The Aggregate Consequences of Place-based Capital Subsidies

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Place-based capital subsidies are common but have ambiguous aggregate consequences. Using a general-equilibrium urban accounting model, we decompose the aggregate consequences into a labor-relocation effect and a capital-stock effect and study their tradeoffs in relation to the geography of capital subsidies. Simulation analysis offers several insights. First, without covariance with urban characteristics, the cost-of-capital dispersion across cities reduces welfare and aggregate productivity because the capital-stock loss exceeds the labor-relocation gains. Second, subsidizing cities with a relatively higher (lower) productive efficiency can raise aggregate productivity (welfare). Third, place-based capital subsidies can improve welfare or aggregate productivity when disparity in urban efficiency is large and the cost-of-capital variance is about half its covariance with urban efficiency. The consequences of changing geography of capital subsidies in China between 2000 and 2007 are evaluated using these insights.

Keywords: place-based policies, spatial economics, capital subsidies, misallocation, welfare, aggregate productivity, China

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1. INTRODUCTION

Government policies often create spatial distortions in the cost of capital. Local governments use capital subsidies to compete for mobile firms (Ossa 2015). National governments use place-based capital subsidies to encourage investment and raise employment in target regions (Criscuolo et al. 2019; Blouri and Ehrlich 2020; Freedman et al. 2021). Large discrepancies in the cost of capital across firms and regions in both developed and emerging-market economies have been documented in a large body of literature on misallocation; according to the standard efficiency requirement, substantial gains in aggregate productivity can be obtained by removing these discrepancies (Hsieh and Klenow 2009; Hopenhayn 2014; Restuccia and Rogerson 2017). In a spatial context, unequal cost of capital can have an ambiguous effect on aggregate efficiency (Fajgelbaum et al. 2019). The ambiguity is rooted in the inefficiency of labor allocation in a spatial economy, where agglomeration spillover effects (e.g., congestion and employment externalities) engender market failure (Glaeser and Gottlieb 2008). Recent studies have sought to quantify the aggregate consequences of place-based capital subsidies using quantitative spatial analysis (e.g., Blouri and Ehrlich 2020; Henderson et al. 2020). Nevertheless, how place-based capital subsidies generally affect the aggregate productivity and welfare is not well understood.

Can place-based capital subsidies address the market failure in spatial allocation of labor? Fajgelbaum and Gaubert (2020) show that an efficient spatial economy balances the marginal benefit against the opportunity cost of attracting workers to each location, whereas a free-market outcome equalizes the average benefit against the opportunity cost. In the market equilibrium, the opportunity cost, or the wage compensation required to attract workers, varies by location according to spatially varied amenities, trade cost, or urban frictions (Redding and Rossi-hansberg 2017). When the marginal benefit is below the average benefit, due to negative net spillovers of agglomeration necessary to limit equilibrium city sizes, welfare can be improved by transferring income from high-wage locations to low-wage locations to encourage worker relocation from places of a low marginal utility of consumption to those of a high marginal utility. Place-based capital subsidies have the effect of spatial transfer of income but also differ from spatial income transfer in two important ways. First, the capital subsidies also alter labor productivity across locations through capital reallocation. Second, they affect aggregate capital productivity in the economy. An important consequence of the latter is the endogenous capital-stock adjustment in a steady-state general equilibrium framework, which has not been emphasized in the extant literature on misallocation.

Using a relatively tractable general equilibrium model of a spatial economy, we show that place-based capital subsidies affect aggregate productivity and welfare through two channels: a capital-stock effect and a labor-relocation effect. The former arises from capital-market clearing in the long run according to aggregate capital productivity: unequal subsidies that lower aggregate return on capital will reduce saving and hence long-run capital stock. The capital stock affects welfare and aggregate productivity equally without altering labor location incentives. The latter arises from labor-market clearing in response to altered relative location advantages and can have different consequences for welfare and aggregate productivity due to unequal local amenity and labor wedge arising from urban frictions.

We adopt the urban accounting model of Desmet and Rossi-Hansberg (2013) to describe the spatial economy, which features a given set of city locations of unequal urban characteristics, a homogeneous traded good, frictionless labor mobility between cities, and a long-run adjustment in saving and investment to clear the capital market. In this setting, no trade takes place between cities, a common reservation utility applies to all workers, and the capital stock adjusts to equalize the aggregate return on capital and capital depreciation. Although not as rich as models featuring heterogeneous traded goods and labor mobility (e.g. Allen and Arkolakis 2014; Henderson et al. 2020), which can capture inter-city trade and utility dispersion across workers, the urban accounting model helps to clarify intuitions about the first-order effects of labor relocation and capital stock adjustment in relation to the geography of capital subsidies. The unequal urban characteristics include productive efficiency, amenity, and excess urban friction. The geography of capital subsidies can be defined by the covariance between the place-specific cost of capital and the unequal urban characteristics.

The geography of capital subsidies affects both the labor-relocation effect and the capital-stock effect. The unequal subsidies not only affect the aggregate return on capital but also alter the relative productivity advantage of individual cities. In equilibrium, the size of each city adjusts to offset changes in location advantages; the overall spillover effect of agglomeration at the margin must be negative for city sizes to be limited. Greater location-advantage disparities across cities raise city-size dispersion as well as welfare, because the more advantageous locations can gain population at the expense of the less advantageous ones. Subsidizing cities of relatively higher productive efficiency, for example, amplifies labor productivity dispersion across the cities. The resulting labor relocation will raise aggregate productivity. At the same time, to the extent that more productive cities have a larger economy, subsidies that favor larger cities would lower aggregate capital productivity and thus reduce capital stock and aggregate output in the long run.

Our decomposition analysis of the aggregate consequences of place-based capital subsidies reveals three fundamental principles. First, the labor-relocation effect often counteracts the capital-stock effect on welfare and aggregate productivity. Second, the tradeoff between these two effects depends on the geography of capital subsidies. And third, the tradeoff differs for welfare and aggregate productivity. In particular, the labor-relocation effect would be weaker for welfare due to the offsetting effect of change in aggregate labor wedge. We employ Monte Carlo simulations to quantitatively assess the tradeoff and find three key results. First, widening the dispersion of the cost of capital across cities, holding constant the geography of capital subsidies, would reduce welfare and aggregate productivity due to a negative capital-stock effect which dominates a positive labor-relocation effect. Second, holding the dispersion of the cost of capital constant, place-based capital subsidies that favor cities of relatively higher productive efficiency would raise aggregate productivity at the expense of welfare. Conversely, place-based capital subsidies that favor cities of relatively low productive efficiency would raise welfare at the expense of aggregate productivity. This result derives from the first and third principles stated above and from the fact that subsidizing the relatively more productive cities produces a positive labor-relocation effect. Third, holding constant the correlation between the cost of capital and the urban productive efficiency, place-based capital subsidies would be most effective for improving welfare or aggregate productivity when the variance of the cost of capital is about half its covariance with urban productive efficiency.

We apply the decomposition analysis to evaluate the consequences of the changing geography of capital subsidies in China between 2000 and 2007. Place-based capital subsidies in 2000 reduced city-size dispersion by subsidizing cities in economically lagging region. The policy would produce a positive capital-stock effect and negative labor-relocation effect. Overall, the policy reduced both welfare and aggregate productivity due to an excessively large variance of the cost of capital relative to the covariance. Economic reforms following China's accession to WTO in 2001 diminished capital subsidies to cities in economically lagging regions and reduced the dispersion of the cost of capital across cities. These two changes both meant a smaller loss in aggregate productivity produced by place-based capital subsidies in 2007, but they had counteracting effects on welfare loss.

The paper proceeds as follows. Section 2 describes the urban accounting model that incorporates place-based capital subsidies. Section 3 shows the decomposition of the aggregate consequences of place-based capital subsidies into a capital-stock effect and a labor-relocation effect and investigates how these two effects are shaped by the geography of capital subsidies. Section 4 presents a quantitative assessment of the capital-stock effect and labor-relocation effect based on Monte Carlo simulations. Section 5 examines changes in the geography of capital subsidies in China between 2000 and 2007 and applies the insights from the previous section to shed light on the aggregate consequences of these changes. Section 6 concludes. The estimation of the cost of capital and the calibration of urban characteristics for Chinese cities are documented in two appendixes.

2. AN URBAN ACCOUNTING MODEL WITH HETEROGENEOUS COST OF CAPITAL

We extend the urban accounting model of Desmet and Rossi-Hansberg (2013) by allowing the cost of capital to vary across cities due to policy interventions.

2.1. Production and consumer choices

The economy consists of a set of cities $\mathcal{C}_t$ in year t, each producing a homogeneous traded numeraire good by competitive firms according to the following aggregate production technology:

$$Y_{it} = A_{it} K_{it}^{\theta_t} H_{it}^{1-\theta_t},$$

where Y_{it}, K_{it}, and H_{it} denote, respectively, the total output, capital stock, and hours worked in city i and period t, θ_t is the capital share of the output, and A_{it} indicates the city-level productive efficiency. Dividing both sides of the equation by city population N_{it}, we obtain the production equation in terms of per-capita quantities:

$$y_{it} = A_{it} k_{it}^{\theta_t} h_{it}^{1-\theta_t}. \tag{1}$$

The first-order conditions production with respect to labor and capital inputs yield the following equations for wage rate w_{it} and the cost of capital r_{it}, respectively:

$$w_{it} h_{it} = (1-\theta_t) y_{it}, \tag{2}$$

$$r_{it} = \theta_t \frac{y_{it}}{k_{it}}. \tag{3}$$

We define $r_{it} = r_t e^{\xi_{it}}$, where r_t is the aggregate return on capital in the economy and ξ_{it} is the cost-of-capital spread equal to the difference between $\ln r_{it}$ and $\ln r_t$. ξ_{it} is a result of government interventions in the form of place-based capital subsidies; it can be written as $\xi_{it} = \xi_{0t} + \xi'_{it}$, where ξ_{0t} is the mean spread identical to all cities and ξ'_{it} is excess spread for city i. The mean spread will be endogenously determined to compensate for any loss or gain in aggregate capital productivity.

A representative consumer-cum-worker is endowed with a unity time, which can be divided into employment time h_{it} and leisure time $1-h_{it}$. In each period, the worker receives a wage $w_{it} h_{it}$ and an equal share of the national capital income $r_t k_t^*$, where $k_t^* = K_t / N_t$ is the national capital stock over the national population. The cost of living in city i includes a city tax, a land rent, and a commuting cost, which are all proportional to the wage at rates τ_{it}^*, R_{it}, and T_{it}, respectively. Thus, the disposable income is $w_{it} h_{it}(1-\tau_{it}) + r_t k_t^*$, where $\tau_{it} \equiv \tau_{it}^{*} + R_{it} + T_{it}$ is the total labor wedge in city i due to urban frictions. The disposable income is spent on consumption c_{it} and capital investment x_t^*. In addition to c_{it}, the worker's utility u_t^* also depends on her leisure time $1 - h_{it}$ and a city-level amenity index γ_{it}:

(4) $$u_t^* = \ln c_{it} + \psi \log(1 - h_{it}) + \gamma_{it}.$$

The worker's utility maximization problem is given by:

$$\max_{\{c_{it}, h_{it}, k_{it}\}} \sum_{t=0}^{\infty} \beta^t u_t^*$$

Subject to the budget constraint:

$$c_{it} + x_t^* = w_{it} h_{it}(1 - \tau_{it}) + r_t k_t^*,$$

and the motion of the capital stock:

$$k_{t+1}^* = (1 - \delta) k_t^* + x_t^*,$$

where β is a discount rate, ψ, the parameter of preference for leisure, and δ the capital depreciation rate. The steady-state condition, $k_{t+1}^* = k_t^*$, requires that the investment equals the capital depreciation $x_t^* = \delta k_t^*$. Assuming the Golden Rule for optimal saving, we have $r_t = \delta$ in the long run. Thus, the consumer budget constraint can be reduced to:

(5) $$c_{it} = w_{it} h_{it}(1 - \tau_{it}).$$

The first-order condition for the employment time to maximize the utility yields:

$$w_{it}(1 - \tau_{it}) = \psi \frac{c_{it}}{1 - h_{it}},$$

which, together with the budget constraint equation (5), gives:

(6) $$h_{it} = \frac{1}{1+\psi}.$$

Substituting equations (3) and (6) into equation (1), we have per-capita income as a function of exogenous variables and parameters:

(7) $$y_{it} = A_{it}^{\frac{1}{1-\theta_t}} \left(\frac{\theta_t}{r_{it}}\right)^{\frac{\theta_t}{1-\theta_t}} \frac{1}{1+\psi}.$$

And from equations (2) and (5), we have:

(8) $$c_{it} = (1-\theta_t) y_{it} (1-\tau_{it}).$$

2.2. Urban frictions

Following Desmet and Rossi-Hansberg (2013), we assume cities to be monocentric, where each worker occupies one unit of residential land and commute to CBD to work. The sum of land rent and commuting cost is thus invariant within a city and equals the commuting cost at the city boundary, which is proportional to the square root of city population N_{it}:

(9) $$R_{it} + T_{it} = \kappa_t^* \left(\frac{N_{it}}{\pi}\right)^{\frac{1}{2}},$$

where κ_t^* denotes the commuting cost per mile in terms of a fraction of wage $w_{it}h_{it}$.[1] In addition to the private commuting cost, the city government spends GS_{it} on public infrastructure, which is a fraction g_{it}^* of the total private commuting cost in the city:

$$GS_{it} = g_{it}^* \frac{2}{3} w_{it} h_{it} \kappa_t^* \pi^{-\frac{1}{2}} N_{it}^{\frac{3}{2}}.$$

Financed by a wage tax at the rate τ_{it}^*, the public budget is $N_{it}h_{it}w_{it}\tau_{it}^* = GS_{it}$, which gives,

$$\tau_{it}^* = \frac{2}{3} g_{it}^* \kappa_t^* \left(\frac{N_{it}}{\pi}\right)^{\frac{1}{2}}.$$

The total labor wedge τ_{it}, then, can be written as

(10) $$\tau_{it} = \tau_{it}^* + R_{it} + T_{it} = \left(\frac{2}{3} g_{it}^* + 1\right) \kappa_t^* \left(\frac{N_{it}}{\pi}\right)^{\frac{1}{2}} \equiv \kappa_t e^{g_{it}} N_{it}^{\frac{1}{2}},$$

[1] Desmet and Rossi-Hansberg (2013) define the unit of measure of κ_t^* inconsistently for the private budget constraint and the public budget constraint. We adopt the consistent unit of measure according to their public budget constraint. The model solution is simplified as a result.

where $g_{it} \equiv \ln\left(\left(\frac{2}{3}g_{it}^{*}+1\right)\kappa_t^{*}\pi^{-\frac{1}{2}}\right)-\ln\kappa_t$ and κ_t is chosen to make the average g_{it} across cities equal to zero. κ_t represents the normal friction common to all cities in period t, whereas g_{it} indicates excess friction specific to individual cities due to unique urban topography and government efficiency.

2.3. Equilibrium

In equilibrium, the worker utility u_t^* is equalized across cities because of free labor mobility. Substituting the per-capita output equation (7) and the consumption equation (8) into the utility function equation (4), we obtain a shifted reservation utility as a function of the urban labor wedge τ_{it} and exogenous variables:

$$\text{(11)}\quad u_t \equiv u_t^* + (1+\psi)\ln(1+\psi) - \psi\ln(\psi) - \ln(1-\theta_t) - \frac{\theta_t}{1-\theta_t}\ln\left(\frac{\theta_t}{r_t}\right) = \frac{1}{1-\theta_t}\dot{A}_{it} - \frac{\theta_t}{1-\theta_t}\xi_{it} + \ln(1-\tau_{it}) + \gamma_{it},$$

where $\dot{A}_{it} \equiv \ln A_{it}$. Equation (11) defines the equilibrium labor wedge, which equalizes worker utility across the cities: $\tau_{it} = \Gamma(\dot{A}_{it}, \gamma_{it}, \xi_{it}; u_t) \equiv 1 - e^{u_t - \gamma_{it} - \frac{1}{1-\theta_t}\dot{A}_{it} + \frac{\theta_t}{1-\theta_t}\xi_{it}}$. The labor wedge is also a concave function of city population according to equation (10), which determines the equilibrium city population as a function of the equilibrium labor wedge and urban frictions:

$$\text{(12)}\qquad N_{it} = F(\dot{A}_{it}, \gamma_{it}, g_{it}, \xi_{it}; u_t) \equiv \left(\frac{\Gamma}{\kappa_t e^{g_{it}}}\right)^2.$$

According to equation (12), the city population is determined by four exogenous location attributes—the cost-of-capital spread ξ_{it} and the three urban characteristics A_{it}, γ_{it} and g_{it}—and an endogenous reservation utility u_t. The heterogeneous location attributes drive the city-size dispersion in the economy. It can be verified that F decreases in u_t, ξ_{it}, g_{it} and increases in $\dot{A}_{it}$ and γ_{it}. In addition, F is convex with respect to the location attributes.

The equilibrium u_t, which regulates the mean city size, is determined by the national labor-market-clearing condition:

(13) $$\sum_{i \in \mathcal{C}_t} N_{it} = N_t,$$

where N_t is the national labor endowment. The convexity of F with respect to the location characteristics is fundamental to understanding the welfare consequence of the cost-of-capital dispersion across cities. The convexity means that the dispersion of the location attributes elevates the reservation utility required to clear the national labor market. Intuitively, a greater city-size dispersion means a greater share of the national population is concentrated in cities with superior location attributes, which raises welfare. What limits city-size divergence in the presence of heterogeneous location attributes? Total labor wedge in a city, $\tau_{it} N_{it}$, is convex with respect to city population according to equation (10); hence, city-size divergence elevates the national aggregate labor wedge. In equilibrium, the marginal benefit of increased city-size dispersion is balanced by its marginal cost in terms of increased aggregate labor wedge.

The national capital-market-clearing condition is given by:

(14) $$K_t = \sum_{i \in \mathcal{C}_t} N_{it} \frac{\theta_t y_{it}}{r_{it}} = \sum_{i \in \mathcal{C}_t} \frac{N_{it}}{1+\psi} \left(\frac{\theta_t}{r_t}\right)^{\frac{1}{1-\theta_t}} e^{\frac{1}{1-\theta_t}(\dot{A}_{it} - \xi_{0t} - \xi'_{it})},$$

where the first equality follows from equation (3) and the second one, from equation (7) and the definition of r_{it}. With r_t being fixed by the capital depreciation rate in the long run, equation (14) determines the national capital stock as a function of city population, productive efficiency, and the cost-of-capital spread. In particular, given the excess spread $\{\xi'_{it}, i \in \mathcal{C}_t\}$, K_t decreases with the mean spread ξ_{0t}. The place-based capital subsidies determine the excess spread across the cities. The mean spread, however, will adjust endogenously in the long run to equalize the aggregate capital income and the capital depreciation cost:

(15) $$\sum_{i \in \mathcal{C}_t} r_t e^{\xi_{0t} + \xi'_{it}} K_{it} = \delta K_t.$$

Suppose a policy intervention generates $\{\xi'_{it}, i \in \mathcal{C}_t\}$ such that the aggregate capital income (the left-hand side of the equation) is insufficient to cover the aggregate capital depreciation δK_t, then the aggregate capital stock K_t will decrease, requiring ξ_{0t} to rise according to equation (14). In other words, given $\{\xi'_{it}, i \in \mathcal{C}_t\}$, ξ_{0t} must adjust in the long run to satisfy the aggregate capital budget constraint equation (15). With $r_t = \delta$, equation (15) requires:

$$\text{(16)} \qquad \xi_0 = \ln\left(K_t / \sum_{i \in \mathcal{C}_t} K_{it} e^{\xi'_i}\right) = \ln\left(\sum_{i \in \mathcal{C}_t} Y_{it} e^{-\xi'_{it}} / \sum_{i \in \mathcal{C}_t} Y_{it}\right)$$

$$= \ln\left(\sum_{i \in \mathcal{C}_t} N_{it} e^{-\frac{1}{1-\theta_t}\xi'_{it}} / \sum_{i \in \mathcal{C}_t} N_{it} e^{-\frac{\theta_t}{1-\theta_t}\xi'_{it}}\right),$$

where the first equality derives from $r_t e^{\xi_{0t}+\xi'_{it}} K_{it} = \theta_t Y_{it}$ and the second one from equation (14). Note that labor allocation N_{it} is independent of ξ_0 according to equations (12) and (13), where u_t adjust endogenously to clear the labor market. Thus, equation (14) and (15) determine K_t and ξ_0 as a function of the exogenous location attributes $\{A_{it}, \gamma_{it}, g_{it}, \xi_{it}, i \in \mathcal{C}_t\}$ to clear the capital market in the long run.

Equation (16) requires the mean spread to rise with the dispersion of the excess spread by virtue of the convexity of the exponential function of the excess spread. In addition, the mean spread will be higher if larger cities, in terms of economy or population, receive greater capital subsidies (i.e., a more negative ξ'_{it}): the loss in capital productivity in larger cities necessitates a rise in ξ_0 to keep the aggregate return on capital equal to δ.

2.4. Calibrating the model

The urban accounting model above characterizes a spatial economy in terms of its heterogeneous location attributes $\{A_{it}, \gamma_{it}, g_{it}, \xi_{it}, i \in \mathcal{C}_t\}$, its labor endowment N_t, its general commuting technology κ_t, and its aggregate return on capital r_t determined by the capital depreciation rate. The aggregate return on capital r_t and the place-based capital-subsidy policy $\{\xi_{it}, i \in \mathcal{C}_t\}$ can be estimated using firm-level data. The parameter θ_t can be estimated according to the national income accounts. The other fundamentals of the spatial economy can be calibrated based on observed city population N_{it}, output Y_{it}, and per-capita consumption c_{it}, as in Desmet and Rossi-Hansberg (2013).

3. THE GOEGRAPHY OF CAPITAL SUBSIDIES AND THE AGGREGATE CONSEQUENCES: A DECOMPOSITION ANALYSIS

3.1. The decomposition

The equilibrium described above suggest that the aggregate consequences of place-based capital subsidies, defined by $\{\xi_{it} = \xi_{0t} + \xi'_{it}, i \in \mathcal{C}_t\}$, can be decomposed into two components: one relating to capital-stock adjustment captured by the mean spread ξ_{0t} and the other, labor relocation due to the excess spread $\{\xi'_{it}, i \in \mathcal{C}_t\}$. These two effects are orthogonal in that the capital-stock adjustment affects welfare and aggregate productivity without affecting labor allocation across cities. For simplicity, the time subscript in notations will be omitted in this section.

For a formal description of the decomposition, let u, u'_0, and u_0 denote, respectively, the welfare, in terms of the equilibrium reservation utility of workers, under three scenarios of the cost-of-capital spread across cities: (1) the baseline scenario with the place-based capital subsidies in place, i.e., $\{\xi_i = \xi_0 + \xi'_i, i \in \mathcal{C}\}$; (2) the intermediate scenario where the excess spread, $\{\xi'_{it}, i \in \mathcal{C}_t\}$, is removed, i.e., $\{\xi_i = \xi_0, i \in \mathcal{C}\}$; and the alternative scenario, where all cost-of-capital spread is removed, i.e., $\{\xi_i = 0, i \in \mathcal{C}\}$. Similarly, let Y, Y'_0, and Y_0 denote the aggregate productivity, in terms of equilibrium aggregate output $\sum_{i \in \mathcal{C}} Y_i$, under the same three scenarios. The welfare loss of the place-based capital subsidies is measured by $u_0 - u$, which can be divided into two components: $u_0 - u'_0$ and $u'_0 - u$; the former represents the capital-stock effect and the latter the labor-relocation effect. Similarly, the aggregate productivity loss from the place-based capital subsidies, measured by $\ln(Y_0/Y)$, can be divided into two components, $\ln(Y_0/Y'_0)$ and $\ln(Y'_0/Y)$, corresponding to the capital-stock effect and the labor-relocation effect, respectively. The analysis below shows how these two effects are shaped by the geography of capital subsidies, described by the covariance between the excess spread $\{\xi'_{it}, i \in \mathcal{C}_t\}$ and the urban characteristics $\{\dot{A}_{it}, \gamma_{it}, g_{it}, i \in \mathcal{C}_t\}$.

3.2. The capital-stock effect

The capital-stock effect, determined by the mean spread ξ_0, can be easily derived. The capital-market-clearing equation (14) shows that a mean spread ξ_0 is associated with a capital-stock reduction of $\frac{1}{1-\theta}\xi_0$ log points, which also equals to the loss of labor productivity in each city and in aggregate. In addition, according to the urban population function, equation (12), and the labor-market clearing, equation (13), the reservation utility u will decrease by $\frac{\theta}{1-\theta}\xi_0$ to clear the labor market without any labor relocation. In other words, the capital-stock effect on welfare and aggregate productivity is identical: $u_0 - u_0' = \ln(Y_0/Y_0') = \frac{\theta}{1-\theta}\xi_0$.

As equation (16) indicates, the mean spread, and hence the loss in capital stock, rises with the dispersion of the excess spread by virtue of the convexity of ξ_0 with respect to ξ_i'. Moreover, e^{ξ_0} being the average of $e^{-\xi_i'}$ weighted according to Y_i, ξ_0 will be larger if ξ_i' is more negatively correlated with Y_i. In other words, place-based capital subsidies that favor economically larger cities, which are either more productive (higher $\dot{A}_i$) or more livable (higher γ_i or lowers g_i), would reduce aggregate return on capital and hence long-run saving and capital stock. Note that unequal subsidies that raise ξ_0, producing a negative capital-stock effect, would also elevate city-size dispersion.

3.3. The labor-relocation effect on welfare

To examine the labor-relocation effect of place-based capital subsidies on welfare, we rewrite the labor-market-clearing equation (13) using a second-order Taylor expansion of the urban population function F in equation (12) with respect to the exogenous location attributes and the endogenous reservation utility. Let $\boldsymbol{G}_i \equiv [\dot{A}_i, \gamma_i, g_i, \xi_i]$ and $\boldsymbol{G}_0 = \text{mean}(\boldsymbol{G}_i)$ be the vector of the location attributes and their mean values, respectively. Note that $\text{mean}(g_i) = 0$ and $\text{mean}(\xi_i) = \xi_0$. The Taylor expansion of N_{it} is:

$$(17) \qquad F(\boldsymbol{G}_i, u) \cong F(\boldsymbol{G}_0, u_0') + (\boldsymbol{G}_i - \boldsymbol{G}_0)[F_{\dot{A}}', F_\gamma', F_g', F_\xi']'$$

$$+(u-u_0')(\boldsymbol{G}_i-\boldsymbol{G}_0)\left[F''_{\dot{A}u},F''_{\gamma u},F''_{gu},F''_{\xi u}\right]'$$

$$+\frac{1}{2}(\boldsymbol{G}_i-\boldsymbol{G}_0)\begin{bmatrix}F''_{\dot{A}} & F''_{\dot{A}\gamma} & F''_{\dot{A}g} & F''_{\dot{A}\xi}\\ F''_{\dot{A}\gamma} & F''_{\gamma} & F''_{\gamma g} & F''_{\gamma\xi}\\ F''_{\dot{A}g} & F''_{\gamma g} & F''_{g} & F''_{g\xi}\\ F''_{\dot{A}\xi} & F''_{\gamma\xi} & F''_{g\xi} & F''_{\xi}\end{bmatrix}(\boldsymbol{G}_i-\boldsymbol{G}_0)'$$

$$+F_u'(u-u_0')+\frac{F_u''}{2}(u-u_0')^2,$$

where F' and F'' denote, respectively, the first-order and second-order derivatives of function F. These derivatives are evaluated at $\boldsymbol{G}_0$ and u_0' and are constants. Substituting equation (17) into the labor-market-clearing equation (13), dividing both sides by I, the number of cities in the economy $\mathcal{C}$, and eliminating the terms associated with linear $\boldsymbol{G}_i-\boldsymbol{G}_0$, which disappears upon averaging across the cities, we obtain:

$$(18)\quad \frac{N}{I}=\sum\nolimits_{i\in\mathcal{C}}\frac{F(\boldsymbol{G}_i,u)}{I}=F(\boldsymbol{G}_0,u_0')+\frac{F''_{\dot{A}}}{2}\sigma_{\dot{A}}^2+\frac{F''_{\gamma}}{2}\sigma_{\gamma}^2+\frac{F''_{g}}{2}\sigma_{g}^2+\frac{F''_{\xi}}{2}\sigma_{\xi}^2$$
$$+F''_{\dot{A}\gamma}\rho_{\dot{A}\gamma}\sigma_{\dot{A}}\sigma_{\gamma}+F''_{\dot{A}g}\rho_{\dot{A}g}\sigma_{\dot{A}}\sigma_{g}+F''_{\dot{A}\xi}\rho_{\dot{A}\xi}\sigma_{\dot{A}}\sigma_{\xi}+F''_{\gamma g}\rho_{\gamma g}\sigma_{\gamma}\sigma_{g}$$
$$+F''_{\gamma\xi}\rho_{\gamma\xi}\sigma_{\gamma}\sigma_{\xi}+F''_{g\xi}\rho_{g\xi}\sigma_{g}\sigma_{\xi}+F_u'\cdot(u-u_0')+\frac{F_u''}{2}(u-u_0')^2.$$

where σ's denote the standard deviations and ρ's, the correlation coefficients, of the location attributes across the cities. Equation (18) defines the equilibrium reservation utility u as a function of the standard deviation of the cost-of-capital spread, σ_ξ. We can differentiate both sides of the summation in equation (18) with respect to σ_ξ, omitting the quadratic utility adjustment term and noting that the left-hand side is a constant, to obtain an approximation for the welfare loss from labor relocation induced by σ_ξ:

$$(19)\quad u_0'-u\approx-\sigma_\xi\frac{du}{d\sigma_\xi}=\sigma_\xi\frac{F''_{\xi}\sigma_\xi+F''_{\dot{A}\xi}\rho_{\dot{A}\xi}\sigma_{\dot{A}}+F''_{\gamma\xi}\rho_{\gamma\xi}\sigma_\gamma+F''_{g\xi}\rho_{g\xi}\sigma_g}{F_u'}$$
$$\equiv\alpha_\xi\sigma_\xi^2+\alpha_A\rho_{\dot{A}\xi}\sigma_{\dot{A}}\sigma_\xi+\alpha_\gamma\rho_{\gamma\xi}\sigma_\gamma\sigma_\xi+\alpha_g\rho_{g\xi}\sigma_g\sigma_\xi.$$

It can be verified that $F_u'=2(\Gamma-1)\Gamma/\kappa^2$, $F_u''=\frac{2\Gamma-1}{\Gamma}F_u'$, $F_\xi''=\left(\frac{\theta}{1-\theta}\right)^2F_u''$, $F''_{\dot{A}\xi}=-\frac{\theta}{(1-\theta)^2}F_u''$, $F''_{\gamma\xi}=-\frac{\theta}{1-\theta}F_u''$, and $F''_{g\xi}=-\frac{2\theta}{1-\theta}F_u'$. Note that $(2\Gamma-1)/\Gamma<0$ as long as the equilibrium labor wedge Γ at $\boldsymbol{G}_0$ and u_0' does not exceed 0.5. Thus, $\alpha_\xi = \left(\frac{\theta}{1-\theta}\right)^2 \frac{2\Gamma-1}{\Gamma} < 0$, $\alpha_A = -\frac{\theta}{(1-\theta)^2}\frac{2\Gamma-1}{\Gamma} > 0$, $\alpha_\gamma = -\frac{\theta}{1-\theta}\frac{2\Gamma-1}{\Gamma} > 0$, and $\alpha_g = -\frac{2\theta}{1-\theta} < 0$.

Equation (19) reveals that the labor-relocation effect of place-based capital subsidies on welfare depends mainly on (i) the dispersion of the cost of capital across cities and (ii) the geography of capital subsidies, defined in terms of the covariance between the excess spread and the urban characteristics. Absent the covariances, a larger dispersion in the excess spread (a larger σ_ξ) raises welfare (creating a negative welfare loss $u_0' - u$): it creates the opportunity for workers to relocate to cities where the cost of capital is much lower and hence labor productivity is much greater. This effect of a larger σ_ξ is like that of a larger dispersion in urban characteristics: the dispersion tends to raise welfare by allowing cities with superior characteristics to gain population at the expense of those with inferior characteristics. This result echoes the insight of Hsieh and Moretti (2019) that national productivity depends crucially on the productive advantages of the most productive cities and the labor-relocation constraints to these cities significantly reduced the US aggregate productivity.

The geography of capital subsidies also matter: the dispersion of ξ_i' can further elevate welfare if ξ_i' reinforces the differential location advantages created by the heterogeneous urban characteristics (i.e., if $\rho_{\dot{A}\xi}$ and $\rho_{\gamma\xi}$ are negative or $\rho_{g\xi}$ is positive) and it can reduce welfare if ξ_i' sufficiently offsets the differential location advantages (i.e., if $\rho_{\dot{A}\xi}$ and $\rho_{\gamma\xi}$ are sufficiently positive or $\rho_{g\xi}$ is sufficiently negative). Note that, in contrast to the capital-stock effect, the labor-relocation effect tends to be positive if place-based capital subsidies elevate city-size dispersion. The positive correlation between the labor-relocation effect on welfare and that on city-size dispersion means that the former would be dampened by changes in aggregate labor wedge which increases with city-size dispersion.

3.4. The labor-relocation effect on aggregate productivity

The above insights to the labor-relocation effect on welfare can be applied to aggregate productivity after accounting for labor wedge and amenity which directly affect welfare but not productivity. First, we note that a favorable capital allocation to a city (i.e., $\xi_i' < 0$) is equivalent to an enhancement of local productive efficiency $\dot{A}_i$. Hence, place-based capital subsidies that elevate the disparity in local productivity across cities, either via unequal excess spread ($\sigma_\xi > 0$) or via favorable capital allocation to more efficient cities ($\rho_{\dot{A}\xi} < 0$), would raise aggregate productivity. Note that, in this case, the gain in aggregate productivity would exceed the gain in welfare due to changes in aggregate labor wedge.

Second, place-based capital subsidies that favor cities with greater amenity γ_i, or smaller excess friction g_i, would affect welfare and aggregate productivity similarly via labor relocation. Making high-amenity cities more productive ($\rho_{\gamma\xi} < 0$) raises welfare and aggregate productivity, as relocating workers would enjoy higher amenity as well as higher productivity, though the welfare gain could be dampened by a larger aggregate labor wedge due to increased city-size dispersion. When cities with relatively low excess friction receive more favorable capital allocations, aggregate productivity would increase because larger cities in the economy become more productive. The welfare increase in this case would not be dampened because the aggregate labor wedge in the economy may not increase when workers leave cities with relatively high excess friction for those with relatively low excess friction.

3.5. The tradeoff between the capital-stock effect and the labor-relocation effects

The decomposition analysis above reveals three fundamental principles regarding the aggregate consequences of place-based capital subsidies. First, the two effects of place-based capital subsidies are counteractive: place-based capital subsidies that improve welfare and aggregate productivity through a positive capital-stock effect would also produce a negative labor-relocation effect. Second, the tradeoff between the two effects depends on the geography of capital subsidies. Place-based capital subsidies that favor cities of relatively higher productive efficiency, for example, would produce a negative capital-stock effect but a positive labor-relocation effect. And third, the tradeoff for welfare differs from that for aggregate productivity. This is because the labor-relocation effect is weaker on welfare than on aggregate productivity, due to the change in aggregate labor wedge associated with labor relocation which dampens the effect of labor relocation on welfare. Given the complexity of interactions between the dispersion of urban characteristics and the geography of capital subsidies, we proceed to quantitatively assess the tradeoff in relation to the geography of capital subsidies using simulations.

4. THE AGGREGATE CONSEQUENCES OF PLACE-BASED CAPITAL SUBSIDIES: A QUATITATIVE ASSESSMENT USING MONTE CARLO SIMULATION

To what extent do the dispersion of the cost-of-capital spread across cities and the covariance of the spread with each of the three urban characteristics affect welfare and aggregate productivity? What features of the geography of capital subsidies are likely to produce gains in welfare or aggregate productivity? To investigate these questions, we employ Monte Carlo simulations to generate a large sample of observations of the geography of capital subsidies in a hypothetical economy and the consequent capital-stock effect and labor-relocation effect of the subsidies on welfare and aggregate productivity. We then apply regression analysis to the simulated data to validate and quantify the tradeoff between the capital-stock effect and the labor-relocation effect predicted in the previous section. The findings of the regression analysis will provide useful insights the questions posed above.

4.1. Baseline Monte Carlo simulation

The simulation is applied to a hypothetical economy defined according to the population N, capital stock K, the number of cities, and the distribution of urban characteristics observed in China in 2000. The urban accounting model is used to compute the counterfactual aggregate consequences of place-based capital subsidies and decompose them into the capital-stock effect and labor-relocation effect described in Section 3.1.

The hypothetical economy $\mathcal{C}$ comprises 191 cities, which is the number of Chinese cities in 2000 that provide required data for urban accounting computation. The calibration of urban characteristics for these Chinese cities, $\{\dot{A}_i, \gamma_i, g_i, i \in \mathcal{C}\}$, is documented in Appendix B. The mean values of these characteristics (4.72, 2.59, and 0.0, respectively) and their standard deviation and correlation coefficients ($\sigma_{\dot{A}} = 0.3$, $\sigma_\gamma = 0.43$, $\sigma_g = 0.71$, $\rho_{\dot{A}\gamma} = -0.73$, $\rho_{\dot{A}g} = 0.27$, and $\rho_{\gamma g} = 0.18$) form the seed parameters of a joint normal distribution that the

Monte Carlo simulation uses to generate random sets of urban characteristics for the hypothetical economy. In addition, we set the seed value for the dispersion of the cost-of-capital spread to be $\sigma_\xi = 0.19$, which is derived from the estimated cost-of-capital spread across Chinese cities in 2000 (see Appendix A). We further set the seed parameters for the geography of capital subsidies to be $\rho_{\dot{A}\xi} = \rho_{\gamma\xi} = \rho_{g\xi} = 0$, so that the simulation can generate a range of covariances between the cost of capital and urban characteristics to produce positive as well as negative capital-stock effect and labor-relocation effect.

From each simulation run, a random set of urban attributes $\{\dot{A}_i, \gamma_i, g_i, \xi_i', i \in \mathcal{C}\}$ is generated according to the joint normal distribution specified above. The realized urban attributes, together with the fixed endowments N and K and parameter θ, are then used to compute a set of simulated data, including the standard deviation and correlation coefficients: σ_ξ, $\sigma_{\dot{A}}$, σ_γ, σ_g, $\rho_{\dot{A}\xi}$, $\rho_{\gamma\xi}$, and $\rho_{g\xi}$; the mean cost-of-capital spread ξ_0, according to equation (16), and the capital-stock effect $\frac{\theta}{1-\theta}\xi_0$; the counterfactual losses in welfare and aggregate productivity from the unequal cost-of-capital spread $\{\xi_0 + \xi_i', i \in \mathcal{C}\}$: $u_0 - u$ and $\ln(Y_0/Y)$; the labor-relocation effects: $u_0' - u = u_0 - u - \frac{\theta}{1-\theta}\xi_0$, and $\ln(Y_0'/Y) = \ln(Y_0/Y) - \frac{\theta}{1-\theta}\xi_0$; and the counterfactual loss in city-size dispersion from $\{\xi_0 + \xi_i', i \in \mathcal{C}\}$: $\ln(q_0/q)$, where $q \equiv N^{90p}/N^{35p}$ is a measure of city-size dispersion defined as the ratio of the 90th percentile city size to the 35th percentile city size and q_0 is the measure for the counterfactual scenario with zero cost-of-capital spread. The simulation is run 1,000 times to produce a sample of 1,000 observations of the geography of capital subsidies and aggregate consequences.

4.2. A quantitative assessment based on simulation results

Figure 1 visualizes the 1,000 observations of the capital-stock effect and labor-relocation effect on welfare (Plot (a)) and aggregate productivity (Plot (b)) produced by the Monte Carlo simulation. The vertical axes of the two panels in the Figure represent the capital-stock effect, which is the same for welfare and aggregate productivity. The horizontal axes represent the labor-relocation effects on welfare and aggregate productivity respectively. The observations in Plot (a) are clustered between two isoquant lines representing the combinations of the capital-stock effect and labor-relocation effect that produce zero welfare loss and 20% welfare loss, respectively. The spread of the observations between these downward sloping isoquant lines reflects the general pattern of tradeoff between the capital-stock effect and labor-relocation effect. Similarly, the observations in Plot (b) are clustered between two isoquant lines representing the combinations of the capital-stock effect and labor-relocation effect that produce zero aggregate productivity loss and 10% aggregate productivity loss, respectively. We notice that the dispersion of the labor-relocation effect is much smaller for welfare than for aggregate productivity, reflecting the compensating variation in aggregate labor wedge that dampens the labor-relocation effect on welfare. As the regression analysis below will further demonstrate, the smaller labor-relocation effect on welfare also explains the larger dispersion in welfare loss (the distance between the two isoquant curves) than that in aggregate productivity loss shown in the two panels. Notice further that several observations lie below the zero-isoquant line in both charts; they represent cases of welfare gains and aggregate productivity gains.

[Insert Figure 1 about here]

Using the simulated data, we estimate the influence of the geography of capital subsidies on aggregate outcomes, including the loss in city-size dispersion, the labor-relocation effects on welfare and aggregate productivity, the capital-stock effect, and the net losses in welfare and aggregate productivity. The OLS estimates are presented in Table 1, where the independent variables include the geographic characteristics of capital subsidies— σ_ξ^2, $\rho_{\dot{A}\xi}\sigma_{\dot{A}}\sigma_\xi$, $\rho_{\gamma\xi}\sigma_\gamma\sigma_\xi$, and $\rho_{g\xi}\sigma_g\sigma_\xi$ — and the dependent variables are the aggregate outcomes determined according to the urban accounting model. The estimates in column (1) shows the loss in city-size dispersion due to unequal cost-of-capital spread. As predicted by the urban accounting equilibrium described in section 2.3, dispersion in the cost-of-capital spread σ_ξ^2elevates city-size dispersion but moderating location advantage disparities, i.e., positive $\rho_{\dot{A}\xi}$ and $\rho_{\gamma\xi}$ or a negative $\rho_{g\xi}$, reduces city-size dispersion. The estimates in columns (2) show that the labor-relocation effect on welfare is affected by the geographic characteristics of capital subsidies in the same way as the city-size dispersion is affected, as predicted by equation (19) in section 3.3. Column (4) shows that the labor-relocation effect on aggregate productivity varies with the geographic characteristics of capital subsidies in a similar way as that on welfare, except that the influences of σ_ξ^2 and $\rho_{\dot{A}\xi}\sigma_{\dot{A}}\sigma_\xi$ are stronger, as predicted in section 3.4.

[Insert Table 1 about here]

Columns (5) and (6) show the net losses in welfare and aggregate productivity resulting from the tradeoff between the labor-relocation effect and the capital-stock effect. Three key findings emerge. The first one relates to the positive estimates of σ_ξ^2. It indicates that, absent covariances between the unequal capital subsidies and the urban characteristics, place-based capital subsidies always reduce welfare and aggregate productivity. This is because the dispersion in the cost of capital across cities has a much bigger effect on capital-stock loss (see column (4)) than on labor-relocation gains (see column (2) and (3)).

The second finding relates to the estimates of the covariance between cost-of-capital spread and local productive efficiency $\rho_{\dot{A}\xi}\sigma_{\dot{A}}\sigma_\xi$, which are of opposite signs for welfare and aggregate productivity. It reflects the different tradeoff between the labor-relocation effect and capital-stock effect for the two aggregate consequences, as explained in section 3.5 and demonstrated by the estimates in columns (2), (3), and (4). Specifically, place-based capital subsidies that reallocate capital between cities of different productive efficiency affect welfare (aggregate productivity) predominantly through the capital-stock (labor-relation) effect. Consequently, by favoring relatively less productive cities ($\rho_{\dot{A}\xi} > 0$), on the one hand, place-based capital subsidies could raise welfare, though at the expense of aggregate productivity. According to the estimates in column (5), place-based capital subsidies would raise welfare if $2.562\sigma_\xi - 2.644\rho_{\dot{A}\xi}\sigma_{\dot{A}} < 0$, or $\rho_{\dot{A}\xi} > 0.97\,\sigma_\xi/\sigma_{\dot{A}}$. On the other hand, by favoring relatively more productive cities ($\rho_{\dot{A}\xi} < 0$), place-based capital subsidies could raise aggregate productivity, though at the expense of welfare. According to the estimates in column (6), place-based capital subsidies would raise aggregate productivity if $1.784\sigma_\xi + 2.042\rho_{\dot{A}\xi}\sigma_{\dot{A}} < 0$, or $\rho_{\dot{A}\xi} < -0.87\,\sigma_\xi/\sigma_{\dot{A}}$. In other words, improvement in welfare (aggregate productivity) could be achieved through place-based capital subsidies if the dispersion in cost-of-capital spread σ_ξ is small relative to the dispersion in productive efficiency $\sigma_{\dot{A}}$ across cities and the correlation between the two attributes $\rho_{\dot{A}\xi}$ is sufficiently positive (negative).

The third finding relates to the estimates of the covariances $\rho_{\gamma\xi}\sigma_\gamma\sigma_\xi$ and $\rho_{g\xi}\sigma_g\sigma_\xi$, which are relatively small. These covariances represent capital reallocation between cities of different amenity level and different excess friction, respectively. The small estimates reflect the resulting labor-relocation effect and capital-stock effect that are of similar magnitude and thus cancel out each other.

These three findings demonstrated by the estimates in columns (5) and (6) suggest three results regarding the aggregate consequences of place-based capital subsidies. First, to improve welfare or aggregate productivity through place-based capital subsidies, the subsidies should be allocated based on local productive efficiency as opposed to local amenity or excess friction. Specifically, to improve welfare (aggregate productivity), the subsidies should favor cities with a relatively lower (higher) productive efficiency.

Second, there is a fundamental tradeoff between welfare improvement and aggregate productivity improvement: place-based capital subsidies that improves one aggregate outcome would be detrimental to the other. This fundamental tradeoff results from the convexity of total labor wedge in cities: improving aggregate productivity through place-based capital subsidies entails elevated city-size dispersion such that the resulting increase in aggregate labor wedge would exceed the aggregate productivity gain to lower welfare.

Third, there is an optimal dispersion of the cost-of-capital spread that maximizes welfare gain or aggregate productivity gain, given a correlation coefficient $\rho_{\dot{A}\xi}$. Although capital reallocation between cities of different productive efficiency can improve welfare or aggregate productivity, the resulting dispersion of the cost-of-capital spread always reduces welfare and aggregate productivity. To evaluate the optimal dispersion of the cost-of-capital spread, we make use of the quadratic function of σ_ξ defined by the estimates in columns (5) and (6) of Table 1, which approximate the impact of place-based capital subsidies on welfare and aggregate productivity. For simplicity, we focus on place-based capital subsidies that are uncorrelated with local amenity and excess friction. The first-order conditions with respect to σ_{ξ} yields an optimal dispersion of the cost-of-capital spread for welfare improvement ($\rho_{\dot{A}\xi} > 0$): $\sigma_{\xi} = 0.516\rho_{\dot{A}\xi}\sigma_{\dot{A}}$; and for aggregate productivity improvement ($\rho_{\dot{A}\xi} < 0$): $\sigma_{\xi} = -0.572\rho_{\dot{A}\xi}\sigma_{\dot{A}}$. In other words, the variance of cost-of-capital spread should be about half its covariance with urban efficiency to maximize the impact of place-based capital subsidies on welfare or aggregate productivity.

The third result above explains why our Monte Carlo simulation results shown in Figure 1 include few cases of welfare gain or aggregate productivity gain. By construction, the correlation coefficient $\rho_{\dot{A}\xi}$ used in the simulation is generally very small. Consequently, the dispersion of the cost of capital across cities is generally too large relative to the covariance to produce net gains in welfare or aggregate productivity.

4.3. The robustness of simulation results

The above analysis of the influence of the geography of capital subsidies on welfare and aggregate productivity is based on the first-order effects of the dispersion of the cost-of-capital spread derived from the second-order Taylor approximation given by equations (17) to (19). To investigate whether the simulation results and regression estimates are sensitive to the omission of higher order moments in the Taylor approximation, we repeat the simulation using an alternative set of seed parameters for the joint distribution of the urban characteristics. Specifically, we change $\rho_{\dot{A}\gamma}$ and $\rho_{\gamma g}$ to zero, while keeping other simulation parameters unchanged. According to equation (19), the change would not alter how the dispersion of the cost-of-capital and its covariance with the urban characteristics affect welfare.

[Insert Figure 2 and Table 2 about here]

Figure 2 display the observations produced by the alternative version of Monte Carlo simulation. The dispersion patterns of the capital-stock effect and labor-relocation effect for welfare and aggregate productivity appear similar to those displayed in Figure 1. We repeat the regression analysis using the new simulation data. The estimates are reported in Table 2 and appear qualitatively similar to those reported in Table 1. In particular, the main findings from Table 1 remain unchanged.

5. THE CONSEQUENCES OF CHANGING GEOGRAPHY OF CAPITAL SUBSIDIES IN CHINA

Interventions in capital allocation across regions and industries are important policy tools for the Chinese government to shape regional and industrial developments. Before 2007, the domestic capital market played very limited role in the allocation of capital to firms (World Bank, 2011). Chinese firms obtained funds mainly from a banking system dominated by *de facto* state banks (Dobson and Kashyap, 2007). Economic reform in the 1990s brought a coastal manufacturing boom as coastal cities were more successful in attracting foreign direct investment (Fujita and Hu, 2001). At the turn of the century, the central government launched the Grand Western Region Development Program in a bid to boost economic development in the lagging western regions. By 2007, continued economic reform following China's WTO accession in late 2001 reduced spatial distortion in capital allocation.

Employing the firm-level data in China available from 2000 to 2007, we estimate the cost of capital for individual firms and use these estimates to identify the cost-of-capital spread for individual cities due to policy interventions. We document the shifts in the geography of capital subsidies in China between 2000 and 2007 according to the covariance between the cost-of-capital spread and the urban characteristics of Chinese cities. We then apply the decomposition method described in Section 3 and the quantitative insights from Section 4 to evaluate the welfare and aggregate productivity consequences of the shifts in the geography of capital subsidies.

5.1. The cost-of-capital spread across Chinese cities

We follow Chen *et al.* (2017) in employing firm-level data to uncover the cost-of-capital spread due to various policy interventions in capital allocation in China.[2] We focus on three

[2] Song and Wu (2015) show that the discrepancies in the cost of capital across firms in China in the 2000s may reduce China's industrial productivity by 20 percent through capital misallocation. Brandt et al. (2013)

key types of interventions that can be detected in firm-level data, namely, the ownership-type-based, the industrial-sector-based, and the location-based interventions. These interventions reflected the central government's priority in boosting the growth of enterprises of particular ownership types, industrial sectors, and regions. Another important source of unequal access to capital is the political ranking of cities (Chen et al., 2017; Henderson et al., 2020). Cities directly under the central government control, including Beijing, Shanghai, Tianjin, and Chongqing, have the status of a province. These provincial-level cities are followed in political power by 15 major cities that have a quasi-provincial status (whose top political leaders are directly appointed by the central government), 10 of which are provincial capital cities and 5 are separate entities in the state economic planning.

The estimation of the cost of capital for individual firms in China, r_{jit}, is documented in Appendix A. We write $r_{jit} = r_t e^{\xi_{jit}}$, where ξ_{jit} is the cost-of-capital spread over the national return on capital r_t for firm j in city i in year t. To uncover the sources of the unequal cost-of-capital spread, we regress ξ_{jit} on firm characteristics that would influence how a firm benefit from the various policy interventions:

$$(20) \quad \xi_{jit} = \mu_{0t} + \mu_{1t} \cdot DPE_j + \mu_{2t} \cdot FIE_j + \mu_{3t} \cdot QP_i + \ Prov_{kt} + Sect_{st} + \boldsymbol{X_j v_t} + \varepsilon_{jt},$$

where the μ's and the $\boldsymbol{v_t}$ vector are coefficients to be estimated, subscript k indicates the province where city i belongs and s the industry sector where firm j belongs. DPE_j and PIE_j are dummy variables for firms registered as domestic private enterprises and foreign-invested enterprises, respectively; they capture the effect of ownership-based policy interventions that affect capital allocation to private and foreign-invested enterprises relative to state-owned enterprises (SOEs, the default ownership type). QP_i is a dummy variable for cities with a quasi-provincial-level status and $Prov_{kt}$ denote the province (and provincial-level city) fixed effects; they capture the effect of location-based policy interventions. $Sect_{st}$ denotes 2-digit industrial sector fixed effects, which capture the effect of sector-based policy

report similar estimates of aggregate productivity loss for Chinese firms due to capital misallocation. They also find that more than half of this loss is due to within-province misallocation between state and non-state sectors. These studies do not account for capital stock adjustment and labor mobility frictions arising from heterogeneous local amenities and urban friction.

interventions. $\boldsymbol{X_j}$ is a vector of control variables accounting for the influence of the firms' market power and susceptibility to financial market frictions. The data and the estimation of equation (20) are reported in Appendix A.

The estimates of equation (20) are then used to compute individual firms' cost-of-capital spread d_{jit} due to various policy interventions:

$$(21) \qquad d_{jit} = d_{0t} + \mu_{1t} \cdot DPE_j + \mu_{2t} \cdot FIE_j + \mu_{3t} \cdot QP_i + Prov_{kt} + Sect_{st},$$

where d_{0t} is a constant to be determined. The cost-of-capital spread for city i, ξ_{it}, is calculated as the capital-weighted average d_{jit} of the individual firms in city i:

$$(22) \qquad \xi_{it} = d_{0t} + \frac{\sum_{j \in \mathcal{J}_{it}} (d_{jit} - d_{0t}) K_{jit}}{\sum_{j \in \mathcal{J}_{it}} K_{jit}} \equiv d_{0t} + \tilde{\xi}_{it},$$

where K_{jit} is the capital stock (total asset) of firm j and $\mathcal{J}_{it}$ denotes the set of firms in city i. For ξ_{it} to satisfy the national capital income budget constraint given by equation (15), parameter d_{0t} must satisfy:

$$(23) \qquad d_{0t} = \ln\left(\sum_{i \in \mathcal{C}_t} Y_{it} e^{-\tilde{\xi}_{it}} / \sum_{i \in \mathcal{C}_t} Y_{it} \right).$$

To check the reliability of the estimates of the cost-of-capital spread for individual cities based on equation (21) and (22), we compare the city capital stock implied by observed city output Y_{it} and the estimated ξ_{it} against the capital stock reported in city statistical yearbook. The two values, shown in Figure A4 in Appendix A, match reasonably well.

The various sources of the unequal cost-of-capital spread across Chinese cities in equation (21) are reported in Appendix A. We note that in 2000, both the ownership-type-based interventions and the location-based interventions played important roles in creating unequal cost of capital across the cities. In particular, the lagging regions, mainly in the West and Northeast, had a notably lower cost-of-capital spread. In 2007, the ownership-type-based interventions no longer play a significant role in creating unequal cost-of-capital spread across cities, as the role of SOEs in the Chinese economy diminished. In addition, the regional disparity in cost-of-capital spread due to location-based interventions decreased.

5.2. The changing geography of capita subsidies in China and the aggregate consequences

To evaluate the geography of capital subsidies in China and their aggregate consequences, we calibrate the urban accounting model described in section 2 using Chinese city data. The data and calibration results are documented in Appendix B. Based on the calibrated urban characteristics and the city-level cost-of-capital spread estimates, the geography of capital subsidies in 2000 and that in 2007 are reported in the top panel of Table 3. We note, first, that the dispersion of cost-of-capital spread, measured by cross-city variance, notably diminished between 2000 and 2007. Second, the cost-of-capital spread in 2000 is positively correlated with urban efficiency $\dot{A}$, reflecting the policy mandate to support the economically lagging regions; by 2007, such spatial distortion in capital allocation largely disappeared. We further note that, in 2000, the variance of cost-of-capital spread is slightly larger than its covariance with urban efficiency; in 2007, the latter is much smaller than the former.

[Insert Table 3 about here]

The bottom panel shows the counterfactual consequences of the place-based capital subsidies in China. The subsidies in 2000, which favor cities in the lagging regions, considerably reduced city-size dispersion; in comparison, the subsidies in 2007 had a much smaller impact on city-size dispersion. In 2000, the subsidies elevated the marginal return on capital, as productive cities were relatively deprived of capital, entailing a long-run increase in capital stock; in contrast, the place-based capital subsidies in 2007 entailed a large loss in capital stock. The labor-relocation effect of the subsidies on aggregate productivity is opposite to the capital-stock effect: it produced a large loss in aggregate productivity in 2000 but a gain in 2007. The loss in welfare due to labor relocation in 2000 is as large as that in aggregate productivity: although welfare suffers less from unfavorable labor relocation arising from subsidizing less productive cities because of compensating changes in labor wedge, it also benefits less from favorable labor relocation arising from a large dispersion of cost-of-capital spread. In 2007, the welfare gain from labor relocation is smaller than the gain in aggregate productivity: the gain is driven by the dispersion in cost-of-capital spread, which benefit welfare less than aggregate productivity due to the dampening effect of associated labor wedge change.

Overall, both aggregate productivity and welfare suffer from place-based capital subsidies in China in 2000 and 2007 due to the excessively large dispersion of cost-of-capital spread relative to the covariance between the spread and urban efficiency. The reduction in the dispersion of cost-of-capital spread across cities and in the covariance between the spread and urban efficiency reduced loss in aggregate productivity from 11.6 log points in 2000 to 3.78 log points in 2007. In comparison, the reduction in welfare loss is smaller, from 12.5 log points to 7.89 log points, because the reduction in the covariance is favorable to aggregate productivity but unfavorable to welfare.

6. CONCLUSIONS

Place-based capital subsidies often arise from various government interventions in capital allocation. Their welfare and aggregate productivity consequences, however, are ambiguous. We have sought to clarify the consequences by studying the capital-stock effect and the labor-relocation effect of unequal capital subsidies in a general-equilibrium urban accounting model. We show these two effects to be counteractive: unequal capital subsidies that raise capital productivity (thus raising capital stock in the long run) would also induce labor relocation detrimental to welfare and aggregate productivity. The tradeoff between these two effects depends on the geography of capital subsidies, or the covariance between the subsidies and the urban characteristics. In addition, the tradeoff differs for welfare and aggregate productivity. Several insights to the aggregate consequences of place-based capital subsidies emerge from simulation analysis. First, the dispersion of cost-of-capital spread across cities, absent any covariance with urban characteristics, always reduces welfare and aggregate productivity because the negative capital-stock effect it produces exceeds its positive labor-relocation effect. Second, holding the dispersion of cost-of-capital spread constant, place-based capital subsidies that favor cities with a relatively higher productive efficiency (i.e., a negative covariance between the spread and the urban productive efficiency) would raise aggregate productivity at the expense of welfare; conversely, place-based capital subsidies that favor cities with a relatively lower productive efficiency would elevate welfare at the expense of aggregate productivity. The opposite consequences for welfare and aggregate productivity arise because the aggregate labor wedge in the economy increases with city-size dispersion. In other words, place-based capital subsidies seldom improve aggregate productivity and welfare at the same time. Third, place-based capital subsidies would be more effective in altering aggregate productivity and welfare when the disparity in productive efficiency across cities is large and the variance of the cost-of-capital spread is about the half the covariance between the spread and the urban efficiency.

These insights are useful for informing and evaluating place-based capital subsidy policies. For illustration, they shed light on the welfare and aggregate productivity consequences of changing geography of capital subsidies in China between 2000 and 2007 as the economic reform narrowed the dispersion of the cost of capital across cities and the capital subsidies to cities in economically lagging regions diminished. The latter change boosted aggregate productivity but not welfare as elevated city-size dispersion also raised aggregate labor wedge due to urban frictions. The reduction in the dispersion of the cost of capital, however, is not big enough to eliminate losses both in welfare and in aggregate productivity due to place-based capital subsidies.

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TABLE 1—OLS ESTIMATES OF THE INFLUENCE OF THE GEOGRAPHY OF CAPITAL SUBSIDIES ON LOSSES IN CITY-SIZE DISPERSION, WELFARE, AND AGGREGATE PRODUCTIVITY DUE TO LABOR-RELOCATION AND CAPITAL-STOCK EFFECTS, BASED ON BASELINE MONTE CARLO SIMULATION DATA

Variables	(1) Loss in size dispersion $\ln(q_0/q)$	(2) Labor-relocation effect on welfare $u_0' - u$	(3) Labor-relocation effect on aggregate productivity $\ln(Y_0'/Y)$	(4) Capital-stock loss $\frac{\theta}{1-\theta}\xi_0$ $= u_0 - u_0'$ $= \ln(Y_0/Y_0')$	(5) Net welfare loss $u_0 - u$	(6) Net loss in aggregate productivity $\ln(Y_0/Y)$
σ_ξ^2	-4.169	-0.876	-1.653	3.438	2.562	1.784
	(1.27)	(0.17)	(0.40)	(0.25)	(0.24)	(0.26)
$\rho_{\dot{A}\xi}\sigma_{\dot{A}}\sigma_\xi$	21.70	2.677	7.362	-5.320	-2.644	2.042
	(2.09)	(0.28)	(0.65)	(0.41)	(0.40)	(0.42)
$\rho_{\gamma\xi}\sigma_\gamma\sigma_\xi$	11.59	1.427	0.655	-1.821	-0.394	-1.166
	(1.46)	(0.20)	(0.45)	(0.29)	(0.28)	(0.30)
$\rho_{g\xi}\sigma_g\sigma_\xi$	-9.206	-1.941	-1.999	1.901	-0.040	-0.098
	(0.61)	(0.08)	(0.19)	(0.12)	(0.12)	(0.12)
Constant	-0.053	0.006	-0.011	-0.001	0.005	-0.011
	(0.05)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
R-squared	0.201	0.393	0.297	0.368	0.209	0.208

Notes: The dependent variables are under column numbers. The sample comprise 1000 observations associated with the 1000 runs of the baseline Monte Carlo simulation. The simulation is based on a joint normal distribution of location attributes with variances calibrated to Chinese city data in 2000: $\sigma_\xi^2 = 0.037$, $\sigma_{\dot{A}}^2 = 0.090$, $\sigma_g^2 = 0.498$, and $\sigma_\gamma^2 = 0.181$. The correlation parameters related to the cost-of-capital spread ξ are set to zero. The covariances between the urban characteristics are $\sigma_{\dot{A}\gamma}^2 = -0.093$, $\sigma_{\dot{A}g}^2 = 0.057$, and $\sigma_{\gamma g}^2 = 0.053$. Standard errors of estimates are in parentheses.

TABLE 2— OLS ESTIMATES OF THE INFLUENCE OF THE GEOGRAPHY OF CAPITAL SUBSIDIES ON LOSSES IN CITY-SIZE DISPERSION, WELFARE, AND AGGREGATE PRODUCTIVITY DUE TO LABOR-RELOCATION AND CAPITAL-STOCK EFFECTS, BASED ON ALTERNATIVE MONTE CARLO SIMULATION DATA

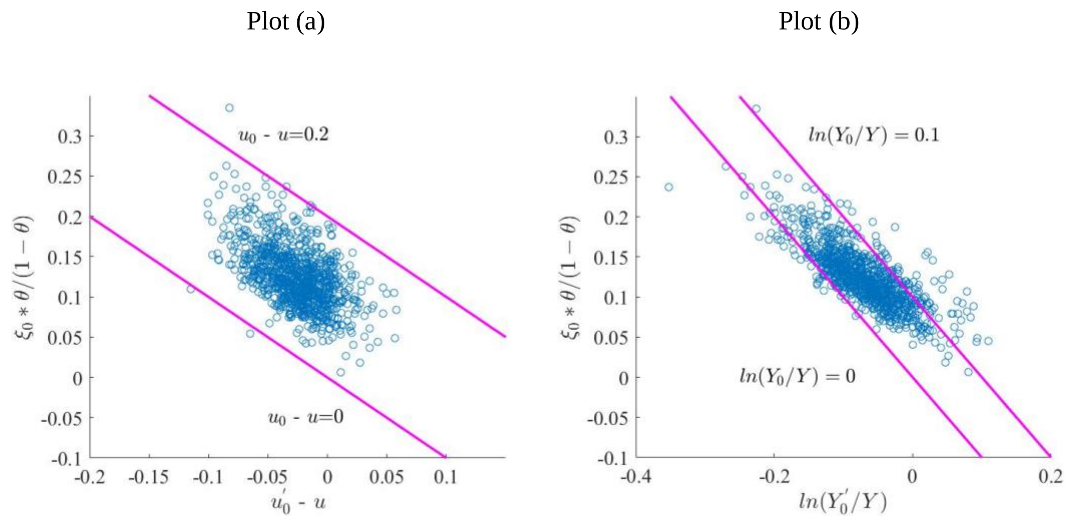
Variables	(1) Loss in size dispersion $\ln(q_0/q)$	(2) Labor-relocation effect on welfare $u_0' - u$	(3) Labor-relocation effect on aggregate productivity $\ln(Y_0'/Y)$	(4) Capital-stock loss $\frac{\theta}{1-\theta}\xi_0 = u_0 - u_0' = \ln(Y_0/Y_0')$	(5) Net welfare loss $u_0 - u$	(6) Net loss in aggregate productivity $\ln(Y_0/Y)$
σ_ξ^2	-8.887	-0.897	-1.809	2.856	1.959	1.047
	(2.38)	(0.25)	(0.39)	(0.30)	(0.30)	(0.16)
$\rho_{\dot{A}\xi}\sigma_{\dot{A}}\sigma_\xi$	10.01	1.446	4.697	-3.488	-2.043	1.209
	(2.18)	(0.23)	(0.32)	(0.28)	(0.28)	(0.14)
$\rho_{\gamma\xi}\sigma_\gamma\sigma_\xi$	7.473	0.694	0.950	-1.177	-0.482	-0.227
	(1.49)	(0.15)	(0.22)	(0.19)	(0.19)	(0.10)
$\rho_{g\xi}\sigma_g\sigma_\xi$	-8.766	-1.789	-1.528	1.669	-0.120	0.140
	(0.95)	(0.10)	(0.14)	(0.12)	(0.12)	(0.06)
Constant	0.215	0.020	0.016	-0.013	0.007	0.004
	(0.09)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
R-squared	0.114	0.268	0.236	0.289	0.096	0.127

Notes: The dependent variables are under column numbers. The sample comprise 1000 observations associated with the 1000 runs of the alternative version of Monte Carlo simulation. The simulation is based on a joint normal distribution of location attributes with variances calibrated to Chinese city data in 2000: $\sigma_\xi^2 = 0.037$, $\sigma_{\dot{A}}^2 = 0.090$, $\sigma_{\mathrm{g}}^2 = 0.498$, and $\sigma_\gamma^2 = 0.181$. The correlation parameters related to the cost-of-capital spread ξ are set to zero. The covariances between the urban characteristics are $\sigma_{\dot{A}\gamma}^2 = 0$, $\sigma_{\dot{A}g}^2 = 0$, and $\sigma_{\gamma g}^2 = 0.053$. Standard errors of estimates are in parentheses.

TABLE 3—DECOMPOSITION OF THE AGGREGATE CONSEQUENCES OF PLACE-BASED CAPITAL SUBSIDIES IN CHINA, 2000 AND 2007

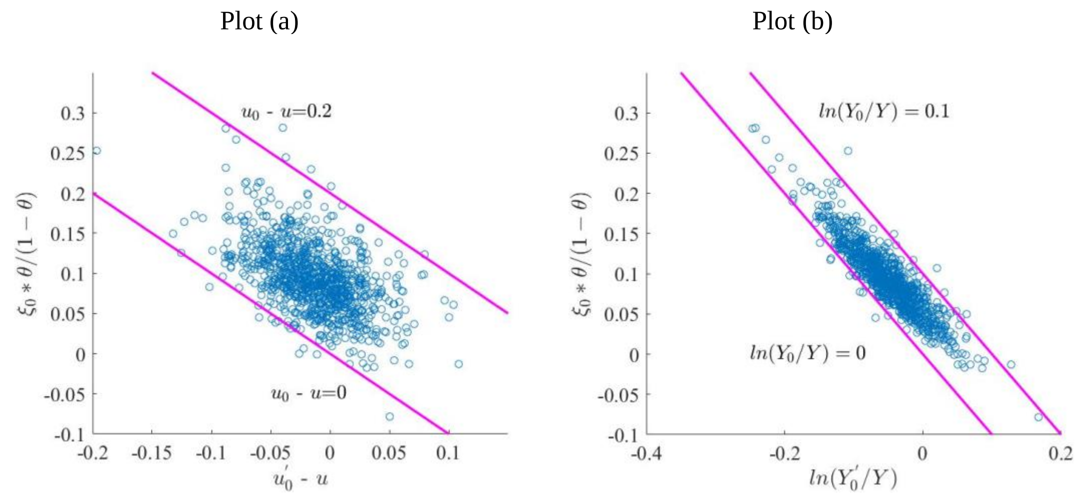
	Year 2000	Year 2007
Year 2000		
Cost-of-capital spread ξ		
Variance	0.037	0.029
Covariance with ln A	0.034	0.009
Covariance with γ	-0.024	0.018
Covariance with g	0.005	0.014
Counterfactual change in aggregate outcomes (%)		
Loss of city-size dispersion $\ln(q_0/q)$	0.78	0.16
Productivity and welfare loss due to ξ_0	-1.39	9.93
Productivity loss due to labor relocation, $\ln(Y_0'/Y)$	13.0	-6.15
Welfare loss due to labor relocation, $u_0' - u$	13.9	-2.04
Net productivity loss $\ln(Y_0/Y)$	11.6	3.78
Net welfare loss $u_0 - u$	12.5	7.89

FIGURE 1. PLOTS OF THE CAPITAL-STOCK EFFECT VS. LABOR-RELOCATION EFFECT ON WELFARE AND AGGREGATE PRODUCTIVITY, BASELINE MONTE CARLO SIMULATION RESULTS



Note: Each plot shows the results of 1000 simulations based on a joint normal distribution of location attributes with variances calibrated to Chinese city data in 2000: $\sigma_\xi^2 = 0.037$, $\sigma_A^2 = 0.090$, $\sigma_g^2 = 0.498$, and $\sigma_\gamma^2 = 0.181$. The correlation parameters related to the cost-of-capital spread ξ are set to zero. The covariances between the urban characteristics are $\sigma_{A\gamma}^2 = -0.093$, $\sigma_{Ag}^2 = 0.057$, and $\sigma_{\gamma g}^2 = 0.053$. The vertical axis shows the capital-stock effect, the horizontal axis, the labor-relocation effect. The diagonal lines identify different levels of net welfare loss $u_0 - u = u_0' - u + \frac{\theta}{1-\theta}\xi_0$ and net productivity loss $\ln(Y_0/Y) = \ln(Y_0'/Y) + \frac{\theta}{1-\theta}\xi_0$.

FIGURE 2. PLOTS OF THE CAPITAL-STOCK EFFECT VS. LABOR-RELOCATION EFFECT ON AGGREGATE PRODUCTIVITY AND WELFARE, ALTERNATIVE MONTE CARLO SIMULATION RESULTS



Note: Each plot shows the results of 1000 simulations based on a joint normal distribution of urban characteristics with variances calibrated to Chinese city data in 2000: $\sigma_{\xi}^2 = 0.037$, $\sigma_{\dot{A}}^2 = 0.090$, $\sigma_{g}^2 = 0.498$, and $\sigma_{\gamma}^2 = 0.181$. The correlation parameters related to the cost-of-capital spread ξ are set to zero. The covariances between the urban characteristics are $\sigma_{\dot{A}\gamma}^2 = 0$, $\sigma_{\dot{A}g}^2 = 0$, and $\sigma_{\gamma g}^2 = 0.053$. The vertical axis shows the capital-stock effect, the horizontal axis, the labor-relocation effect. The diagonal lines identify different levels of net welfare loss $u_0 - u = u_0' - u + \frac{\theta}{1-\theta}\xi_0$ and net productivity loss $\ln(Y_0/Y) = \ln(Y_0'/Y) + \frac{\theta}{1-\theta}\xi_0$.

The Aggregate Consequences of Place-based Capital Subsidies

By Shangming Yang and Yuming Fu

<Online Appendixes>

APPENDIX A. ESTIMATING THE COST-OF-CAPITAL SPREAD AND ITS DETERMINANTS FOR CHINESE FIRMS AND CITIES

The data for estimating the cost of capital for individual firms are from the Annual Survey of Industrial Firms by the National Bureau of Statistics, available from 1998 to 2007 (Chen et al., 2017). The survey covers all SOEs and the firms of other ownership types with annual sales exceeding RMB 5 million yuan. These firms represent most of the industrial output in China. For each firm, the survey reports its location, sector, ownership type, year of establishment, value added, employment, and detailed financial information, such as income and balance-sheet components. We exclude from our analysis firms with missing or negative value for any of these variables: output, profit, wage payable, employment benefit payable, total asset, and total liability. We further exclude firms with fewer than 10 employees, negative liquid asset, or negative fixed asset. The industrial sector classification is adjusted according to Brandt et al. (2012).

A firm's cost of capital depends on both the cost of debt and the cost of equity. The former cost is affected by access to credit and the latter can be effectively reduced by favorable tax rates and land lease terms. To capture the full distortion, we seek to measure the overall cost of capital, rather than just the cost of borrowing as in Bai et al. (2006). The cost of capital of a firm should equal to its marginal revenue product of capital; we follow the literature in using a firm's average revenue product of capital to approximate it (Chen et al., 2017). The deviation between the average revenue product and the marginal revenue product would increase with the firm's market power, which we will seek to control for in estimating the policy influences on the firms' cost of capital.

To determine the overall cost of capital of individual firms, we assume an identical capital share of value added in each 3-digit industrial sector, denoted by α_{st}, where subscript s

indicates the industrial sector and t indicate year. α_{st} is estimated as unity minus the average labor share of value added in sector s:

$$\alpha_{st} = 1 - \frac{\sum_{j\in\mathcal{S}_{st}}\left(wage_{jt} + welfare_{jt}\right)}{\sum_{j\in\mathcal{S}_{st}} VA_{jt}},$$

where $\mathcal{S}_{st}$ is the set of firms in sector s in year t, $wage_{jt}$ is the total wage expense of firm j in year t, $welfare_{jt}$ is the total worker welfare compensation, and VA_{jt} is the firm's value added. The cost of capital for firm j in sector s, based on its average revenue product of capital, is computed as:

$$r_{jst} = \frac{\alpha_{st} \cdot VA_{jt}}{K_{jt}}, \qquad j \in \mathcal{S}_{st}$$

where K_{jt} is the firm's capital stock or total asset.

To estimate equation (20), we classify the firms' ownership types according to the ownership-type codes in the Annual Survey of Industrial Firms (see Table A1). SOEs are identified as domestic firms with ownership type codes 110, 141, 143, and 151. Domestic private enterprises are non-SOE domestic firms (coded with first digit 1). Foreign-invested firms include those with capital investment from Hong Kong, Macau, and Taiwan (coded with first digit 2) and from other countries (coded with first digit 3). The control variables $\boldsymbol{X_j}$ include the firms' market power and susceptibility to financial market frictions. The former is measured by its sales share in 3-digit sector. The latter is controlled for by the firm's characteristics, including log age, log employment size, liquid asset share of total asset, and net worth (total asset net of total liabilities as a fraction of total asset). These characteristics are found in the literature to affect firm's cost of capital (Wu 2018; David and Venkateswaran 2019). In addition, we include in $\boldsymbol{X_j}$ a dummy variable for firms located in an urban district; these firms would be less affected by the financial market frictions than rural firms due to their proximity to financial institutions.

[Insert Table A1 about here]

Equation (20) is estimated using weighted-least-square method, with weight proportional to each firm's total asset. To minimize the influence of outliers, we remove from our estimation sample those firms with an estimated r_{jst} in both the bottom and the top 4% tails of the distribution of $\log(r_{jst})$. Table A2 reports the regression estimates for year 2000 and 2007. Compared to SOEs, domestic private enterprise ($DPE_j = 1$) and foreign-invested enterprises ($FIE_j = 1$) tend to have a higher cost-of-capital spread; the capital subsidy received by SOEs appear to be larger in 2007. Firms in cities with a quasi-province status ($QP_j = 1$) enjoy a slight advantage in access to capital in 2000 and the advantage increased slightly in 2007. Market power is positively correlated the firm's cost-of-capital spread. With respect to the financial market frictions, a longer presence and a larger employment size are negatively correlated with the spread, but a higher liquid asset share is positively correlated with it. Firms situated in urban districts have a lower spread relative to their counterparts in rural districts.

[Insert Table A2 about here]

The province fixed effects are shown in Figure A1. In 2000, the western provinces in general, including the provincial-level city Chongqing, and the three eastern-region provincial-level cities enjoyed a relatively low cost of capital. In addition, favorable access to capital was enjoyed by the firms in the three northeastern rustbelt provinces and in Hainan Island off the southeast coast, which became a province and a special economic zone in 1988. In 2007, the cost-of-capital differences across the regions are narrowed, though Hainan and some of the western provinces, such as Xinjiang, Qinghai, Ningxia, and Yunnan, continued to receive heavy subsidies. In addition, Beijing and Shanghai received more favorable access to capital.

[Insert Figure A1 about here]

[Insert Figure A2 about here]

Figure A2 shows the industrial sector fixed effects. In 2000, sectors with more favorable access to capital include paper products, non-metallic mineral products, general machines, special equipment, chemical material and products, spinning industry, transportation equipment, plastic products, chemical fibers, metal smelting and pressing, metal products, rubber products, and furniture. In 2007, some of these sectors, including metal smelting and pressing and rubber products, lost favorable access to capital, perhaps due to their overcapacity; but the communication, computer, and other electronic equipment sector and the pharmaceutical sector gained favorable access. The sectors receiving more favorable access to capital are often the ones competing more successfully in the global manufacturing export market—Figure A3 show a clear negative correlation between a sector's cost of capital (the average value of the sector fixed effects between 2000 and 2007) and its export performance between 2000 and 2007 in terms of export revenue growth and the increase in the export share of sales.

[Insert Figure A3 about here]

We use the estimates reported in Table A2 to calculate the cities' cost-of-capital spread, ξ_{it}, according to Equation (21) and Equation (22). Capital stock is also reported in *China City Statistical Yearbook*. To verify that the cross-city variation in the per-capita capital stock statistics reflects the influence of the policy interventions in capital allocation, we compare the official capital stock statistics against the per-capita capital stock implied by the estimated city cost of capital $r_{it} = r_t e^{\xi_{it}}$ and the reported per-capita city output GRP. r_t is calibrated according to the national capital stock and output statistics. Figure A4 shows that the reported and inferred per-capita capital stock are closely correlated.

[Insert Figure A4 about here]

APPENDIX B. CALIBRATING THE URBAN CHARACTERISTICS OF CHINESE CITIES

The city-level variables for calibrating the urban accounting model are obtained mainly from *China City Statistical Yearbook*. Those variables include gross regional production (GRP) Y_{it}, population N_{it}, and per-capita total consumer spending $c_{it} + w_{it}h_{it}(R_{it} + T_{it})$. The resident population in year 2000 is obtained from 2000 population census. The residential population for year 2007 is estimated according to GRP and the average GRP per resident reported in 2007 City Statistical Yearbook. Our sample includes cities at the prefecture level or above. These cities often comprise urban districts as well as rural districts. Unless noted otherwise, the city-level variables are measured according to urban-district statistics. Consumer expenditure components are obtained from the *China Statistical Yearbook for Regional Economies*.

We follow Bai et al. (2006) to estimate the capital share of national income θ_t by identifying the average labor share of provincial GDP as $1-\theta_t$. Our θ_t estimates are 0.5043 for year 2000 and 0.5714 for year 2007, which are close to $\theta = 0.5221$ adopted in Bai *et al.* (2006). The leisure preference parameter ψ is inferred from the total daily working hours of nonagricultural workers divided by 14 hours and by urban population. It is estimated to be 2.3, implying an employment share of labor time $h_{it} = \frac{1}{1+\psi} = 0.3$; the estimate, however, does not affect our urban accounting results. The city production efficiency A_{it}, wage rate w_{it}, and per capita capital stock k_{it} are then calibrated using equations (1), (2) and (3) based on the estimates of θ_t, h_{it}, per capita city GRP, and r_{it}.

The estimation of the overall labor wedge τ_{it} requires information of consumer expenditure components, including expenditure on housing and commuting. Such information is available from the *China Statistical Yearbook for Regional Economies* but only at the province level. To impute the rent and commuting expenses at the city level, we first seek to estimate the parameter κ_t^* in equation (9) using the province-level housing and commuting expense share of total consumer expenditure, which is denoted by η_{pt}:

$$\text{(B1)} \qquad \eta_{kt} = \frac{\sum_{i\in\mathcal{I}_k}(1-\theta_t)y_{it}(R_{it}+T_{it})N_{it}}{\sum_{i\in\mathcal{I}_k}\big(c_{it}+(1-\theta_t)y_{it}(R_{it}+T_{it})\big)N_{it}} = \frac{\kappa_t^*\pi^{-\frac{1}{2}}\sum_{i\in\mathcal{I}_k}(1-\theta_t)y_{it}N_{it}^{\frac{3}{2}}}{\sum_{i\in\mathcal{I}_k}\tilde{c}_{it}N_{it}},$$

where $\mathcal{I}_k$ denotes the set of cities in province k and $\tilde{c}_{it} = c_{it} + w_{it}h_{it}(R_{it}+T_{it})$. κ_t^* can be determined from Equation (B1) according to population-weighted average provincial η_{kt} The overall labor wedge for each city, τ_{it}, can be determined using equation (8):

$$1-\tau_{it} = \frac{c_{it}}{(1-\theta_t)y_{it}} = \frac{\tilde{c}_{it}-(1-\theta_t)y_{it}\kappa_t^*(N_{it}/\pi)^{\frac{1}{2}}}{(1-\theta_t)y_{it}}.$$

Since we can calculate τ_{it} for the years 2000, 2005, and 2010, when reliable city population statistics are available, we use the average τ_{it} of the latter two years to approximate that for the year 2007. We next decompose τ_{it} into urban friction parameter κ_t and excess friction g_{it} in equation (10) by estimating the regression:

(B2) $$\ln \tau_{it} - \frac{1}{2}\ln N_{it} = \ln \kappa_t + g_{it} = \varsigma_t + \varepsilon_{it},$$

where ς_t is a constant and ε_{it} is the residual. Equation (B2) gives $\kappa_t = e^{\varsigma_t}$ and $g_{it} = \varepsilon_{it}$. We further set the baseline reservation utility $u_t^* = 10$ and compute the amenity index γ_{it} using equation (11). Since γ_{it} is calibrated as a residual factor in accounting for the city population, it can pick up measurement errors in other variables, such as A_{it} and N_{it}.

The descriptive statistics for the calibrated urban characteristics $\ln A_{it}$, γ_{it}, and g_{it} are reported in Table B1.

[Insert Table B1 about here]

TABLE A1—FIRM REGISTRATION TYPES IN THE ANNUAL SURVEY OF INDUSTRIAL FIRMS BY NBS

Code	Type	Code	Type
	Domestic firms		Firms with capital investment from Hong Kong, Macao, Taiwan (HMT)
110	State-owned firms	210	Joint venture
120	Collective-owned firms	220	cooperative enterprises
130	Joint-equity cooperative enterprises	230	HMT sole-proprietorship enterprise
141	State-owned joint venture	240	HMT corporation
142	Collective-owned joint venture	290	Other HMT firms
143	State and Collective joint venture		Firms with capital investment from foreign countries
149	Other joint venture	310	Sino-foreign joint venture
151	State-funded limited-liability company	320	Sino-foreign cooperative enterprises
159	Other limited-liability company	330	Foreign sole-proprietorship enterprise
160	Corporation	340	Foreign corporation
171	Sole-proprietorship privately-operated enterprise	390	Other foreign firms
172	Partnership privately-operated enterprise		
173	Privately-operated limited-liability company		
174	Privately-operated Corporation		
190	Other domestic firms		

TABLE A2—THE ESTIMATES OF FIRMS' COST-OF-CAPITAL SPREAD

	(1)	(2)
Variables	Year 2000	Year 2007
FIE	0.352	0.310
	(0.01)	(0.01)
DPE	0.348	0.298
	(0.01)	(0.00)
QP	-0.025	-0.066
	(0.01)	(0.00)
Age	-0.020	-0.031
	(0.00)	(0.00)
Size	-0.057	-0.043
	(0.00)	(0.00)
Liquid_Asset	0.696	0.491
	(0.02)	(0.01)
Market_Power	5.260	1.412
	(0.10)	(0.06)
Urban_District	-0.210	-0.138
	(0.01)	(0.00)
Constant	-2.590	-1.964
	(0.03)	(0.02)
Observations	103,113	222,133
R-squared	0.230	0.151
Province FE	YES	YES
Sector FE	YES	YES

Notes: The dependent variable is $\xi_{jst} = \ln(r_{jst}/r_t)$. The first five explanatory variables are foreign-invested enterprise, domestic private enterprise, quasi-provincial cities, firm age (log), and firm employment size (log). *Liquid_Asset* is calculated as: $(cash\ holdings + 0.715 \times receivables + 0.547 \times inventory + 0.535 \times fixed\ assets)/total\ asset$. *Market_Power* is calculated as a firm's sales share in its 3-digit sectors. *Urban_District* is a dummy for firms located in urban districts. The regression is estimated using weighted least square method, with weight proportional to each firm's total asset. Standard errors are in parentheses; all estimates are statistically significant at 1% level.

TABLE B1—SUMMARY STATISTICS OF CALIBRATED URBAN CHARACTERISTICS

Summary statistics

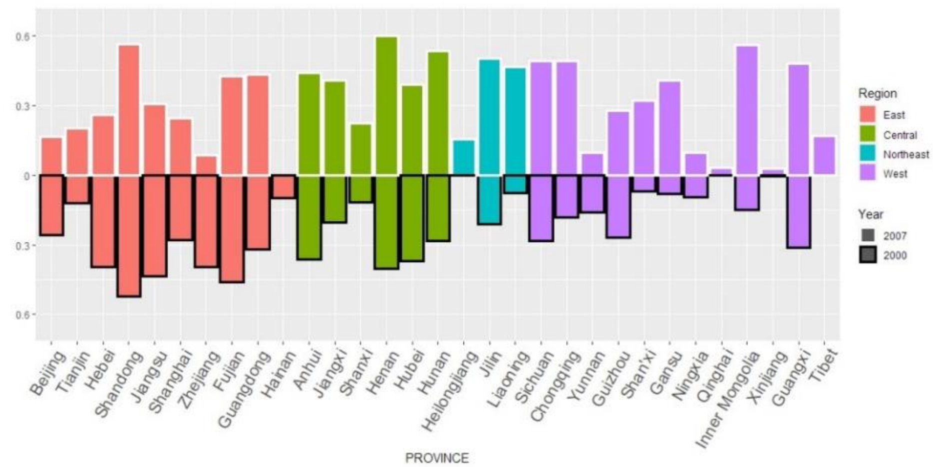
	N	Mean	Stdev	Min	Max
		Year 2000			
$\dot{A}$	191	4.72	0.3	3.89	5.65
γ	191	2.59	0.43	1.03	3.64
g	191	0.00	0.71	-3.3	1.28
		Year 2007			
$\ln A$	202	4.58	0.23	4.06	5.29
γ	202	2.09	0.4	1.15	3.35
g	202	0.00	0.51	-1.74	1.16

Correlation coefficients

Variables	$\dot{A}$	γ	g
$\dot{A}$	1.00	-0.73	0.27
γ	-0.67	1.00	0.18
g	0.36	0.07	1.00

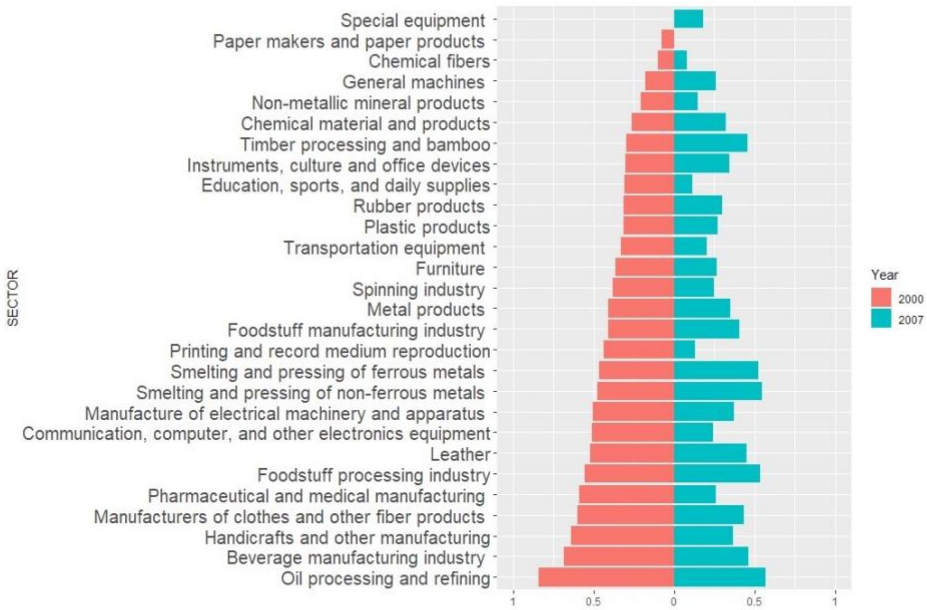
Note: The figures above the diagonal are the coefficients for year 2000; those below, for year 2007.

FIGURE A1. THE PROVINCE FIXED EFFECTS



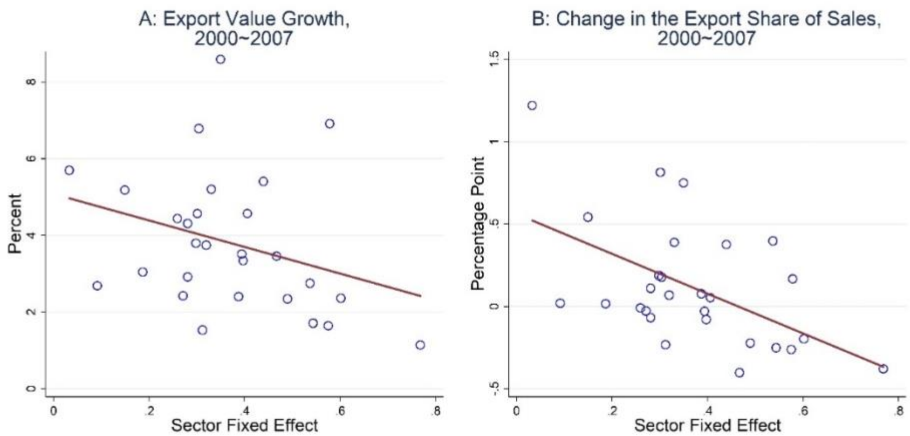
Notes: The Figure displays the province fixed effects in Table A2.

FIGURE A2. THE SECTOR FIXED EFFECTS



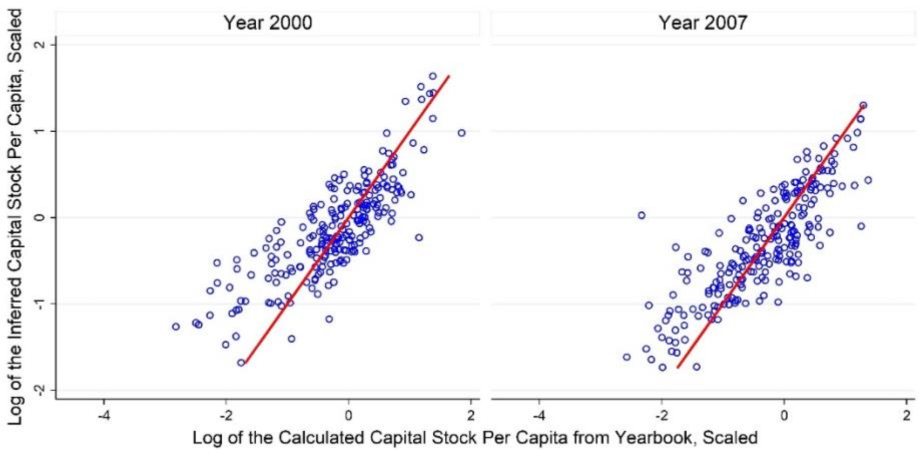
Notes: The Figure displays the industrial-sector fixed effects in Table A2.

FIGURE A3. THE RELATIVE COST OF CAPITAL AND EXPORT PERFORMANCE ACROSS TWO-DIGIT INDUSTRY SECTORS



Notes: The relative cost of capital across the 2-digit industrial sectors (horizontal axis) is based on the average sector fixed effect estimates for each year from 2000 to 2007.

FIGURE A4. CORRELATION BETWEEN THE INFERRED CAPITAL STOCK PER CAPITA AND THE CAPITAL STOCK REPORTED BY CHINA CITY STATISTICAL YEARBOOK



Notes: The calculated capital stock per capita (horizontal axis) is based on the capital stock reported by City Statistical Yearbook and the residential population of individual cities. The inferred per-capita capital stock (vertical axis) is calculated as $(\theta y_j / r_j)$ where θ is the capital share of national income, y_j is per-capita city output (or GRP), and r_j is the estimated city cost of capital. The values shown on both axes are relative to the national capital stock per capita.