker (in 2017 dollars).[55] These increases amount to annual increases of $75 and $25, respectively, from 1980 to 2000. Column 2 reports that local TFPR growth in Houston, all else equal, would have induced employment declines in each of the other 192 cities, on average, by 291 workers from 1980 to 2000. This employment decline is associated with a $9 increase in earnings and a $8 decline in rent, on average, from 1980 to 2000 for workers in other cities (or annual effects of $0.45 and $0.40, respectively). These indirect effects in each of the other cities are small, on average, but these indirect effects will be economically substantial when summed across all cities.

TFPR growth in San Jose generates substantially larger direct effects and indirect effects (Panel B), due in part to greater TFPR growth in San Jose than in Houston. San Jose generates larger indirect effects on housing costs relative to earnings, as compared to Houston, because San Jose is drawing more workers from cities with a more inelastic housing supply than the cities losing workers to Houston.

The direct effects and indirect effects from TFPR growth in Cincinnati (Panel C) are substantially smaller. These effects are smaller than those for San Jose because San Jose experienced a substantially larger increase in local TFPR. The direct effects on earnings and rents are similar to those for Houston, given their similar estimated changes in TFPR from 1980 to 1990, but Cincinnati generates smaller indirect effects because it is substantially smaller than Houston.

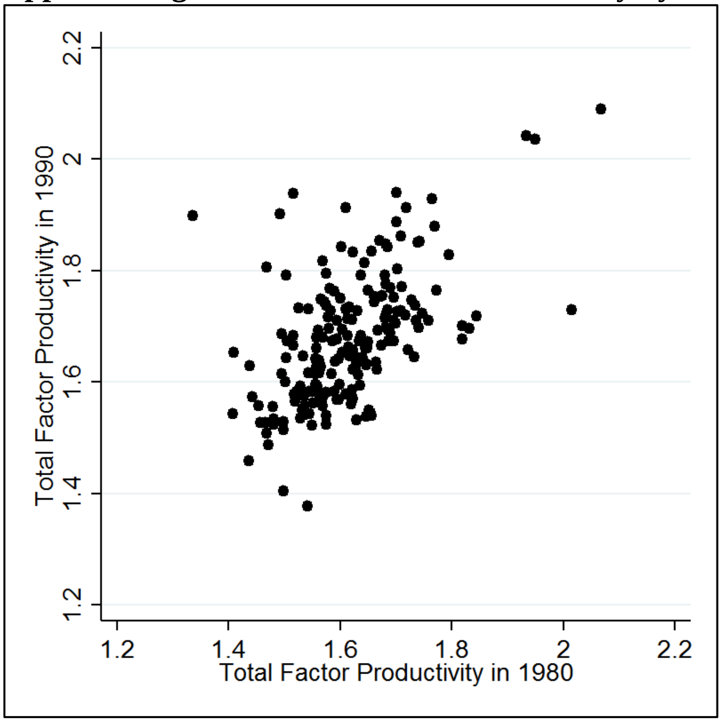
Columns 3, 4, and 5 report that the estimated indirect effects are not sensitive to alternative assumptions about worker migration flows and allowing the elasticity of labor demand to vary across cities. Columns 3 and 4 report similar indirect effects on earnings and housing costs in the average other city, assuming that workers are drawn from other cities in propor-

[55] For comparability to our analysis in Table 2, and our discussion of changes in purchasing power, we assume that workers' baseline housing costs equal 0.33 times their baseline earnings. This assumption results in housing costs being measured on a comparable scale as earnings, given that earnings are greater than expenditures (e.g., due to taxes). For this table, we report numbers for renters.

tion to those other cities' population (Column 3) or assuming that workers are drawn from other cities based on predicted migrant flows (Column 4). Column 5 reports similar indirect effects on earnings, allowing for the elasticity of labor demand to vary across cities according to their baseline industry shares and industry-level labor shares.[56]

[56]For Column 5, we assume that workers are drawn from other cities according to the data on migration flows from 1975-1980 (as in Column 2).

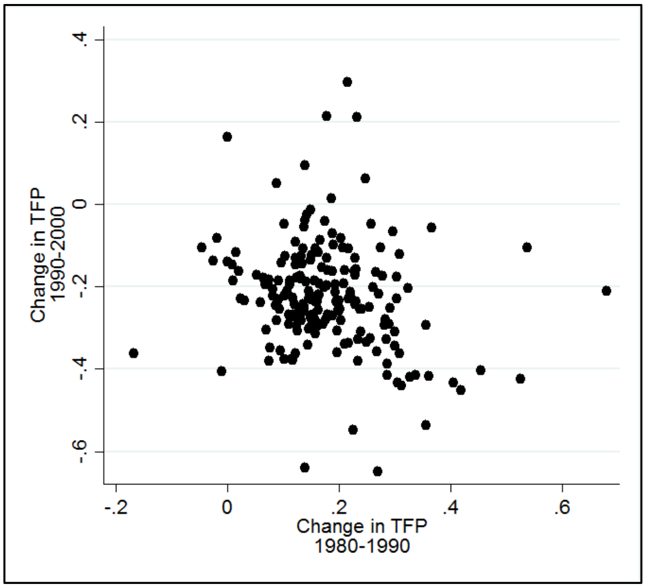
Appendix Figure 1. Total Factor Productivity by City, 1980 and 1990



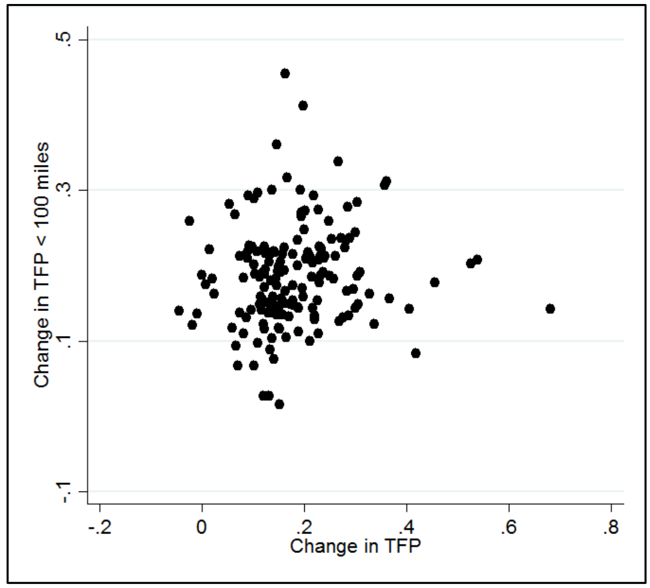
Notes: For each city (MSA), the figure plots TFP in 1990 against TFP in 1980. The estimated coefficient is 0.610, with a standard error 0.099, and an R-squared of 0.298.

Appendix Figure 2. Serial Correlation and Spatial Correlation in TFPR Changes

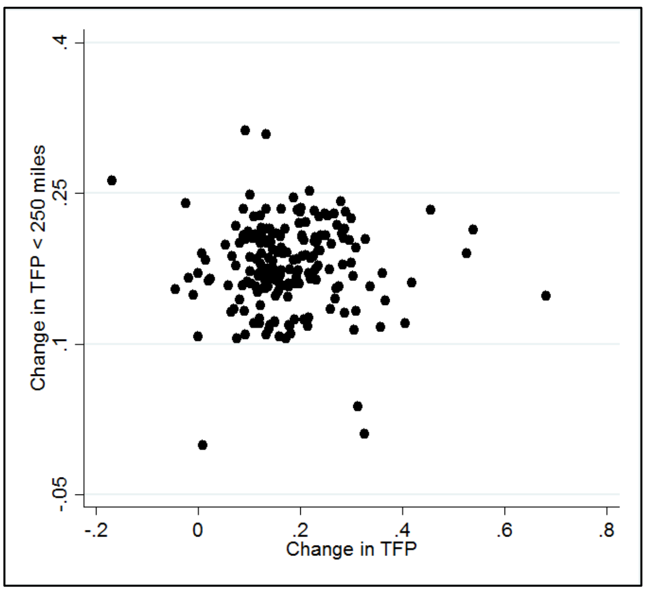
Panel A. 1980-1990 vs. 1990-2000



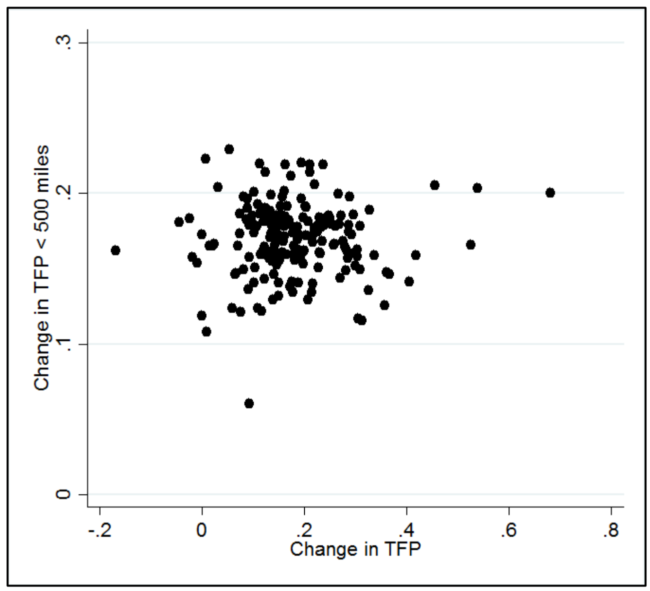
Panel B. Local vs. Within 100 Miles



Panel C. Local vs. Within 250 Miles

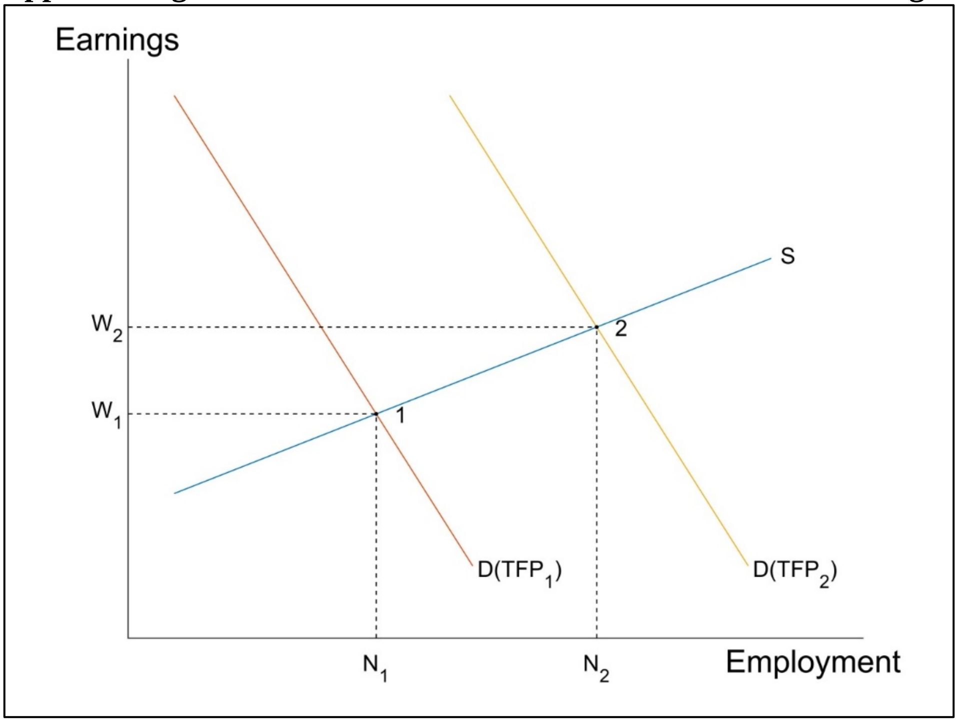


Panel D. Local vs. Within 500 Miles



Notes: Panels show correlations between changes in TFPR. Panel A: changes in city TFPR from 1980 to 1990 vs. changes in city TFPR from 1990 to 2000 (coefficient -0.232, standard error 0.136, R-squared 0.025). Panels B – D: changes in city TFPR from 1980 to 1990 vs. changes in nearby cities' average TFPR from 1980 to 1990 within 100 miles (coefficient 0.062, standard error 0.046, R-squared 0.009) within 250 miles (coefficient -0.004, standard error 0.036, R-squared 0.000) or within 500 miles (coefficient 0.009, standard error 0.018, R-squared 0.001).

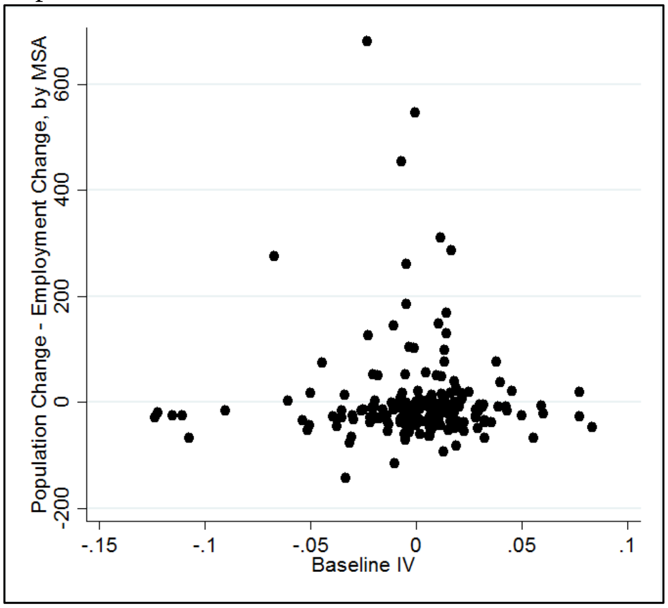
Appendix Figure 3. Effects of a Local TFP Shock on Local Earnings and Local Employment



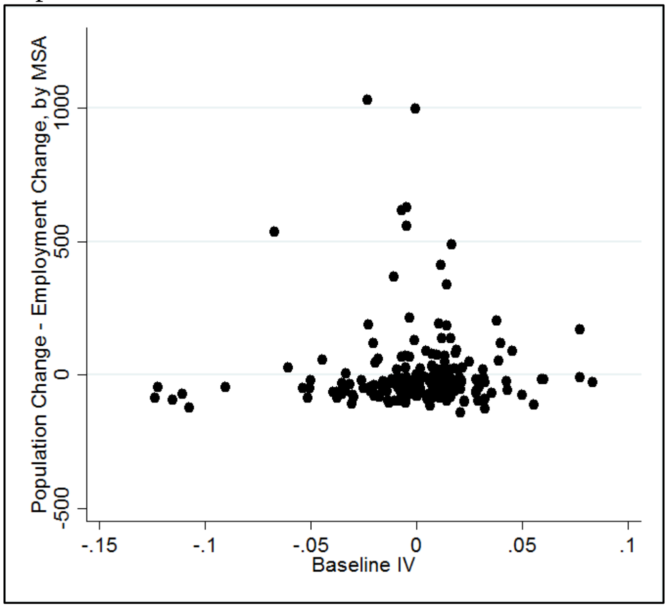
Notes: S is local labor supply and D(TFP) is local labor demand as a function of TFP. Point 1 represents the equilibrium before the TFP shock. The TFP shock shifts the demand curve to the right, D(TFP_2). The new equilibrium is point 2.

Appendix Figure 4. Local TFPR Growth and Changes in Working-Age Population and Workers

Panel A. City-level Changes in Working-Age Population Minus Workers, 1980 to 1990



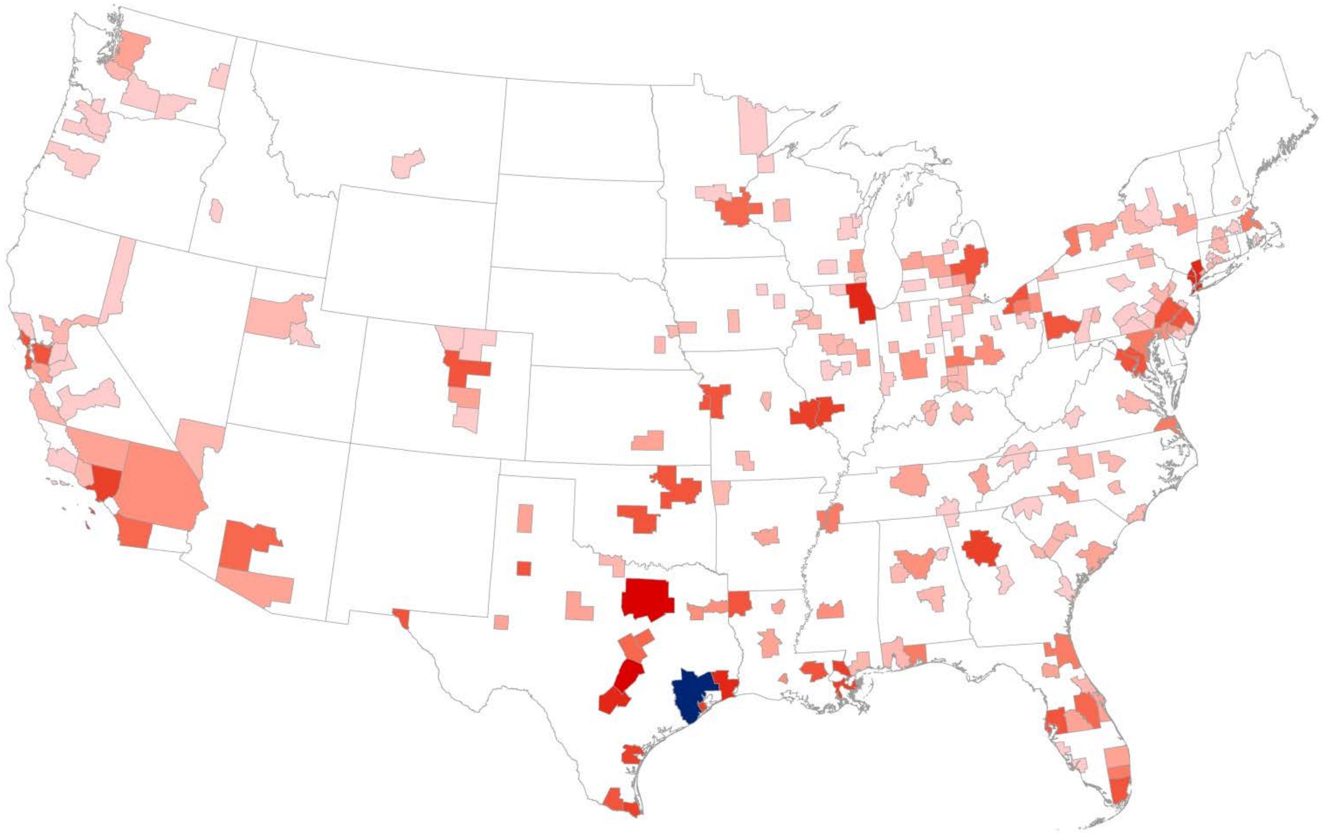
Panel B. City-level Changes in Working-Age Population Minus Workers, 1980 to 2000



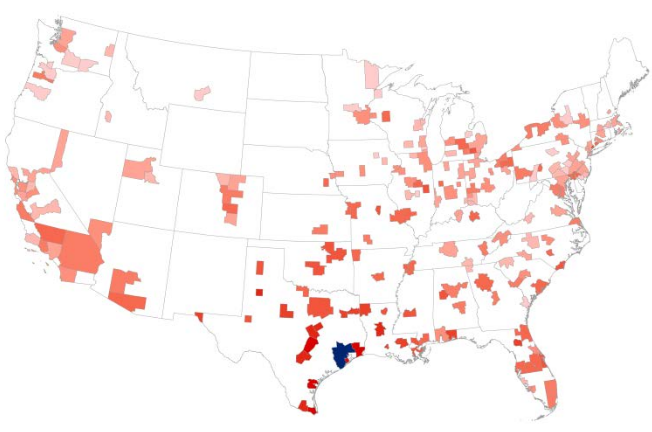
Notes: Each Panel shows city-level changes in the working-age population (ages 19 to 65) minus the number of workers (in thousands), plotted against the city-level predicted change in TFPR (based on our baseline instrument). In Panel A, the estimated coefficient is -48.78 with a standard error of 164.91. In Panel B, the estimated coefficient is 104.54 with a standard error of 298.74.

Appendix Figure 5. Indirect Effects of a TFPR Shock in Houston (Blue) on Other MSAs

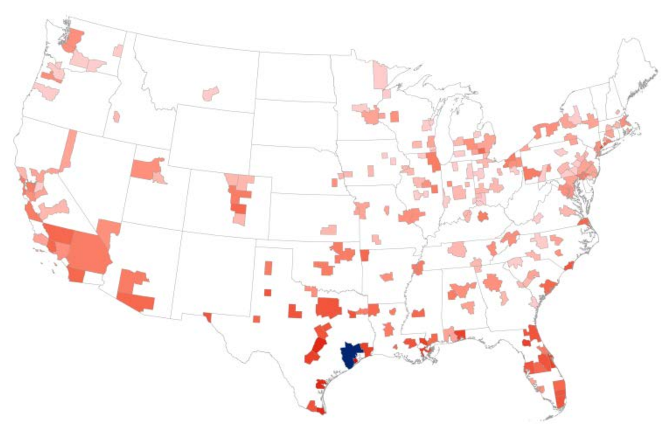
Panel A. Indirect Effects on Employment in Other MSAs



Panel B. Indirect Effects on Earnings



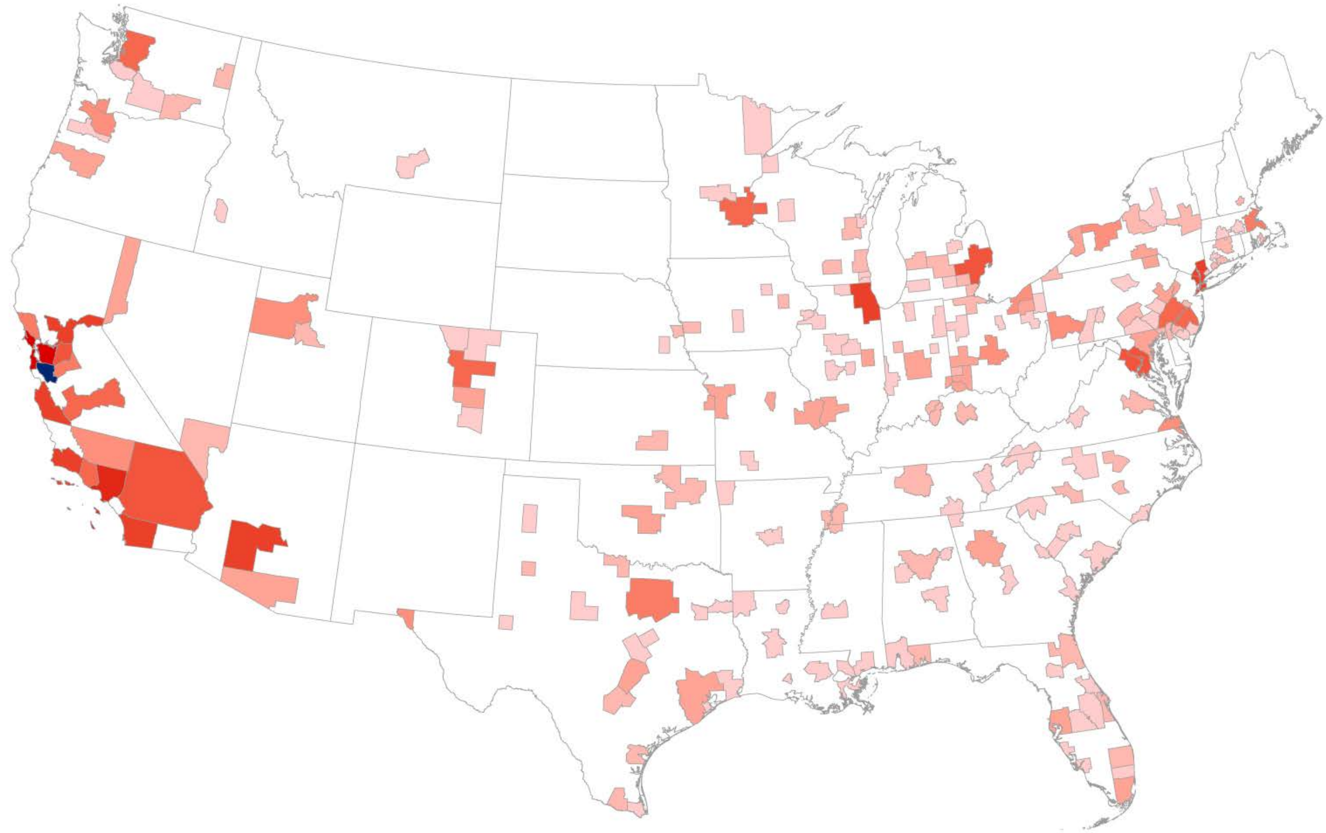
Panel C. Indirect Effects on Housing Rent



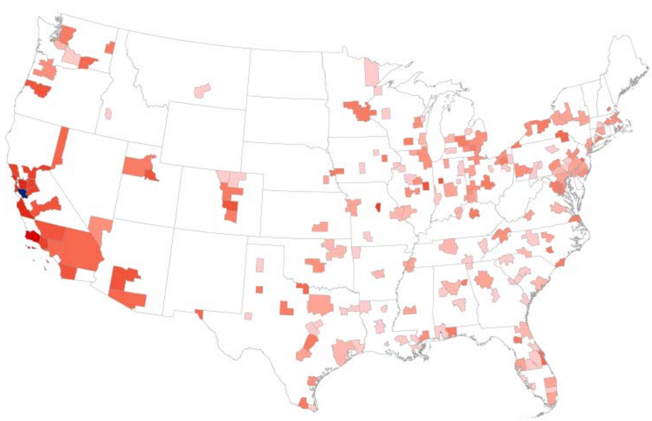
Notes: Each Panel shows the geographic distribution of estimated indirect effects from local TFPR growth in Houston (1980 to 1990) on employment, earnings, and housing rent in other MSAs (1980 to 2000). MSAs are in 10 equal-sized bins, with darker-shaded MSAs receiving larger indirect effects (negative in Panels A and C, positive in Panel B). Houston is in dark blue.

Appendix Figure 6. Indirect Effects of a TFPR Shock in San Jose (Blue) on Other MSAs

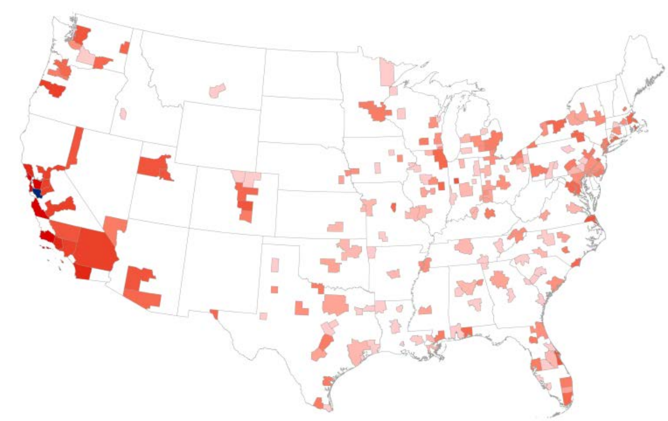
Panel A. Indirect Effects on Employment in Other MSAs



Panel B. Indirect Effects on Earnings



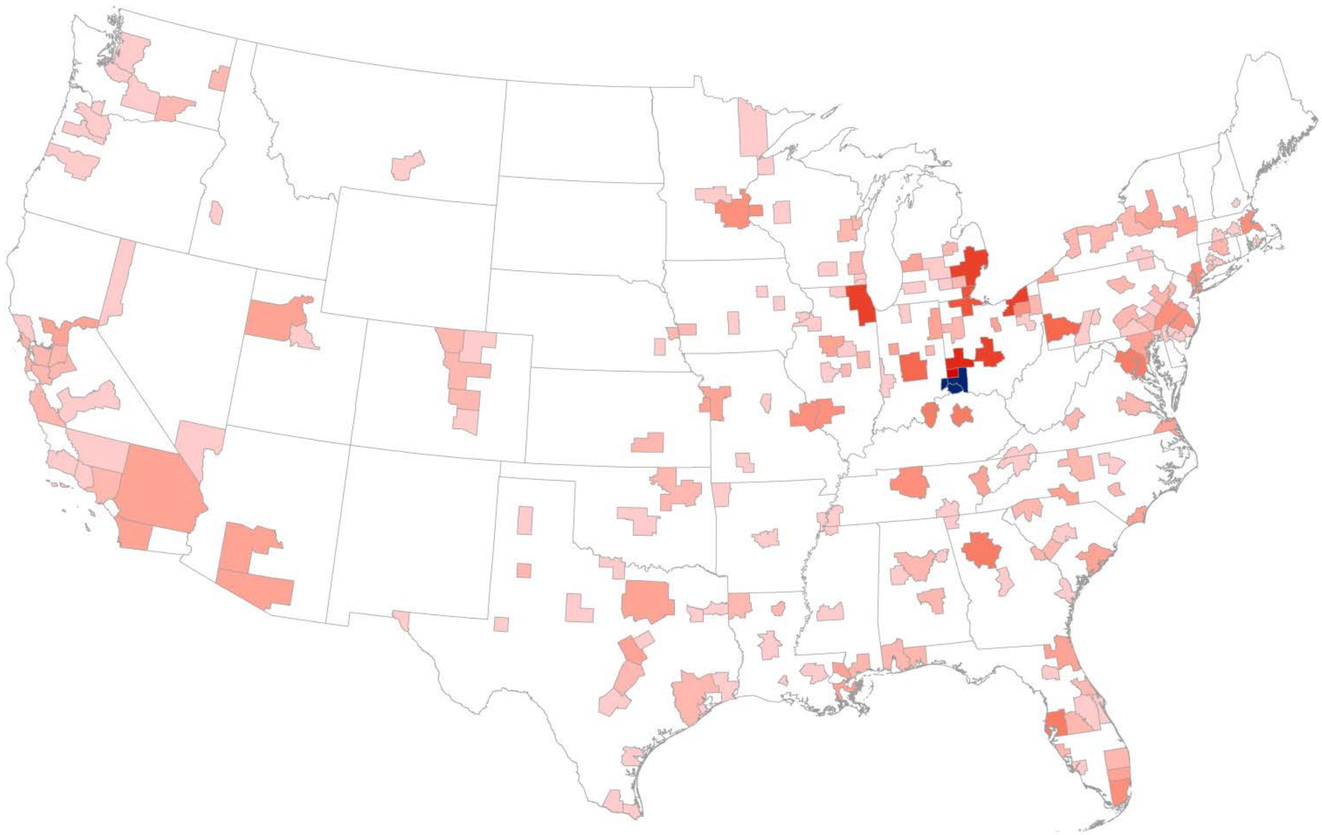
Panel C. Indirect Effects on Housing Rent



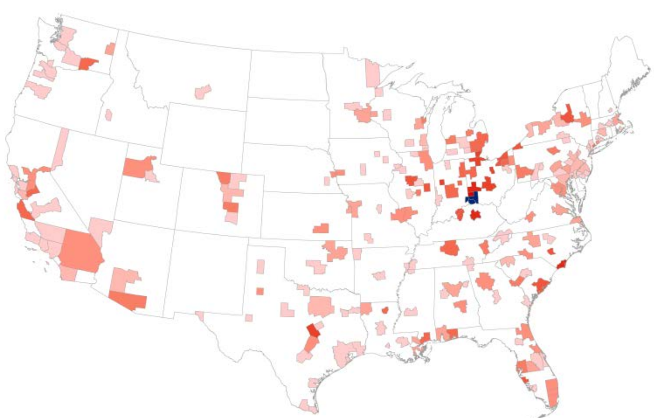
Notes: Each Panel shows the geographic distribution of estimated indirect effects from local TFPR growth in San Jose (1980 to 1990) on employment, earnings, and housing rent in other MSAs (1980 to 2000). MSAs are in 10 equal-sized bins, with darker-shaded MSAs receiving larger indirect effects (negative in Panels A and C, positive in Panel B). San Jose is in dark blue.

Appendix Figure 7. Indirect Effects of a TFPR Shock in Cincinnati (Blue) on Other MSAs

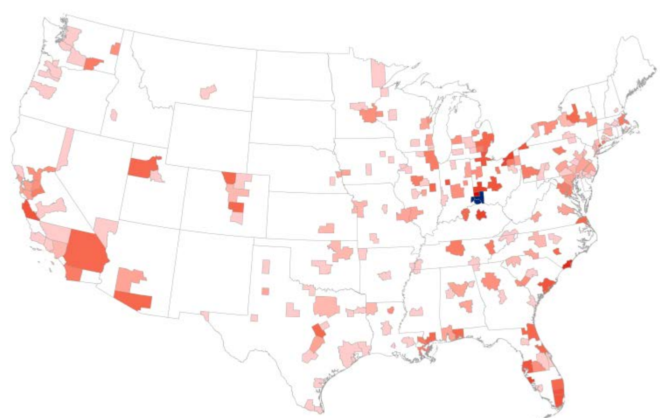
Panel A. Indirect Effects on Employment in Other MSAs



Panel B. Indirect Effects on Earnings



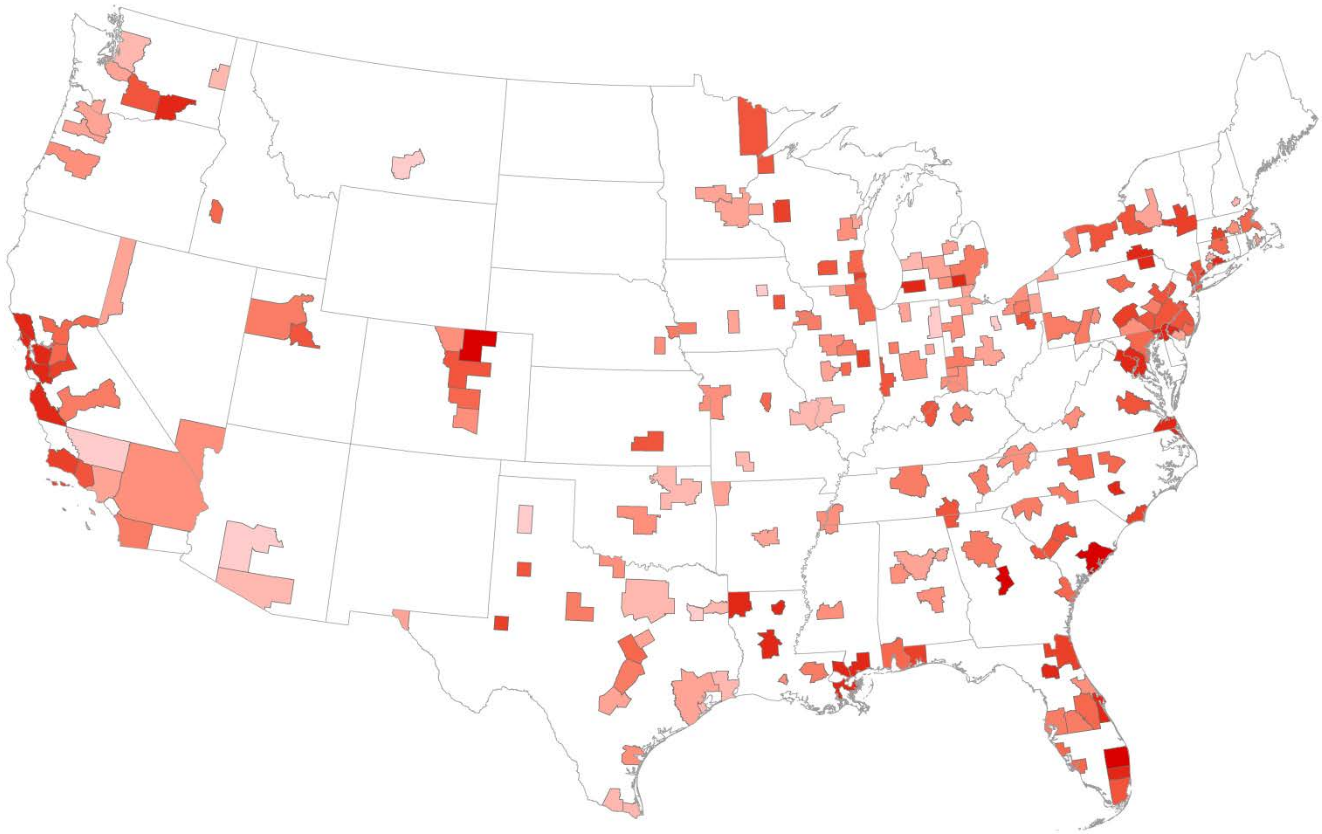
Panel C. Indirect Effects on Housing Rent



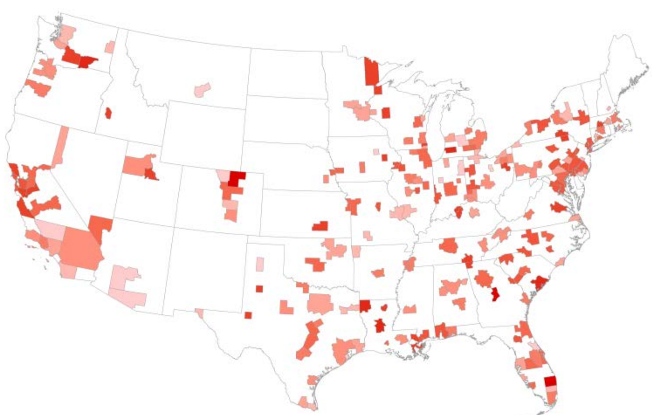
Notes: Each Panel shows the geographic distribution of estimated indirect effects from local TFPR growth in Cincinnati (1980 to 1990) on employment, earnings, and housing rent in other MSAs (1980 to 2000). MSAs are in 10 equal-sized bins, with darker-shaded MSAs receiving larger indirect effects (negative in Panels A and C, positive in Panel B). Cincinnati is in dark blue.

Appendix Figure 8. Direct, Indirect, and Combined Effects of TFPR Growth on Purchasing Power of Renters

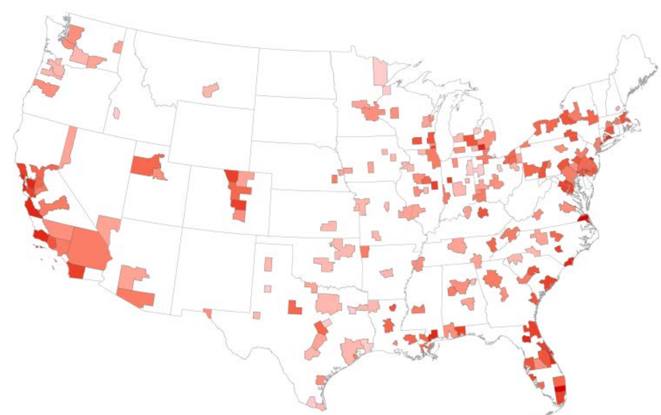
Panel A. Combined Effects of TFPR Growth in All MSAs



Panel B. Direct Effects

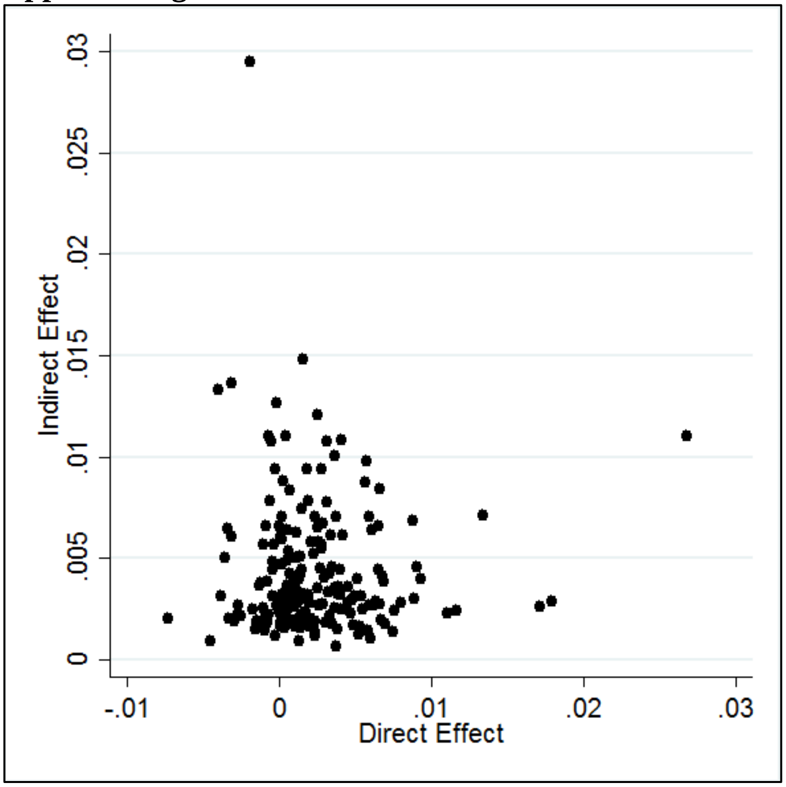


Panel C. Indirect Effects



Notes: Each Panel shows the geographic distribution of estimated combined effects on purchasing power of renters (Panel A), direct effects on purchasing power of renters (Panel B), and indirect effects on purchasing power of renters (Panel C) from TFPR growth in each MSA. MSAs are in 10 equal-sized bins, with darker-shaded MSAs receiving larger effects.

Appendix Figure 9. Indirect Effects and Direct Effects on Cities from TFPR Growth



Notes: For each city (MSA), this figure plots the annualized indirect effect of TFPR growth on purchasing power of renters (in percentage terms) against the annualized direct effect of TFPR growth on log purchasing power of renters (in percentage terms). The estimated coefficient is -0.010, with a standard error of 0.081, and an R-squared of 0.000.

Appendix Table 1. City Characteristics in 1980 and Average Changes Over Time

	City Mean in:	Log Change in City Mean from:	
	1980	1980 to 1990	1980 to 2000
MSA Characteristic:	(1)	(2)	(3)
Employment	174,361	0.105	0.300
	[355,906]	[0.188]	[0.241]
Employment, College	31,725	0.321	0.668
	[74,496]	[0.211]	[0.266]
Employment, Some College	36,297	0.557	0.492
	[74,509]	[0.170]	[0.244]
Employment, High School or less	106,338	-0.193	0.081
	[209,462]	[0.198]	[0.261]
Employment, Manufacturing Sector	57,906	-0.096	-0.061
	[120,535]	[0.237]	[0.300]
Employment, Non-Manufacturing	116,455	0.211	0.467
	[240,047]	[0.168]	[0.217]
Annual Earnings	45,824	0.083	0.186
	[5,349]	[0.074]	[0.108]
Annual Earnings, College	65,848	0.145	0.277
	[7,114]	[0.059]	[0.091]
Annual Earnings, Some College	46,093	0.036	0.112
	[4,763]	[0.070]	[0.081]
Annual Earnings, High School or less	40,792	-0.032	0.017
	[4,850]	[0.070]	[0.076]
Annual Housing Rent	9,730	0.153	0.154
	[1,272]	[0.127]	[0.118]
Home Value	166,071	0.101	0.208
	[51,886]	[0.269]	[0.190]
Number of Housing Units	137,291	0.063	0.259
	[276,743]	[0.179]	[0.237]
Homeowners	117,700	0.075	0.335
	[211,976]	[0.191]	[0.248]
Renters	56,660	0.176	0.288
	[150,510]	[0.200]	[0.249]
Total Factor Productivity	1.649	0.053	0.110
	[0.088]	[0.074]	[0.122]
Number of MSAs	193	193	193

Notes: Column 1 reports average city (MSA) characteristics in 1980. Column 2 reports the average change (in logs) in city characteristics from 1980 to 1990 and Column 3 reports the average change (in logs) from 1980 to 2000, weighted by city manufacturing output in 1980. Dollar values are reported in 2017 US dollars (CPI). Education groups are defined as: "College" includes workers who have completed 4 or more years of college, "Some College" includes workers who completed between 1 and 3 years of college, "High School or less" includes workers who completed 12 years of education or fewer. Standard deviations are reported in brackets.

Appendix Table 2. OLS Impacts of TFPR Growth on Employment, Earnings, and Housing Costs

	Cross-section, 1980 and 1990	Change from 1980 to 1990	Change from 1980 to 2000	Change from 1980 to 2010
	(1)	(2)	(3)	(4)
Panel A. Log Employment	3.59***	0.05	0.15	-0.04
	(1.06)	(0.17)	(0.23)	(0.27)
Panel B. Log Earnings	0.33***	0.14*	0.29**	0.28**
	(0.07)	(0.07)	(0.12)	(0.14)
Panel C. Log Cost of Rent	0.54***	0.25**	0.42***	0.34**
	(0.11)	(0.12)	(0.14)	(0.14)
Panel D. Log Home Value	1.10***	0.48**	0.68***	0.72***
	(0.24)	(0.23)	(0.20)	(0.25)
Panel E. Log Purchasing Power				
Renters	0.03	0.01	0.06	0.09
	(0.04)	(0.04)	(0.06)	(0.10)
Homeowners (Case A)	0.21***	0.08	0.19**	0.20*
	(0.05)	(0.05)	(0.09)	(0.12)
Homeowners (Case B)	0.39***	0.16**	0.33**	0.32**
	(0.08)	(0.08)	(0.13)	(0.15)

Notes: The reported estimates are from OLS specifications. Column 1 reports estimates from a pooled cross-section: the indicated city characteristic from each panel is regressed on city revenue total factor productivity (TFPR) in 1980 and 1990, controlling for region-by-year fixed effects and weighting each city by its total manufacturing output. Columns 2, 3, and 4 report OLS estimates that correspond to the IV estimates in Table 2. Robust standard errors are reported in parentheses. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Appendix Table 3. Direct Effect of Local TFPR Growth on Local Housing Costs, by City Elasticity of Housing Supply

	Medium-run Effect: Change from 1980 to 1990		Difference:	Long-run Effect: Change from 1980 to 2000		Difference:
	Below Mean Housing Elasticity	Above Mean Housing Elasticity	(2) - (1)	Below Mean Housing Elasticity	Above Mean Housing Elasticity	(5) - (4)
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Log Cost of Rent	1.131*	0.641	-0.490	2.335**	1.195***	-1.140
	(0.613)	(0.410)	(0.738)	(1.095)	(0.441)	(1.181)
Panel B. Log Home Value	1.809*	1.490**	-0.319	3.373*	2.168***	-1.205
	(0.993)	(0.735)	(1.236)	(1.723)	(0.638)	(1.838)

Notes: The reported estimates correspond to those in Table 2, but estimated separately for cities with below-mean housing elasticity (Columns 1 and 4) and above-mean housing elasticity (Columns 2 and 5). Columns 3 and 6 report the difference in the estimated coefficients. The regressions include the 171 cities for which Saiz (2010) reports housing supply elasticities. Robust standard errors are reported in parentheses. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Appendix Table 4. OLS Impacts of TFPR Growth, by Education Level

	Pooled Cross-Section:			Medium-run Effect: Change from 1980 to 1990			Long-run Effect: Change from 1980 to 2000		
	College	Some College	No College	College	Some College	No College	College	Some College	No College
	(1)	(2)	(3)	(5)	(6)	(7)	(8)	(9)	(10)
Panel A. Log Employment	4.72***	3.90***	3.24***	-0.05	0.03	0.11	0.26	0.18	0.02
	(1.13)	(1.03)	(1.04)	(0.21)	(0.18)	(0.18)	(0.27)	(0.28)	(0.25)
Panel B. Log Earnings	0.29***	0.25***	0.12**	0.13**	0.14**	0.15**	0.24**	0.20**	0.18**
	(0.06)	(0.06)	(0.05)	(0.05)	(0.06)	(0.06)	(0.09)	(0.08)	(0.08)
Panel C. Log Cost of Rent	0.56***	0.54***	0.51***	0.17	0.27**	0.25**	0.37**	0.37***	0.37***
	(0.13)	(0.11)	(0.10)	(0.14)	(0.11)	(0.12)	(0.16)	(0.12)	(0.12)
Panel D. Log Home Value	0.87***	0.94***	1.04***	0.47**	0.53**	0.52**	0.63***	0.65***	0.68***
	(0.22)	(0.22)	(0.24)	(0.19)	(0.23)	(0.25)	(0.17)	(0.18)	(0.20)
Panel E. Log Purchasing Power									
Renters	-0.03	-0.05	-0.16***	0.03	-0.01	0.01	0.03	-0.01	-0.03
	(0.05)	(0.04)	(0.05)	(0.06)	(0.04)	(0.06)	(0.06)	(0.05)	(0.06)
Homeowners (Case A)	0.16***	0.13***	0.01	0.09**	0.08	0.09*	0.15**	0.12*	0.10
	(0.04)	(0.04)	(0.05)	(0.04)	(0.05)	(0.05)	(0.07)	(0.06)	(0.06)
Homeowners (Case B)	0.34***	0.31***	0.17***	0.14**	0.17**	0.17**	0.27**	0.24**	0.22***
	(0.07)	(0.07)	(0.06)	(0.06)	(0.07)	(0.07)	(0.11)	(0.09)	(0.08)

Notes: The reported estimates are analogous to those in Table 4, but correspond to the OLS specifications (as in Appendix Table 2). Robust standard errors are reported in parentheses. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Appendix Table 5. OLS Impacts of TFPR Growth on Earnings Inequality

	Cross-section, 1980 and 1990	Change from 1980 to 1990	Change from 1980 to 2000
	(1)	(2)	(3)
Panel A. 90/10 Centile Difference in			
Log Earnings	0.155***	-0.032	0.070
	(0.054)	(0.067)	(0.132)
Panel B. 90/50 Centile Difference in			
Log Earnings	0.144***	-0.075*	-0.099
	(0.047)	(0.044)	(0.061)
Panel C. 50/10 Centile Difference in			
Log Earnings	0.011	0.043	0.169
	(0.043)	(0.059)	(0.103)

Notes: The reported estimates are analogous to those in Table 5, but correspond to the OLS specifications (as in Appendix Table 2). Robust standard errors are reported in parentheses. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Appendix Table 6. Direct Effects of Local TFPR Growth, by Sector

	Medium-run Effect: Change from 1980 to 1990		Long-run Effect: Change from 1980 to 2000	
	Manufacturing	Non-Manufacturing	Manufacturing	Non-Manufacturing
	(1)	(2)	(3)	(4)
Panel A. Log Employment	2.61***	2.17***	3.75***	4.13***
	(0.95)	(0.70)	(1.26)	(1.17)
Panel B. Implied Multiplier	1.62***		2.21***	
	(0.25)		(0.32)	
Panel C. Log Earnings	0.74**	0.83***	0.88**	1.45***
	(0.30)	(0.29)	(0.38)	(0.46)

Notes: In Panel A, columns 1 and 2 report estimates that correspond to those in column 1 of Table 2, but separately for the manufacturing sector (column 1) and non-manufacturing sectors (column 2). Columns 3 and 4 report analogous estimates for the long-run effect by sector, corresponding to the estimates in column 2 of Table 2. Panel B reports the implied multiplier effect: the number of additional jobs in non-manufacturing sectors associated with a increase of one job in the manufacturing sector. Panel C reports estimated impacts on log earnings, as in Table 2, but separately for the manufacturing sector and non-manufacturing sector. Robust standard errors are reported in parentheses. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Appendix Table 7. Pre-trends in Local Employment, Earnings, Housing Costs

		Controlling for Outcome Change from 1970 to 1980:	
	Pre-trends: Change from 1970 to 1980	Medium-run Effect: Change from 1980 to 1990	Long-run Effect: Change from 1980 to 2000
	(1)	(2)	(3)
Panel A. Log Employment	-0.45	2.73***	4.75***
	(0.99)	(1.02)	(1.58)
Panel B. Log Earnings	-0.82***	0.70**	1.40***
	(0.25)	(0.29)	(0.51)
Panel C. Log Cost of Rent	-1.22***	0.61	1.25**
	(0.41)	(0.53)	(0.53)
Panel D. Log Home Value	-1.05*	2.41***	3.13***
	(0.63)	(0.91)	(0.91)
Panel E. Log Purchasing Power			
Renters	-0.14	0.49**	0.88**
	(0.19)	(0.25)	(0.36)
Homeowners (Case A)	-0.54***	0.76***	1.31***
	(0.20)	(0.26)	(0.44)
Homeowners (Case B)	-0.94***	0.66**	1.43***
	(0.28)	(0.31)	(0.55)

Notes: Column 1 reports estimates from equation 1 in the text, but regressing changes in city outcomes from 1970 to 1980 on changes in city TFPR from 1980 to 1990. Entries are the estimated coefficient on the change in city TFPR from 1980 to 1990. Columns 2 and 3 report estimates from equations 1 and 2 in the text, controlling also for the change in MSA outcome from 1970 to 1980. In each column, we instrument for changes in city TFPR using the predicted change in TFPR, based on our baseline instrument. In each column, the sample is restricted to 110 MSAs with data from 1970. Robust standard errors are reported in parentheses. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Appendix Table 8. Direct Effect of Local TFPR Growth, Alternative Specifications

	Outcome Change from 1980 to 2000:					
	Long-run Effect: TFP Change from 1980 to 1990		Medium-Run Effect: TFP Change from 1980 to 2000	Long-run Effect: TFP Change from 1980 to 1990		
	Control: TFP Change from 1990 to 2000	Control: Instrumented TFP Change from 1990 to 2000		Control: Instrumented TFP Change from 1980 to 1990 in Nearby MSAs		
				Within 500 Miles	Within 250 Miles	Within 100 Miles
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A. Log Employment	3.73***	4.36**	1.79***	4.04***	4.53***	3.66***
	(1.09)	(1.80)	(0.61)	(1.26)	(1.70)	(1.35)
Panel B. Log Earnings	1.31***	1.06*	0.75***	1.36***	1.27**	1.11**
	(0.40)	(0.60)	(0.28)	(0.43)	(0.55)	(0.48)
Panel C. Log Cost of Rent	1.39***	1.09	0.79**	1.43***	1.14**	1.04**
	(0.42)	(0.68)	(0.32)	(0.44)	(0.49)	(0.44)
Panel D. Log Home Value	2.21***	2.48**	1.14**	2.02***	1.92**	1.95***
	(0.70)	(1.17)	(0.47)	(0.67)	(0.82)	(0.71)
Panel E. Log Purchasing Power						
Renters	0.53**	0.45	0.31**	0.56**	0.63**	0.52*
	(0.22)	(0.30)	(0.13)	(0.24)	(0.32)	(0.28)
Homeowners (Case A)	0.99***	0.81*	0.57***	1.03***	1.01**	0.87**
	(0.32)	(0.46)	(0.21)	(0.35)	(0.45)	(0.39)
Homeowners (Case B)	1.45***	1.16*	0.83***	1.51***	1.38**	1.21**
	(0.44)	(0.66)	(0.31)	(0.47)	(0.59)	(0.52)
First Stage Coefficient	0.89***	0.76***	0.88***	0.85***	0.70***	0.84***
(See Table Notes)	(0.17)	(0.19)	(0.20)	(0.19)	(0.19)	(0.19)
Instrument F-statistic	26.06	11.96	19.68	21.26	13.18	18.65

Notes: Column 1 reports estimates corresponding to those in Column 2 of Table 2, but controlling for the change in TFP from 1990 to 2000. Column 2 reports estimates from the same specification, but instrumenting for the change in TFP from 1990 to 2000 with the predicted change in TFP from 1990 to 2000 constructed as in our baseline instrument. Column 3 reports estimates from a long-difference specification, regressing changes in each outcome on changes in TFP from 1980 to 2000, and instrumenting using the predicted change in TFP from 1980 to 2000 constructed as in our baseline instrument. Columns 4, 5, and 6 report estimates corresponding to those in Column 2 of Table 2, but controlling for average changes in TFP from 1980 to 1990 in cities within 500 miles, 250 miles, or 100 miles. TFP changes in nearby cities are instrumented using the predicted change in TFP for those cities, constructed as in our baseline instrument. Robust standard errors are reported in parentheses. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Appendix Table 9. Heterogeneity in Direct Effects of Local TFPR Growth, by City Size and Prior Growth Rate

	Heterogeneity by 1980 City Employment:		Heterogeneity by 1970-to-1980 Employment Growth Rate:	
	Above-Median Cities	Below-Median Cities	Above-Median Cities	Below-Median Cities
	(1)	(2)	(1)	(2)
Panel A. Log Employment	2.76**	2.41*	3.11*	2.53**
	(1.09)	(1.36)	(1.79)	(1.08)
Panel B. Log Earnings	1.38***	0.31	1.51**	1.66*
	(0.42)	(0.30)	(0.69)	(0.88)
Panel C. Log Cost of Rent	1.47***	0.55	1.85	1.80*
	(0.56)	(0.41)	(1.33)	(1.09)
Panel D. Log Home Value	2.63***	1.01*	3.05	4.71*
	(0.97)	(0.58)	(2.05)	(2.74)
Panel E. Log Purchasing Power				
Renters	0.56**	-0.00	0.48	0.65*
	(0.28)	(0.12)	(0.34)	(0.35)
Homeowners (Case A)	1.04***	0.18	1.08**	1.24*
	(0.34)	(0.21)	(0.44)	(0.65)
Homeowners (Case B)	1.53***	0.36	1.69**	1.84*
	(0.46)	(0.33)	(0.81)	(0.99)

Notes: Columns 1 and 2 report estimates from equation 1 in the text, restricted to 96 sample cities with above-median 1980 employment (Column 1) or 97 sample cities with below-median 1980 employment (Column 2). Columns 3 and 4 report estimates from equation 1 in the text, restricted to 55 sample cities with above-median employment growth rates from 1970 to 1980 (Column 3) and below-median employment growth rates from 1970 to 1980 (Column 4) among the 110 sample cities with data from 1970. In each column, we instrument for changes in city TFPR using the predicted change in TFPR, based on our baseline instrument. Robust standard errors are reported in parentheses. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Appendix Table 10. Direct Effect of Local TFPR Growth, Clustering by MSA Group or State

	Medium-run Effect: Change from 1980 to 1990		Long-run Effect: Change from 1980 to 2000	
	Cluster by MSA Group	Cluster by State	Cluster by MSA Group	Cluster by State
	(1)	(2)	(3)	(4)
Panel A. Log Employment	2.38***	2.38***	4.16***	4.16***
	(0.61)	(0.62)	(0.92)	(0.85)
Panel B. Log Earnings	0.91***	0.91***	1.45***	1.45***
	(0.24)	(0.25)	(0.35)	(0.31)
Panel C. Log Cost of Rent	0.98**	0.98**	1.47***	1.47***
	(0.37)	(0.40)	(0.35)	(0.30)
Panel D. Log Home Value	1.74**	1.74**	2.46***	2.46***
	(0.67)	(0.71)	(0.63)	(0.64)
Panel E. Log Purchasing Power				
Renters	0.36***	0.36***	0.62***	0.62***
	(0.12)	(0.08)	(0.19)	(0.18)
Homeowners (Case A)	0.68***	0.68***	1.11***	1.11***
	(0.17)	(0.16)	(0.28)	(0.25)
Homeowners (Case B)	1.01***	1.01***	1.60***	1.60***
	(0.27)	(0.28)	(0.38)	(0.34)
Number of Clusters	114	42	114	42

Notes: The estimates correspond to those in Table 2, but adjusting the estimated standard errors to cluster by contiguous MSA groupings (Columns 1 and 3) or cluster by state (Columns 2 and 4). *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Appendix Table 11. Direct Effect of Local TFPR Growth, Adjusting Inference for Correlation in Industry Shares

	Medium-run Effect: Change from 1980 to 1990				Long-run Effect: Change from 1980 to 2000			
	Baseline IV	Stock IV	Export IV	Patent IV	Baseline IV	Stock IV	Export IV	Patent IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A. Log Employment	2.38***	2.20***	3.94***	0.66	4.16***	2.92***	5.89***	1.71
	(0.85)	(0.71)	(0.66)	(1.28)	(1.30)	(0.96)	(1.01)	(1.56)
Panel B. Log Earnings	0.90***	1.20***	1.53***	1.11	1.45***	1.72***	2.27***	2.08*
	(0.38)	(0.44)	(0.36)	(0.64)	(0.57)	(0.68)	(0.56)	(1.12)
Panel C. Log Cost of Rent	0.98	1.75**	1.72***	2.13**	1.47***	2.25***	2.13***	1.90**
	(0.60)	(0.86)	(0.51)	(1.02)	(0.56)	(0.82)	(0.48)	(0.96)
Panel D. Log Home Value	1.74*	3.03*	2.98***	3.73**	2.46***	2.45**	3.55***	2.86**
	(1.04)	(1.62)	(0.90)	(1.76)	(0.80)	(1.12)	(0.60)	(1.34)
Panel E. Log Purchasing Power								
Renters	0.36**	0.22	0.57***	-0.09	0.62*	0.46	1.08***	1.02*
	(0.18)	(0.17)	(0.16)	(0.21)	(0.32)	(0.34)	(0.32)	(0.59)
Homeowners (Case A)	0.68***	0.80***	1.13***	0.62	1.11***	1.20**	1.79***	1.64*
	(0.26)	(0.26)	(0.26)	(0.43)	(0.46)	(0.46)	(0.46)	(0.90)
Homeowners (Case B)	1.01***	1.38***	1.70***	1.32*	1.60***	1.94***	2.49***	2.27*
	(0.43)	(0.52)	(0.40)	(0.74)	(0.62)	(0.76)	(0.60)	(1.21)

Notes: The estimates correspond to those in Tables 2 and 3, using alternative instrumental variables, when adjusting the estimated standard errors for correlated outcomes among cities with similar baseline industry shares (Adao et al. 2019). *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Appendix Table 12. Direct Effect of Local TFP Growth, Additional Control Variables

	Medium-run Effect: Change from 1980 to 1990				Long-run Effect: Change from 1980 to 2000			
	Control for 1980 MFG Share	Controls for Broad Industry Shares	Control for 1980 O&G Share	Controls for Changes in Composition	Control for 1980 MFG Share	Controls for Broad Industry Shares	Control for 1980 O&G Share	Controls for Changes in Composition
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A. Log Employment	2.30***	1.85**	2.44**	-	4.01***	3.61***	4.40***	-
	(0.74)	(0.77)	(1.04)		(1.12)	(1.17)	(1.64)	
Panel B. Log Earnings	0.87***	0.67**	0.84**	0.89***	1.39***	1.22***	1.44**	1.12***
	(0.29)	(0.26)	(0.40)	(0.29)	(0.40)	(0.41)	(0.62)	(0.32)
Panel C. Log Cost of Rent	0.95**	0.46	0.51	1.17**	1.43***	1.16***	1.15**	1.61***
	(0.42)	(0.30)	(0.41)	(0.52)	(0.43)	(0.42)	(0.53)	(0.49)
Panel D. Log Home Value	1.69**	0.79	0.94	1.85**	2.42***	1.70**	1.54*	2.49***
	(0.70)	(0.56)	(0.75)	(0.74)	(0.76)	(0.69)	(0.81)	(0.81)
Panel E. Log Purchasing Power								
Renters	0.34**	0.41**	0.55**	0.31*	0.59***	0.57***	0.79**	0.46***
	(0.15)	(0.17)	(0.25)	(0.17)	(0.22)	(0.22)	(0.35)	(0.17)
Homeowners (Case A)	0.65***	0.56***	0.72**	0.69***	1.06***	0.96***	1.17**	0.95***
	(0.21)	(0.22)	(0.33)	(0.23)	(0.32)	(0.32)	(0.51)	(0.26)
Homeowners (Case B)	0.97***	0.71**	0.89**	1.07***	1.53***	1.34***	1.55**	1.44***
	(0.32)	(0.29)	(0.44)	(0.37)	(0.44)	(0.44)	(0.67)	(0.39)
First Stage Coefficient	0.81***	0.86***	0.79***	0.81***	0.81***	0.86***	0.79***	0.81***
(See Table Notes)	(0.16)	(0.19)	(0.21)	(0.16)	(0.16)	(0.19)	(0.21)	(0.16)
Instrument F-statistic	25.21	20.48	13.70	24.21	25.21	20.48	13.70	24.21

Notes: The estimates correspond to those in Table 2, with additional control variables. Columns 1 and 5 control for the city manufacturing employment share in 1980. Columns 2 and 6 control for the city employment share in 1980 in broad industry categories: Agriculture, Forestry, and Fishing; Mining; Construction and Manufacturing; Transportation and Public Utilities; Wholesale Trade and Retail Trade; and Finance, Insurance, and Real Estate and Services. Columns 3 and 7 control for the city employment share in 1980 in the oil and gas industry. Columns 4 and 8, in Panel B, are individual-level regressions that adjust annual earnings for worker composition by controlling for age, age squared, education (high school, some college, college), race, and gender (and cluster standard errors at the city level). Columns 4 and 8, in Panels C and D, are also individual-level regressions that adjust housing costs for physical characteristics by controlling for the number of rooms and number of bedrooms (dummy variables for each number), whether the home is part of a multi-unit structure, and the presence of a kitchen or plumbing (and cluster standard errors at the city level). Columns 4 and 8, Panel E, include both sets of individual-level controls. Robust standard errors are reported in parentheses. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Appendix Table 13. Direct Effect of Local TFPR Growth, Aggregating MSAs

	Medium-run Effect: Change from 1980 to 1990				Long-run Effect: Change from 1980 to 2000			
	>10% Migrant Flows	>5% Migrant Flows	Contiguous MSAs	No Region Fixed Effects	>10% Migrant Flows	>5% Migrant Flows	Contiguous MSAs	No Region Fixed Effects
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A. Log Employment	2.46***	2.55***	1.67**	2.21***	4.21***	4.58***	3.36**	3.64***
	(0.88)	(0.90)	(0.65)	(0.77)	(1.32)	(1.53)	(1.34)	(1.15)
Panel B. Log Earnings	0.95***	0.98***	0.83***	1.06***	1.51***	1.60***	1.62***	1.58***
	(0.32)	(0.34)	(0.22)	(0.37)	(0.53)	(0.59)	(0.58)	(0.49)
Panel C. Log Cost of Rent	1.10***	1.14***	1.01***	1.22**	1.25***	1.34**	1.57***	1.59***
	(0.35)	(0.36)	(0.29)	(0.60)	(0.47)	(0.53)	(0.57)	(0.56)
Panel D. Log Home Value	2.01***	2.18***	1.87***	2.67**	2.53***	2.76***	2.95***	2.62**
	(0.59)	(0.61)	(0.52)	(1.14)	(0.73)	(0.84)	(0.99)	(1.02)
Panel E. Log Purchasing Power								
Renters	0.33**	0.35**	0.27***	0.38**	0.81***	0.84***	0.74**	0.69***
	(0.17)	(0.17)	(0.10)	(0.19)	(0.29)	(0.32)	(0.29)	(0.25)
Homeowners (Case A)	0.63**	0.64**	0.60***	0.78***	1.22***	1.29***	1.26**	1.21***
	(0.27)	(0.28)	(0.17)	(0.26)	(0.42)	(0.47)	(0.46)	(0.38)
Homeowners (Case B)	0.93**	0.92**	0.93***	1.18***	1.63***	1.73***	1.78**	1.74***
	(0.39)	(0.40)	(0.25)	(0.42)	(0.57)	(0.64)	(0.64)	(0.54)
Number of Observations	183	171	114	193	183	171	114	193

Notes: The estimates correspond to those in Table 2, but aggregating data from MSAs to create one observation. Columns 1 and 5 combine an MSA with other MSAs when that MSA receives more than 10% of its migrants from other MSAs (and 5% of its migrants for Columns 2 and 6). Columns 3 and 7 combine contiguous MSAs into 114 MSA groups. Columns 4 and 8 are our baseline specification, from Table 2, but omitting Census region fixed effects. *** denotes statistical significance at the 1% level, ** at the 5% level, and * at the 10% level.

Appendix Table 14. Long-Run Direct And Indirect Effects of TFPR Growth in Three Cities

	Direct Effects on Indicated City	Indirect Effects on Average Other City: Baseline	Robustness		
	(1)	(2)	(3)	(4)	(5)
Panel A. Houston TFPR Growth					
Employment	86,031	-291	-291	-291	-291
	(27,371)	(93)	(93)	(93)	(93)
Earnings	1,490	8.9	9.9	8.3	8.0
	(488)	(2.8)	(3.1)	(2.6)	(2.5)
Rent	501	-8.4	-12.4	-7.4	-8.4
	(160)	(2.6)	(3.9)	(2.3)	(2.6)
Panel B. San Jose TFPR Growth					
Employment	361,765	-1,413	-1,413	-1,413	-1,413
	(151,101)	(590)	(590)	(590)	(590)
Earnings	11,756	51.1	47.0	42.4	48.1
	(4251)	(20.1)	(19.5)	(17.4)	(18.9)
Rent	3,957	-78.5	-57.7	-45.1	-78.5
	(1395)	(30.7)	(23.9)	(18.5)	(30.7)
Panel C. Cincinnati TFPR Growth					
Employment	26,002	-84	-84	-84	-84
	(8,199)	(27)	(27)	(27)	(27)
Earnings	1,115	2.3	2.8	2.3	1.9
	(364)	(0.7)	(0.9)	(0.7)	(0.6)
Rent	375	-1.9	-3.5	-2.0	-1.9
	(119)	(0.6)	(1.1)	(0.6)	(0.6)

Notes: All monetary values are in 2017 dollars. Column 1 reports the direct effects of 1980 to 1990 TFPR growth in Houston (panel A), San Jose (Panel B) and Cincinnati (Panel C) on 1980 to 2000 changes in employment, earnings, and rent in that same city. Column 2 reports indirect effects of 1980 to 1990 TFPR growth in Houston (panel A), San Jose (Panel B), and Cincinnati (Panel C) on 1980 to 2000 changes in employment, earnings, and rent in the average other city, under our baseline assumption on migration flows that is based on measured migrant flows from 1975 to 1980. Columns 3 and 4 report indirect effects under alternative assumptions on migration flows: in Column 3, that migration flows from other sample cities are proportion to their population sizes; in Column 4, that migration flows are based on predicted migration flows only (taking the predicted values from regressing 1975-1980 migrant flows on log origin city size, log destination city size, log geographic distance, and log economic distance). Column 5 reports indirect effects for our baseline assumption on migration flows, but it allows the elasticity of labor demand to vary across cities according to their industry shares. Robust standard errors are reported in parantheses.

Appendix Table 15. Geographic Variation in Annualized Direct Effects and Indirect Effects on Purchasing Power of Renters

	Direct Effect (1)	Indirect Effect (2)	Total Effect (3)	Total % Effect (4)
Panel A: Top Tercile Direct Effect & Top Tercile Indirect Effect				
Group Average (N = 21)	252	256	508	1.4%
Examples:				
Binghamton, NY	237	180	417	1.2%
Charleston-N.Charleston,SC	431	262	693	2.2%
New Orleans, LA	245	162	408	1.1%
San Jose, CA	252	285	537	1.2%
Panel B: Top Tercile Direct Effect & Bottom Tercile Indirect Effect				
Group Average (N = 22)	220	59	279	0.8%
Examples:				
Chattanooga, TN/GA	194	83	277	0.8%
Decatur, IL	155	65	220	0.5%
Greenville-Spartanburg-Anderson SC	152	52	204	0.6%
Omaha, NE/IA	119	74	193	0.5%
Panel C: Bottom Tercile Direct Effect & Top Tercile Indirect Effect				
Group Average (N = 21)	-29	260	231	0.7%
Examples:				
Cleveland, OH	-6	173	167	0.4%
Lexington-Fayette, KY	-16	193	177	0.5%
Salt Lake City-Ogden, UT	17	160	177	0.5%
Trenton, NJ	-25	333	308	0.8%
Panel D: Bottom Tercile Direct Effect & Bottom Tercile Indirect Effect				
Group Average (N = 23)	-52	59	8	0.0%
Examples:				
Dallas-Fort Worth, TX	-15	55	40	0.1%
St. Louis, MO-IL	-50	71	21	0.1%
Tulsa, OK	-17	53	36	0.1%
Youngstown-Warren, OH-PA	15	82	97	0.2%

Notes: This table shows geographical differences in the long-run annualized effects of TFPR growth on renters' purchasing power. All entries are in 2017 dollars. Column 1 shows the direct annualized effect of TFPR growth on per-worker purchasing power, column 2 shows the indirect annualized effect, column 3 shows the total annualized effect (sum of direct and indirect effect), and column 4 shows the annual percent effect with respect to 1980 average earnings for renters in each city. Panel A shows example cities (out of a group of 21) that belong both to the top tercile of the distribution of direct effects and to the top tercile of the distribution of indirect effects from TFPR growth. Panel B shows example cities (out of a group of 22) that belong both to the top tercile of the distribution of direct effects and to the bottom tercile of the distribution of indirect effects from TFPR growth. Panel C shows example cities (out of a group of 21) that belong both to the bottom tercile of the distribution of direct effects and to the top tercile of the distribution of indirect effects from TFPR growth. Panel D shows example cities (out of a group of 23) that belong both to the bottom tercile of the distribution of direct effects and to the bottom tercile of the distribution of indirect effects from TFPR growth.

Appendix Table 16. Geographic Variation in Annualized Direct Effects and Indirect Effects on Purchasing Power of Homeowners

	Direct Effect	Indirect Effect	Total Effect	Total % Effect
	(1)	(2)	(3)	(4)
Panel A: Top Tercile Direct Effect & Top Tercile Indirect Effect				
Group Average (N = 19)	538	232	770	1.5%
Examples:				
Binghamton, NY	582	175	757	1.6%
Charleston-N.Charleston,SC	1,021	213	1,234	2.9%
San Jose, CA	649	231	880	1.4%
Wilmington, DE/NJ/MD	433	263	696	1.2%
Panel B: Top Tercile Direct Effect & Bottom Tercile Indirect Effect				
Group Average (N = 23)	529	61	591	1.2%
Examples:				
Chattanooga, TN/GA	472	79	550	1.2%
Decatur, IL	357	69	425	0.8%
Greenville-Spartanburg-Anderson SC	350	49	399	1.0%
Wichita, KS	473	66	539	1.1%
Panel C: Bottom Tercile Direct Effect & Top Tercile Indirect Effect				
Group Average (N = 18)	-83	247	164	0.3%
Examples:				
Bridgeport, CT	20	179	199	0.3%
Lexington-Fayette, KY	-43	212	169	0.3%
Santa Cruz, CA	46	340	386	0.7%
Trenton, NJ	-62	319	258	0.5%
Panel D: Bottom Tercile Direct Effect & Bottom Tercile Indirect Effect				
Group Average (N = 25)	-137	60	-77	-0.2%
Examples:				
Dallas-Fort Worth, TX	-38	56	18	0.0%
Grand Rapids, MI	4	59	63	0.1%
St. Louis, MO-IL	-124	70	-54	-0.1%
Tulsa, OK	-44	59	15	0.0%

Notes: The reported estimates correspond to those in Appendix Table 15, but for homeowners rather than renters. The table shows geographical differences in the long-run annualized effects of TFPR growth on homeowners' purchasing power. All entries are in 2017 dollars. Column 1 shows the direct annualized effect of TFPR growth on per-worker purchasing power, column 2 shows the indirect annualized effect, column 3 shows the total annualized effect (sum of direct and indirect effect), and column 4 shows the annual percent effect with respect to 1980 average earnings for homeowners in each city.