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FInance, Endogenous TFP, and Misallocation

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Abstract

In the standard macro-finance model, financial constraints affect small or young firms but not large or old ones, and the implied dispersion in the marginal revenue product of capital (MRPK) of a firm cohort is less persistent compared to the data. We extend the model by allowing firm productivity to be endogenous to firms' financial constraints. With endogenous productivity, a firm's optimal demand for capital increases with collateral, financial constraints and dispersion of MRPK persist, and even large firms are likely to be constrained. Our model with endogenous productivity also amplifies productivity loss arising from financial frictions by two-fold.

Keywords: Collateral Constraint, Endogenous Firm Productivity, Firm Dynamics, Misallocation, Aggregate Productivity, China.

JEL classification: E13, G31, L16, L26, O41.

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1 Introduction

A recent literature argues that the misallocation of production factors, and especially the misallocation of capital, is a main reason for low total factor productivity (TFP) in developing countries (Restuccia and Rogerson, 2008; Hsieh and Klenow, 2009), which in turn, is the main source of per capita income differences (Klenow and Rodríguez-Clare, 1997; Caselli, 2005). While financial frictions are a potential natural source of misallocation, the literature assessing the quantitative importance of this channel on aggregate TFP finds small effects (Buera et al., 2011; Moll, 2014; Midrigan and Xu, 2014). The literature typically models financial frictions by assuming that firms face collateral constraints. In these models, the quantitative effects of collateral constraints are small due to the incentive of productive firms to undo collateral constraints through self financing.[1] These models' predictions are also at odds with the imprint of misallocation across both the firm size distribution and the firm life cycle in developing countries. While firm-level evidence from developing countries suggests that large firms may face more severe distortions (Hsieh and Olken, 2014), these models predict that financial constraints distort mainly small or young firms. Furthermore, while the data suggest that the dispersion in marginal revenue product of capital (MRPK) for a cohort of firms is highly persistent over time (Banerjee and Moll, 2010; David and Venkateswaran, 2019), these models predict a short dispersion half-life as self-financing quickly undoes financial frictions (Moll, 2014).

A common assumption used in financial constraint models is that firm-level TFP is exogenous and not affected by financial frictions. Available empirical evidence, however, suggests that firms can invest in TFP-enhancing activities. There is an extensive literature examining how firms can increase their TFP by investing in research and development (R&D) (Klette and Griliches, 2000; Hall et al., 2010). More recently, there is also a growing literature exploring how firms can improve their TFP by investing in management practices or hiring professional managers (Bloom and Van Reenen, 2010). In this paper, we introduce such firm investments in TFP to the standard collateral constraint model used by Midrigan and Xu

[1] The literature does find larger effects of financial constraints at the extensive margin, on entry decisions of firms. Our focus in this paper, however, is on the misallocation of production factors among incumbent firms.

(2014) and re-examine the quantitative effects of financial frictions on capital misallocation and aggregate TFP. We argue that endogenizing firm TFP can significantly counteract the self-financing channel, better match financial constraints faced by firms across both the firm size distribution and the firm life cycle in the data, and amplify the impact of financial frictions on aggregate productivity.

The logic of our argument is as follows. Consider a firm with a productive blueprint but little collateral in a country with weak financial development, and consequently, tight collateral requirements. Initially, the firm can only operate on a small scale due to its limited collateral, which yields an MRPK that is substantially higher than the interest rate.This high MRPK then incentivizes the firm to save towards relaxing the collateral constraint, and as it does so, its MRPK declines. This is the standard self-financing channel that mitigates the impact of collateral constraints on aggregate TFP, limits distortions to small firms and young firms, and generates quantitatively fast-resolving MRPK dispersion for a cohort of firms. We introduce the option to enhance TFP through, for example, hiring professional managers. In our framework, a firm has the incentive, as it grows and accumulates collateral, to make complementary investments in TFP, which raise its optimal scale and demand for capital. Therefore, firm demand for capital increases with collateral. This new channel partially counteracts the self-financing channel. With endogenous TFP, the MRPK dispersion of a firm cohort is more persistent, and large firms and old firms are more likely to be financially constrained.

Our quantitative analysis uses Chinese firm-level data and examines management practices as an endogenous firm productivity input, following Bloom and Van Reenen (2010). We provide a quantitative comparison between our model with endogenous firm TFP and an otherwise identical model but with exogenous firm TFP. To ensure fairness of comparison, we calibrate both models to match exactly the same set of moments commonly chosen in the literature. In particular, we calibrate the collateral constraint and productivity shock process such that, in the steady state, both models generate the same debt-to-output ratio and output dispersion—moments used in Moll (2014) and Midrigan and Xu (2014), among others. We calibrate the endogenous productivity input parameters to match the distribution of hired managers in the Chinese data. Comparing the results from the two calibrated models, we find that it takes twice as much time for a high-productivity but low-collateral entrepreneur to save up to the unconstrained level when firm TFP is endogenous. Examining a cohort of such firms reveals that the dispersion in their MRPK is more persistent under the endogenous firm TFP model, with a half-life of the dispersion that is around one-third longer. Consequently, in the steady state, firms are more likely to face binding financial constraints in the endogenous firm TFP model than in the exogenous firm TFP model, and the differences are larger for larger firms. As a result, the efficiency gain associated with eliminating the collateral constraint from the endogenous firm TFP model is twice as large as that of the exogenous firm TFP model, at 19.9 percent versus 10.1 percent.

Our paper mainly contributes to the misallocation literature.[2] Several papers have also documented that endogenizing firm TFP amplifies aggregate productivity loss arising from policy distortions (e.g. Gabler and Poschke, 2013; Bhattacharya et al., 2013; Da-Rocha et al., 2019; Vereshchagina, 2020). We differ from these papers by highlighting that, in addition to effects on aggregate productivity, endogenizing firm TFP allows us to better match the persistence in MRPK dispersion among firm cohorts and also to explain how large and productive firms may be constrained as well. We also explore micro data to restrict the parameters governing endogenous firm TFP through management practices. In this way, our paper is also related to the recent macroeconomic literature on the firm size distribution, firm management, and their relationship to economic development.[3] Additionally, our paper studies frictions in the Chinese context, and hence is also related to the literature on misallocation in China.[4]

2 Evidence on Endogenous Firm Productivity

We start by documenting that, in the Chinese context, firm TFP is indeed significantly correlated with management practices, measured at the number of hired managers, consistent

[2]See Restuccia and Rogerson (2008), Guner et al. (2008), Hsieh and Klenow (2009), Buera et al. (2011), Moll (2014), and Midrigan and Xu (2014), among others.

[3]See Bloom and Van Reenen (2010), Haltiwanger et al. (2013), Hsieh and Klenow (2014), Akcigit et al. (2019), and Grobovšek (2020), among others.

[4]See Brandt et al. (2013), Hsieh and Song (2015), Adamopoulos et al. (2017), and Bai et al. (2018), among others.

with the findings in the literature surveyed by Bloom and Van Reenen (2010). We then compare firms with high and low MRPK, and find that those with above industry average MRPK are less likely to hire outside managers or may hire fewer outside managers. Our empirical evidence suggests that the Chinese firms with tighter borrowing constraints invest less in management practices and have lower TFP.

We use Annual Surveys of Industrial Production from the National Bureau of Statistics of China, which have been widely used in existing literature (e.g. Hsieh and Klenow, 2009; David and Venkateswaran, 2019).[5] The data cover private manufacturing firms with sales above five million RMB (around eight hundred thousand USD) in the previous year and all state-owned enterprises regardless of sales. More than 1.6 million firm-year observations are recorded in our data, ranging from the year 1998 to 2007. The data include information on firms' capital, labor, intermediate input, and output. Additionally the 2004 sample also details information on worker composition, including information on hired managers.

We first use the full sample of the panel data to estimate firm-level TFP.[6] Consider a firm that produces its output (value added) by combining capital and labor:

$$y_{it} = \omega_{it} + b_k k_{it} + b_n n_{it} + \varepsilon_{it},$$

where y_{it}, k_{it}, l_{it}, and ω_{it} are (log) output, capital, labor, and TFP; b_k and b_l are the input elasticities of capital and labor, respectively. While y_{it}, k_{it}, and n_{it} are observed in the data, we need to estimate b_k and b_l in order to obtain a measure of the unobserved firm TFP, ω_{it}. We follow Levinsohn and Petrin (2003) and use expenditures on the intermediate input to control for unobserved firm TFP. We estimate b_k and b_n for each 2-digit industry code and then calculate firm TFP as the residual.

Given the estimated firm-level TFP, we then use the 2004 cross-section data to examine the relationship between TFP and management practices. A recent literature finds that firm management matters, and in particular, hiring outside managers helps improve firm productivity (Bloom and Van Reenen, 2007, 2010). We approximate management practices

[5]See Appendix A for a detailed description of data.

[6]We explicitly purge away differences in value added between state-owned and non-state-owned firms before estimating firm TFP.

Table 1: Firm TFP, Managers, and Financial Constraint

Dependent Variable	Log firm TFP		Employs managers	Share of managerial workers
	(1)	(2)	(3)	(4)
Employs managers	0.2914			
	(0.0039)			
Share of managerial workers		0.6812		
		(0.0235)		
Above-average MRPK (lagged)			−0.0509	−0.0015
			(0.0032)	(0.0005)
Industry-Prefecture FE	Yes	Yes	Yes	Yes
R^2	0.10	0.08	0.10	0.13
Obs.	245,999	245,999	82,199	82,199

Note: Columns (1) and (2) show the regression results with log firm TFP estimated following Levinsohn and Petrin (2003) as the dependent variable and an indicator for a firm employing managers (extensive margin) or a firm's share of managerial workers (intensive margin) as independent variables. Columns (3) and (4) show the regression results with management measures as dependent variables and a lagged indicator of financial constraint as an independent variable, proxied by firms with MRPK above the industry-prefecture average. Data are the Annual Surveys of Industrial Production from the National Bureau of Statistics of China.

by the fraction of firm employees that are managers, i.e., workers with senior titles who are not technicians. We examine both the extensive margin, whether a firm hires outside managers, and the intensive margin, the share of workers who are managers. We investigate how the estimated firm TFP in China is related to management practices by regressing firm TFP on these two measures of management, controlling for prefecture-industry fixed effects. The results are reported in columns (1) and (2) of Table 1. We find that firms with hired managers have on average 29.1 percent higher TFP than firms without hired managers, and that firms with a one percentage point greater manager share tend to have 0.7 percent higher firm TFP.[7]

We highlight that firm TFP is endogenous with respect to the collateral constraint, as firms with a binding collateral constraint tend to spend less on improving TFP. We compare management input in 2004 between firms with a binding collateral constraint in the previous (2003) period and other firms. We regress the variable of interest on a dummy variable indicating a binding collateral constraint, proxied by firm MRPK exceeding its 2-

[7]Note that we drop those firms with more than half of its workers classified as managers as firms are unlikely to hire so many managers in reality, so these observations are likely the result of measurement errors.

digit industry-prefecture average, controlling for prefecture-industry fixed effects. We find that firms with a lagged binding collateral constraint are 5.1 percent less likely to hire managers, and on average have a 0.1 percent lower share of managerial workers.[8]

Motivated by the evidence on the relationship between firm-level TFP, management practices, and collateral constraints, we next study a model of financial frictions with endogenous firm-level TFP.

3 Model

The economy consists of two types of infinitely-lived individuals: workers and entrepreneurs. There is a measure N_w of infinitely-lived workers. In each period, each worker has one unit of time that is supplied inelastically as labor and earns the wage income. These individuals live hand-to-mouth and do not save. In addition, there is a measure N_e of infinitely-lived entrepreneurs. Entrepreneurs differ in entrepreneurial ability z, which has a cumulative distribution $F_z : \mathbb{R}_+ \mapsto [0, 1]$ and is exogenous to the entrepreneur. Entrepreneurs can operate firms to produce the single output good, which can be used for consumption or capital formation. This output good is treated as the numeraire. Entrepreneurs choose to consume or save their firm profit. Note that we abstract from the occupational choice problem between entrepreneurs and workers to focus on the misallocation along the intensive margin rather than selection. Allowing for selection would further amplify the impact of financial frictions, as highlighted in Buera et al. (2011) and Midrigan and Xu (2014).

3.1 Basic Setup

Entrepreneurs' preferences are described by the following utility function:

$$U(\mathbf{c}) = \mathbb{E}_z\Big[\sum_{t=0}^{\infty} \beta^t u(c_t)\Big], \quad \text{where} \quad u(c_t) = \frac{c_t^{1-\sigma} - 1}{1 - \sigma}.$$

[8]In Appendix B, we also show that firm TFP is significantly correlated with R&D activities, and firms with a binding collateral constraint tend to spend less on R&D.

Here, β is the discount factor and σ is the coefficient of relative risk aversion. The expectation is taken over the realization of ability z, which varies over time according to a stochastic process known to entrepreneurs. Worker preferences are similar except that they are not subject to the uncertainty arising from entrepreneurial ability.

A representative financial intermediary owns capital and rents it to entrepreneurs at interest rate R. This financial intermediary finances its capital through issuing a one-period, risk-free bond, denoted as a, at interest rate r. This financial intermediary makes zero profit, and hence we have $R = r + \delta$ in equilibrium, where δ is the depreciation rate of capital.

An entrepreneur with ability z can operate a firm with endogenous productivity $A(z, m)$. Here, m is the input that helps improve firm TFP, such as management practices. We assume that $A(z, m)$ is increasing in entrepreneurial ability z and increasing and concave in productivity input m. The production function is

$$y = A(z, m)^{1-\gamma} \left(k^{\alpha} n^{1-\alpha}\right)^{\gamma},$$

where k and n are capital and labor input, respectively, and α and γ determine the factor shares and the span of control.

We follow Moll (2014) and assume that the collateral constraint takes the form of $k \leqslant \phi a$, where a is the entrepreneur's asset holdings used as collateral, and parameter ϕ hence governs the stringency of the collateral constraint, where a smaller ϕ indicates a tighter constraint. This parameter can be interpreted as the degree of contract enforcement in an economy, as in Buera et al. (2011) and Midrigan and Xu (2014).

The firm, operated by an entrepreneur with ability z and assets a, has the following profit maximization problem:

$$\pi(a, z) = \max_{m,k,n} \left\{ A(z, m)^{1-\gamma} \left(k^{\alpha} n^{1-\alpha}\right)^{\gamma} - Rk - wn - p_m m \right\}, \quad s.t. \quad k \leqslant \phi a, \qquad (1)$$

where R and w are the interest rate and wage rate, respectively, and p_m is the unit cost of productivity input m employed to improve productivity. We use the output good as the numeraire and hence its price is normalized to unity. Denote the demand for capital, labor, and the productivity input as $k^d(a, z)$, $n^d(a, z)$, and $m^d(a, z)$, respectively.

Additionally, the entrepreneur outsources the production of the productivity input m to a representative firm, which uses κ_y units of final output and κ_n units of labor to produce one unit of productivity input m. This representative firm makes zero profits, and hence the unit cost of m satisfies $p_m = \kappa_y + w\kappa_n$.

An entrepreneur begins a period with asset holdings a and ability z. Her consumption-savings problem can be written in recursive form:

$$\begin{aligned} V(a,z) = \max_{a' \geqslant 0} & \left\{ \frac{c^{1-\sigma}}{1-\sigma} + \beta \mathbb{E}_{z'}[V(a',z')|z] \right\}, \\ \text{s.t.} \quad & c + a' \leqslant (1+r)a + \pi(a,z), \end{aligned} \tag{2}$$

where we use x' to denote the value of x in the next period.

3.2 Aggregation and Equilibrium

Let $G(a,z)$ be the joint distribution of entrepreneurs over the asset holdings and ability. Aggregate demand of productivity input m is given by

$$M^d = N_e \int_{a,z} m^d(a,z) G(\mathrm{d}a, \mathrm{d}z),$$

where $m^d(a,z)$ represents the demand for the productivity input of a firm with asset holdings a and entrepreneurial productivity z. To produce M^d units of productivity input, $M^d\kappa_y$ units of output and $M^d\kappa_n$ units of labor are used. Aggregate capital, labor, and output demands are hence given by

$$K^d = N_e \int_{a,z} k^d(a,z) G(\mathrm{d}a, \mathrm{d}z), \tag{3}$$

$$N^d = N_e \int_{a,z} n^d(a,z) G(\mathrm{d}a, \mathrm{d}z) + M^d \kappa_n, \tag{4}$$

$$Y^d = N_e \int_{a,z} c(a,z) G(\mathrm{d}a, \mathrm{d}z) + N_w c_w + M^d \kappa_y, \tag{5}$$

where $k^d(a,z)$ and $n^d(a,z)$ represent firm demand for capital and labor, respectively; $c(a,z)$ is the entrepreneur's consumption function given states (a,z); and c_w is worker consumption.

Aggregate capital supply is

$$K^s = N_e \int_{a,z} aG(da, dz). \tag{6}$$

We now define the stationary equilibrium as follows:

Definition 1 (Competitive Equilibrium)**.** *A stationary competitive equilibrium for this economy consists of prices w and r; entrepreneur's optimal savings function $a'(a,z)$, optimal factor demands $k^d(a,z)$, $n^d(a,z)$, and $m^d(a,z)$; and a stationary distribution $G(a,z)$ over entrepreneur assets and ability that satisfies the following conditions:*

1. *Given prices and borrowing limits, $k^d(a,z)$, $n^d(a,z)$, and $m^d(a,z)$ solve the firm's problem.*
2. *Given prices, $a'(a,z)$ solves the entrepreneurs' consumption-savings problem.*
3. *Wage w clears the labor market: $N_w = N^d$.*
4. *Interest rate r clears the capital market: $K^s = K^d$.*
5. *The joint distribution of assets and productivity $G(a,z)$ is stationary.*

3.3 Characterization

We briefly describe how endogenous firm TFP interacts with the collateral constraint. Consider again the profit maximization problem of a firm operated by an entrepreneur with assets a and ability z:

$$\max_{m,k,n} \left\{ A(z,m)^{1-\gamma} \left(k^\alpha n^{1-\alpha}\right)^\gamma - Rk - wn - p_m m \right\}, \quad s.t. \quad k \leqslant \phi a.$$

If the credit constraint is non-binding the unconstrained or optimal capital demand can be written as an increasing function of the firm TFP, $A(z,m)$:

$$k^O(z,m) = A(z,m)\gamma^{\frac{1}{1-\gamma}} \left(\frac{\alpha}{R}\right)^{\frac{1-\gamma(1-\alpha)}{1-\gamma}} \left(\frac{1-\alpha}{w}\right)^{\frac{(1-\alpha)\gamma}{1-\gamma}}. \tag{7}$$

We now focus on the case where the collateral constraint is binding, and hence capital demand is constrained at $k^C = \phi a$. The marginal product of capital (MPK)[9] can then be written as a function of $A(z,m)$ and ϕa:

$$\log(\text{MPK}^C) = \zeta\Big(\log A(z,m) - \log(\phi a)\Big) + \Omega, \tag{8}$$

where $\zeta = \frac{1-\gamma}{1-(1-\alpha)\gamma} > 0$, and Ω is a collection of constants. Holding $A(z,m)$ constant, MPK^C decreases in a: As an entrepreneur accumulates asset holdings a, the collateral constraint loosens and hence firm MPK declines. This is the well-known self-financing channel highlighted in Moll (2014).

In our framework with endogenous firm TFP, we can show that $\log A(z,m)$ increases in a, which tends to increase MPK^C. To see this, note that the first-order condition with respect to m is

$$p_m = (1-\gamma)A(z,m)^{-\frac{\alpha\gamma}{1-(1-\alpha)\gamma}}(\phi a)^{\frac{\alpha\gamma}{1-(1-\alpha)\gamma}}\Big(\frac{(1-\alpha)\gamma}{w}\Big)^{\frac{(1-\alpha)\gamma}{1-(1-\alpha)\gamma}}\frac{\partial A(z,m)}{\partial m}. \tag{9}$$

Given our assumptions that $A(z,m)$ increases in m at a decreasing rate, the right-hand side of equation (9) is decreasing in m, and hence it implies a unique solution to m, denoted as m^*. Moreover, m^* is increasing in a: As the entrepreneur accumulates assets and the collateral constraint relaxes, the firm increases its demand in the productivity input, thereby raising $A(z,m^*)$.

Therefore, as the firm's asset holdings a increases, its collateral constraint relaxes, and it can therefore rent more capital. At the same time, the availability of more capital also motivates the firm to invest in the productivity input to boost its TFP which, in turn, raises its return to capital. As a result, the firm's demand for capital also increases, as can be seen from equation (7). The overall effect on firm MPK, from equation (8), depends on $\log A(z,m^*) - \log(\phi a)$ and is ambiguous. However, it is unambiguous that endogenous productivity mitigates the self-financing channel, allowing the collateral constraint to have a much more persistent effect on firms.

[9]Note that our models have perfectly competitive firms facing the same output price, which is normalized to unity. Therefore their marginal revenue product of capital (MRPK) is the same as the marginal product of capital (MPK).

4 Quantitative Results

We now quantify the role of the collateral constraint after calibrating our framework to Chinese data. In particular, we compare the predictions of our model to that of an otherwise identical model with exogenous firm TFP, which is similar to Buera et al. (2011) or Midrigan and Xu (2014) without the extensive margin.

4.1 Calibration

Given that our goal is to compare the quantitative predictions of two models—with endogenous or exogenous firm TFP—it is crucial that we calibrate them to match the same set of data moments. Equally important is that we target a set of moments that are typically chosen in the literature to help illustrate the comparison. As long as the two models are calibrated to the same set of moments, the exact value of the data moments is less important: We calculate the data moments using information from the Annual Surveys of Industrial Production and the 2005 Chinese Population Census, both of which are from the National Bureau of Statistics of China. Also note that matching the same set of moments does not imply the same parameter values between the two models: In fact, most parameters have different values. Intuitively, the value of a parameter is meaningful only within a specific model setup; when the model setup changes, the parameter values change, and it is improper to directly compare parameter values of different models.[10]

4.1.1 Parameterization

For our quantitative analysis, we interpret productivity input m as managerial practices, i.e., hiring outside managers helps improve firm TFP, as in Bloom and Van Reenen (2007) and Akcigit et al. (2019). In particular, we follow Akcigit et al. (2019) and assume the functional form of firm TFP to be $A(z, m) = e^z(T + \lambda m)^\theta$, where T is the entrepreneur's own time

[10]In Vereshchagina (2020), endogenous firm TFP matters only if it is dynamic, i.e., the productivity input has a persistent effect on productivity. This is specific to her calibration strategy of choosing to match the same distributional moments on profit and capital, while leaving the dispersion of firm TFP and output different. We instead choose to match the same output dispersion, commonly chosen in the literature, since it directly disciplines the equilibrium dispersion of firm TFP, which is crucial in calculating efficiency gain. In this setup, endogenous firm TFP matters even if it is static.

spent in management, which we normalize to unity; m is the measure of hired outside managers; $\lambda < 1$ governs the contribution of the outside managers to firm TFP. This λ can be interpreted as supervision efficiency, given that the entrepreneur needs to expend effort to supervise the outside managers, with a lower λ indicating a lower supervision efficiency (Akcigit et al., 2019). Finally, $\theta < 1$ determines the return to management, which guarantees $A(z, m)$ to be concave in m.

We follow Midrigan and Xu (2014) in assuming that entrepreneurial ability follows an AR(1) process with Gaussian disturbances:

$$z' = (1 - \rho)z + \varepsilon_z,$$

where ρ determines the autocorrelation of ability, and ε_z is the disturbance term with has a standard deviation of σ_ε.

4.1.2 Determining Parameter Values

Demographics and Preferences.—N_w and N_e govern the population share of workers and entrepreneurs. We normalize $N_e = 1$ and choose $N_w = 5.43$ such that 15.5 percent of individuals are entrepreneurs, as in the 2005 Chinese Population Census. We choose the coefficient of relative risk aversion σ to be 2. The discount factor β is chosen to match the overall capital-output ratio of 3 in both models.

Entrepreneurial Ability Distribution.—We follow Midrigan and Xu (2014) and choose autocorrelation parameter ρ and dispersion parameter σ_ε to jointly match two moments: the one-year autocorrelation of log output of 0.86 and the standard deviation of 1.22 in the data.

Technologies.—The span-of-control parameter γ is set to 0.7, a value commonly used in the literature. The elasticity of capital input α is chosen to match capital share of 0.33.[11] The rate of depreciation δ is set to 0.06.

Collateral Constraint.—We follow the common practice in the literature of choosing ϕ to

[11] Note that, with collateral constraints, a capital share of 0.33 does not necessarily imply $\alpha\gamma = 0.33$. This relationship holds only if MPK equals the interest rate for all firms, which is not the case with collateral constraints.

Table 2: Calibration—Parameters and Values

Parameters	Value		Data Moments
	Endo. TFP	Exog. TFP	
N_e: measure of entrepreneurs	1	1	Normalization
N_w: measure of workers	5.433	5.433	Entrepreneur share of 15.5%
σ: coefficient of relative risk aversion	2	2	Literature
β: discount factor	0.881	0.885	Capital-output ratio of 3
ρ: autocorrelation of ability	0.827	0.833	1-year autocorrelation of output of 0.86
σ_ε: s.d. of i.i.d. disturbance	0.760	0.741	S.d. of log output of 1.22
γ: span of control	0.7	0.7	Literature
α: elasticity of capital ($\alpha\gamma$)	0.603	0.568	Capital share of 0.33
δ: depreciation rate	0.06	0.06	Literature
ϕ: collateral constraint	2.024	2.154	Debt-to-output ratio of 1.06
κ_y: output used to produce management	0.392	–	Manager wage premium of 1.96
κ_n: labor used to produce management	1	–	Normalization
λ: efficiency of supervision	0.267	–	manager distribution among large firms
θ: return to management	0.416	–	4.1% of workers work as managers

Note: This table lists parameters and calibrated values in both models—endogenous firm TFP and exogenous firm TFP.

match the debt-to-output ratio in the Chinese data of 1.06.

Management.—The management parameters only apply to the model with endogenous firm TFP. Recall that one unit of the productivity input is produced with κ_y units of the final output good and κ_n units of labor. Since we interpret the productivity input as outside managers, we choose $\kappa_n = 1$, i.e., one worker can work as a manager. We choose κ_y such that the wage premium of managers relative to workers, calculated as $p_m/w = (\kappa_y + \kappa_n w)/w$, is 1.96, consistent with the data moment from the 2005 Chinese Population Census. The efficiency of supervision λ and the return to management θ are chosen to jointly match two moments: The top one percent largest firms employ 59.9 percent of the managers working at the top five percent largest firms; in aggregate, 4.1 percent of the worker population works as managers.

In summary, we have 14 parameters (10 if firm TFP is exogenous) in total, with N_e, N_w, σ, γ, δ, and κ_n being directly assigned values, and κ_y, β, ρ, σ_ε, α, ϕ, λ, and θ being jointly determined by comparing equilibrium model moments with those from the data. The value of these parameters are listed in Table 2.

4.2 Model Comparison

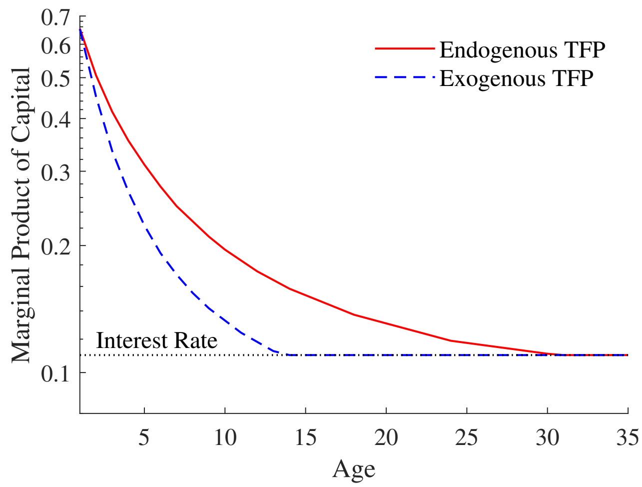
We now compare the quantitative predictions of our model with endogenous firm TFP to those of a model with exogenous firm TFP, both of which are calibrated to match the same sets of moments.

We begin by showing how endogenizing firm TFP quantitatively increases the persistence of collateral constraints. With exogenous firm TFP, the self-financing channel (as described in Section 3.3) means that the persistence of the collateral constraints are short-lived, as firms accumulate assets to expand their size until they can operate at their unconstrained scale. However, in the endogenous TFP setting, the self-financing mechanism is partly offset: As firms accumulate more assets and grow, they also make changes that raise their TFP, increasing their MPK. To illustrate how much persistence increases, Figure 1 traces out the MPK path of a highly productive but initially poor entrepreneur in each model. We consider a peak-ability entrepreneur (with ability z at the highest grid point) who has little collateral (with assets a at the 5th percentile), for whom the collateral constraint initially binds in both models. In the exogenous TFP model, this entrepreneur, following her optimal policy function, undoes the collateral constraint in about 13 periods (dashed blue line). In contrast, the same entrepreneur in the endogenous TFP economy takes more than twice as long (red line), illustrating a significant increase in persistence with endogenous firm TFP.

Our endogenous firm TFP model also increases the persistence of MPK dispersion for firm cohorts, improving the ability of models with collateral constraints to match this feature of the data—for instance, David and Venkateswaran (2019) document that MPK dispersion is very persistent.[12] Consider a firm cohort consisting of the peak-ability entrepreneurs (with z at the highest grid point), who have initial assets matching the equilibrium invariant conditional distribution for their type, $G(a, z|z = z^{max})$. The collateral constraint is initially binding for many of these firms. We use their policy functions to calculate the evolution of their assets and to trace out the dispersion of MPK within this cohort over time. The results are reported in the first four rows of Table 3. In the exogenous firm TFP model, the standard deviation of log MPK falls to only 11.8 percent of its initial level by the 10th period,

[12] Feng (2018) finds that, if we focus on the balanced panel (as we do here), then MPK dispersion declines by only around 10% during the first five periods.

Figure 1: Evolution of MPK over Time



Note: This figure illustrates the evolution of MPK for a firm operated by a peak-ability entrepreneur (with ability z at the highest grid point) who has little collateral (with assets a at the 5th percentile). For illustrative purposes, we assume here that this entrepreneur's ability z does not change over time, and we use this entrepreneur's policy functions and equilibrium prices to calculate the evolution of assets.

and it vanishes by the 14th period, implying a dispersion half-life around 4.6 periods.[13] In the endogenous firm TFP model, however, the standard deviation remains at 33.4 percent of its initial level by the 10th period and only falls to 14.0 percent by the 20th period. The half-life of the dispersion is around 6.2 periods, which is significantly higher than that of the exogenous TFP model.

Due to greater persistence in the collateral constraint, firms of all sizes are more likely to be financially constrained in the the model with endogenous TFP than in the model with exogenous TFP. Furthermore, the difference in the share of financially constrained firms increases with firm size, as shown in the middle four rows of Table 3, from 1.4 percentage points among the first quartile (the 25 percent smallest firms) to 10.2 percentage points among the fourth quartile (the 25 percent largest firms).

Consequently, endogenizing firm TFP nearly doubles the effect of a collateral constraint on aggregate TFP. Eliminating collateral constraints in the endogenous firm TFP model increases aggregate TFP by 19.9 percent, in contrast to only 10.1 percent in the exogenous TFP model. The reason is that, in the endogenous firm TFP model, we find a higher degree

[13]Time is discrete in our model, and hence this half-life is obtained through interpolation.

Table 3: Comparison between Two Setups

	Endogenous TFP	Exogenous TFP
Dispersion in MPK of a constructed cohort:		
Initial (normalized, %)	100	100
5th period (%)	57.4	46.6
10th period (%)	33.4	11.8
20th period (%)	14.0	0
% of firms with binding financial constraint, by firm size:		
Q1	18.1	16.7
Q2	38.2	33.8
Q3	49.2	42.7
Q4	67.7	57.5
Changes after eliminating financial constraint (%)		
Aggregate output	+19.9	+10.1
Firm capital usage, by TFP quartiles:		
Q1	−47.9	−33.0
Q2	−46.9	−30.2
Q3	−33.1	−16.9
Q4	+63.7	+37.2

Note: This table compares moments of interest computed at the stationary equilibrium for both endogenous and exogenous firm TFP models calibrated to match the same data moments. MPK dispersion is computed from a firm cohort consisting of entrepreneurs with ability z at the highest grid point and initial assets matching the equilibrium conditional distribution for their type, $G(a, z|z = z^{max})$.

of "rank reversal," i.e. increasing the incidences of less productive firms having more capital than more productive firms, reflected in a smaller-than-1 rank correlation between firm TFP and capital input (Hopenhayn, 2014). After eliminating the collateral constraint, the amount of capital used by the highest-TFP quartile firms increases by 63.7 percent in the endogenous firm TFP model in contrast to only 37.2 percent in the exogenous firm TFP model. See the last four rows of Table 3.

The larger aggregate TFP loss in our endogenous firm TFP model are not driven by the two channels identified as important in the literature: higher equilibrium firm TFP dispersion and lower firm TFP persistence. First, the standard deviation of firm TFP is very similar between the two models (0.413 in the endogenous firm TFP model and 0.404 in the exogenous firm TFP model), as we calibrate the ability distribution in both to match the same data moment, dispersion in firm output. We also assess the robustness by re-calibrating the exogenous firm TFP model to match the same equilibrium TFP dispersion of 0.413 rather than the output dispersion in our original calibration. All predictions are very similar to our baseline comparison: For instance, the dispersion half-life of MPK remains at 4.63 periods, and the efficiency gain of eliminating the collateral constraint changes from 10.1 percent to 10.9 percent. Second, while the literature shows that less persistent ability processes increase TFP losses (e.g. Moll, 2014), this is not the driving reason in our case, as the calibrated values of ρ are very similar between our models. A robustness exercise in Appendix C shows that imposing the same value of ρ does not change our results. More generally, Appendix C shows that our results hold even if we restrict all parameter values to be the same in both models (except for the managerial parameters which only exist in the endogenous firm TFP model).

5 Conclusion

The canonical model of collateral constraint typically predicts that they bind only for young firms and small firms, while older firms are unaffected due to their accumulated assets. This self-financing channel also leads these models to generate dispersion in MRPK that declines too rapidly within a firm cohort compared to the data. We argue that endogenizing firm

TFP moves the predictions of models with collateral constraints closer to the data, by partly offsetting the effects of the self-financing channel. In the quantitative analysis, we then take managerial practices as one interpretation for endogenous firm TFP and calibrate our model to Chinese data. By comparing our model to a similarly calibrated exogenous firm TFP model, we find that, in the endogenous TFP model, it takes more than twice as long for an entrepreneur with high productivity but low net worth to accumulate enough assets to become unconstrained, and the dispersion of MRPK within a firm cohort is also substantially more persistent. These properties imply that, with endogenous firm TFP, high-productivity firms are more likely to be constrained; there is substantially more "rank reversal" in capital allocation where less productive firms may end up with more capital than productive firms; and, as a result, the impact of a collateral constraint on aggregate output is twice as large.

Although our quantitative exercise models endogenous firm TFP as management practices, our findings are more general and other sources of endogenous firm TFP, such as R&D investment or human capital accumulation of entrepreneurs, share the same qualitative properties. In particular, compared to an exogenous firm TFP model, all these versions of endogenous firm TFP should predict greater persistence in the dispersion of MPK among a firm cohort, leading to larger efficiency gains from eliminating collateral constraints.[14]

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[14] For instance, Lopez-Martin (2016) finds that the collateral constraint has a larger impact on productivity if we allow for R&D. The reason should be exactly as we discussed above.

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Finance, Endogenous TFP, and Misallocation
Online Appendix

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A Data

We use the NBS China's Annual Surveys of Industrial Production to estimate firm TFP and document its correlation with firm financial constraints and management practices. This data set is widely used in the literature (e.g. Hsieh and Klenow, 2009). Our sample covers private manufacturing firms with sales above five million RMB (around eight hundred thousand USD) in the previous year and all state-owned enterprises regardless of sales. More than 1.6 million firm-year observations are recorded in our data, ranging from the year 1998 to 2007. We have information on firms' capital, labor, intermediate input, and output. Additionally, the 2004 wave also details information on worker composition, including information on hired managers. In the 2001 and 2005–2007 waves, we also observe firm R&D expenditures.

We restrict our sample to manufacturing firms only, which is the common practice in the literature (Hsieh and Klenow, 2009). We follow Brandt and Zhu (2010) and calculate firm value added as the sum of labor cost (wage and welfare expenditures), value-added tax, depreciation, and profit. We measure labor and capital input as the head count of employees and the value of net fixed asset, respectively. Given the 2004 wave's detailed employee composition, we count managers as employees with senior titles who are not technicians. We construct MRPK as the average product of capital net of industry-prefecture and year fixed effects.

To control for the differences between state-owned firms and private firms, we explicitly regress firm value added on ownership, industry-prefecture, and year fixed effects to obtain the residual that is in turn used in calculating the dispersion and autocorrelation of output and estimating the firm production function. We further trim each wave of our sample by one percent on each tail for for value added, capital, labor, and intermediate input separately. Then, we estimate the input elasticities for each 2-digit industry code following Levinsohn and Petrin (2003), using the expenditures on intermediate input to control for the unobserved firm TFP. Firm-level TFP is then obtained as the residual.

We use information on employee composition from 2004 wave to calculate other moments used in calibration, such as the share of managers among all employees and debt-to-output ratio. The debt-to-output ratio is constructed as the ratio of interest expenditure and value added, both of which are observed in the data, divided by an interest rate of 5 percent per year which is the equilibrium interest rate in our baseline calibration.

We also use 2005 Chinese Population Census to calculate the share of entrepreneurs in the labor force and the wage premium of managers. In particular, we classify an individual as an entrepreneur if her reported status is either employer or self-employed and then calculate the share of entrepreneurs accordingly. We classify an individual as a manager if this person is considered a decision maker of an enterprise but serves as an employee rather than an employer.[1] We then calculate the geometric average of income among managers and among non-managers separately, the difference of which is our measure of the manager wage premium.

B Additional Empirical Evidence

In Section 2, we show that firm TFP is endogenous to the financial constraint, as management input increases firm TFP, and firms with a binding collateral constraint have lower management input. In our data, we also have information on R&D expenditure for the years 2001 and 2005–2007. We now consider the effects of R&D expenditures on firm TFP,

[1]We keep individuals who work in non-agriculture only. Within non-agriculture, the data do not clearly distinguish between manufacturing and service workers.

Table 1: Firm TFP, R&D, and Financial Constraint

Dependent Variable	Log firm TFP		Positive positive R&D	Log R&D expenditures
	(1)	(2)	(3)	(4)
Positive R&D	0.6387			
	(0.0031)			
Log R&D expenditures		0.2210		
		(0.0013)		
Above-average MRPK (lagged)			−0.0092	−0.0779
			(0.0007)	(0.0151)
Industry-Prefecture FE	Yes	Yes	Yes	Yes
R^2	0.10	0.34	0.07	0.11
Obs.	963,706	102,776	707,994	82,042

Note: Columns (1) and (2) show the regression results with log firm TFP estimated following Levinsohn and Petrin (2003) as the dependent variable and a (lagged) indicator of a firm incurring R&D expenditures (extensive margin) or log R&D expenditure (intensive margin) as independent variables. Columns (3) and (4) show the regression results with R&D measures as dependent variables and a (lagged) indicator of the financial constraint as an independent variable, proxied by firms with MRPK above the industry-prefecture average. Data are the Annual Surveys of Industrial Production from the National Bureau of Statistics of China.

again focusing on two measures: the extensive margin—whether a firm invest in R&D; and the intensive margin—the amount of R&D expenditure. We find that, after controlling for prefecture-industry and year fixed effects, firms that invest in R&D expenditures have on average 64 percent higher TFP compared to firms that do not invest in R&D, and that one more percent of R&D expenditure is also associated with 0.22 percent higher firm TFP, both of which are significant at the one percent level. Additionally, we find that the collateral constraint interacts with R&D expenditures. Particularly, firms with a binding collateral constraint in the previous period are 1.0 percent less likely to invest in R&D, and their R&D expenditures, if any, are on average 7.8 percent lower, compared to firms that do not face a binding collateral constraint. We report detailed results in Table 1.

C Robustness on Parameter Values

As discussed in Section 4, we compare the quantitative predictions of two models after calibrating them to match the same set of moments. This strategy leads to different parameter values between models. We note that it is not appropriate to force the two models to have the same parameter values, as parameter values are only meaningful within a specific model setup. Nevertheless, in this section, we explore what happens if we restrict some parameters to be the same between two models, and highlight that our results are not driven by different parameter values between models.

To start with, in our baseline calibration, ϕ—the parameter governing the collateral constraint—turns out to be slightly lower in the endogenous firm TFP model (2.024) than in the exogenous firm TFP model (2.154), in order to match the same debt-to-output ratio. Here, we explore the case where we restrict ϕ to be 2.024 in the exogenous firm TFP model as well, and re-calibrate all other parameters to match the same set of moments, except for the debt-to-output ratio, which was used to pin down ϕ. The re-calibrated parameter values are in Table 2. Note that the exogenous TFP model now implies a debt-to-output ratio of 1.02, which is lower than the data moment (1.06), and hence the collateral constraint is tighter. Even with this tighter collateral constraint, the exogenous TFP model implies that an entrepreneur with ability z at the highest grid point but 5th percentile asset holdings only needs 14 periods of self-financing to attain the unconstrained level. This is not too different from the 13 periods required under the same model in the baseline calibration, and is substantially shorter than the 30 periods needed under the endogenous TFP model. Examining a firm cohort of entrepreneurs with highest grid point ability z and the equilibrium distribution of assets a, the dispersion of MPK has a half-life of 4.80 periods, which is again not too different from the 4.63 periods in the baseline calibration and is substantially shorter than the 6.19 periods of the endogenous firm TFP model. In addition, eliminating the collateral constraint increases aggregate output by 11.9 percent, which is still substantially smaller than the 19.9 percent of the exogenous firm TFP model. We summarize this comparison in Table 3.

We also assess the role of other parameters. For instance, as Moll (2014) argues, the persistence parameter for ability, ρ, is crucial in determining the extent of misallocation. We first note that the calibrated value of ρ is very similar between the endogenous and exogenous firm TFP models, and hence the results are unlikely driven by the difference in ρ between models. Nevertheless, we experiment by restricting the ρ in both models to be 0.827, consistent with that of the endogenous firm TFP model. We then re-calibrate all

Table 2: Calibration—Robustness

Parameters	Value				
	Endo. TFP	Exog. TFP			
	Baseline	Baseline	Same ϕ	Same ρ	Same α
N_e: measure of entrepreneurs	1	1	1	1	1
N_w: measure of workers	5.433	5.433	5.433	5.433	5.433
σ: coefficient of relative risk aversion	2	2	2	2	2
β: discount factor	0.881	0.885	0.882	0.885	0.884
ρ: autocorrelation of ability	0.827	0.833	0.831	0.827	0.831
σ_ε: s.d. of i.i.d. disturbance	0.760	0.741	0.755	0.756	0.758
α: capital share	0.603	0.568	0.579	0.570	0.603
γ: span-of-control	0.7	0.7	0.7	0.7	0.7
δ: depreciation rate	0.06	0.06	0.06	0.06	0.06
ϕ: collateral constraint	2.024	2.154	2.024	2.151	2.013
κ_k: output used to produce management	0.392	–	–	–	–
κ_n: labor used to produce management	1	–	–	–	–
λ: efficiency of supervision	0.267	–	–	–	–
θ: return to management	0.416	–	–	–	–

Note: This table lists the parameters and calibrated values associated with the alternative calibration exercises.

other parameters matching the same set of moments, without targeting the autocorrelation of firm output, which was used to calibrate ρ. The quantitative predictions associated with this alternative calibration are almost identical to that of the baseline calibration (see Table 3), with an even shorter dispersion half-life of MPK.

In the baseline calibration, matching the same capital share of 0.33 implies a smaller α for the exogenous firm TFP model. We hence also experiment with restricting α to be the same here. Again, we re-calibrate the exogenous firm TFP model, restricting the value of α to be the same as that of the endogenous firm TFP model, without targeting the capital income share. In this case, the capital share in the exogenous TFP model is 0.343, which is higher than 0.33. While a larger capital share amplifies the role of the collateral constraint slightly, it is still considerably different from that of the endogenous firm TFP model (see Table 3).

Lastly, we explore the case where we restrict all corresponding parameter values between the two models to be the same; i.e., for the exogenous firm TFP model, we directly use the parameter values from the endogenous firm TFP model, except for setting λ and θ to zero. In this case we cannot match any calibration moments for the exogenous firm TFP

Table 3: Quantitative Predictions with Different Parameter Values

Model Outcomes	Value					
	Endo. TFP	Exog. TFP				
	Baseline	Baseline	Same ϕ	Same ρ	Same α	Same all
Periods requiring self-financing	30	13	14	13	15	14
Dispersion half-life of MPK	6.19	4.63	4.80	4.60	4.95	4.88
Efficiency gain (%)	19.9	10.1	11.9	10.5	12.8	12.5

Note: This table lists the quantitative predictions associated with different parameter values. The first row reports the number of periods needed for an entrepreneur with highest grid point ability z and 5th percentile asset a to self-finance her way out of her collateral constraint. The second row reports the dispersion half-life of firm MPK within a cohort of entrepreneurs with the highest grid point ability z and the equilibrium distribution of assets a. The last row reports the efficiency gain of eliminating the collateral constraint.

model. Even in this extreme scenario the predicted role of the collateral constraint is still substantially smaller than that of the endogenous firm TFP model (see Table 3).

We hence conclude that the different quantitative effects of the collateral constraint between the two models are not driven by differences in parameter values between models. More importantly, we argue again that the parameter values are only meaningful within a specific model setup, and hence a fair comparison between models should be in the baseline calibration, where we calibrate the two models to match the same set of moments, rather than to restrict them to take on the same parameter values.

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