Leverage and Productivity

Huiyu Li [*]

Federal Reserve Bank of San Francisco

September 15, 2021

Abstract

This paper argues that earning-based borrowing is important for understanding the extent to which financial frictions lower aggregate productivity (TFP) across countries. It builds a general equilibrium model of misallocation due to financial frictions wherein firms borrow by pledging assets and earnings. The model is disciplined to match evidence on aggregate leverage and on the firm-level relationship between leverage and the output-to-capital ratio. Conditional on aggregate leverage, the TFP loss from financial frictions shrinks with the pledgeability of earnings. Similarly, for a given difference in aggregate leverage between two countries, financial frictions may contribute significantly more to TFP differences when the poorer country has lower pledgeability of earnings.

Keywords: aggregate productivity, misallocation, financial frictions, earning-based borrowing

JEL code: D24, E23, O16, O47

[*]Email: tohuiyu@gmail.com. Economic Research, Federal Reserve Bank of San Francisco, 101 Market St. San Francisco, CA, 94105, U.S.A. This paper was a chapter in my doctoral dissertation at Stanford University. I thank my advisors Pete Klenow, Martin Schneider, Takeo Hoshi and Nicolas Bloom for their guidance as well as Timo Boppart, Toni Braun, Andrea Eisfeldt, Bob Hall, David Lagakos, Hanbaek Lee and Monika Piazzesi for their advice and encouragement. I am grateful for the support of the Leonard W. Ely and Shirley R. Ely Graduate Student Fund Fellowship from the Stanford Institute for Economic Policy Research, the Stanford IRiSS Dissertation Fellowship, the Stanford FSI Japan Fund Dissertation Fellowship and the Shorenstein Predoctoral Fellowship in Contemporary Asia. Remy Beauregard and Mary Yilma provided excellent research assistance. The views in this paper are solely the responsibility of the author and should not be interpreted as reflecting the views of the Federal Reserve Bank of San Francisco or the Board of Governors of the Federal Reserve System.

Introduction

To what extent do financial frictions lower aggregate productivity (TFP) across countries? In theory, financial frictions arise when firms cannot credibly commit to repay loans out of their future earnings or assets. As a result, the borrowing capacity of a firm may be smaller than the financing needed for the firm to produce at its optimal scale. This can happen for a firm with low internal funds relative to its productivity. When many firms are borrowing constrained in this way, aggregate productivity can be significantly smaller than in an economy where firms can commit to repay. This paper investigates the extent of this form of friction for a large panel of firms from Japan. In particular, I study whether the borrowing constraint is due to low plegeability of earnings or low plegeability of assets. This distinction matters because for the same observed aggregate leverage ratio, a common proxy of financial development across countries, aggregate productivity loss from financial frictions shrinks with the pledgeability of earnings.

More specifically, I extend a standard general equilibrium model of aggregate productivity loss due to financial frictions so that the extent of the frictions depends on the share of assets and one-period-ahead earnings that a lender can recover when its client-firm defaults. I depart from standard inference approaches by allowing the share pledgeable to differ for assets and earnings. When earnings are not pledgeable, the borrowing capacity of a firm is proportional to its asset and does not vary with the firm's productivity. On the other hand, when earnings are pledgeable, more productive firms have higher earnings and hence can borrow more than less productive firms even if they all have the same asset[1].

I estimate the shares of earnings and assets that are pledgeable using two pieces of evidence. First is the aggregate external-financing-to-GDP ratio, a

[1]Rising borrowing capacity with firm productivity is also a feature of microfoundations where more productive firms lose more when they default. See, for example, Cooley and Quadrini (2001), Albuquerque and Hopenhayn (2004), Buera and Shin (2013) and Arellano et al. (2012).

measure of aggregate leverage that is commonly used to discipline the plegeability of asset in models where earnings are assumed to be not plegeable or have the same plegeability as assets. As in the literature, this moment is informative of the share of assets that is pledgeable in my model. The second piece of evidence is the elasticity of firm-level leverage with respect to firm-level output-to-capital ratio for firms with above median output-to-capital ratio. In my model, constrained firms have higher output-to-capital ratio because they are not able to expand production even though their marginal product of capital exceeds the rental rate. The output-to-capital ratio of constrained firms increases with firm productivity. When earnings are not pledgeable at all, the leverage of constrained firms is constant and does not correlate with firm productivity or firm's output-to-capital ratio. However, when earnings are pledgeable, leverage and output-to-capital ratio of constrained firms are positively correlated because both increase with firm productivity. Hence I choose the pledgeability of earnings such that the elasticity in my model matches that the empirical elasticity.

In the data, I find that the elasticity of firm leverage with respect to firm output-to-capital ratio is about 2.3 to 3.2, after controlling for year and firm fixed effects. That is, leverage increases by 2 to 3%, on average, for every 1% increase in firm output-to-capital ratio. The model matches this empirical elasticity, the aggregate leverage, and other data moments the best when firms in my model can pledge one-fifth their one-year-ahead revenue and all of their assets. At these parameter values the aggregate productivity loss due to financial frictions in Japan is just under 1%[2].

I explore the aggregate implications of my findings by comparing the aggregate productivity loss due to financial frictions under my benchmark estimation that matches the empirical elasticity with the loss when I estimate the model under the restriction that earnings are not pledgeable or has same

[2]Aggregate productivity loss is defined as the difference between the first-best productivity and the model productivity as a percentage of the first-best productivity. The first best is achieved when all firms are unconstrained.

plegeability as asset. These restrictions appear in many papers quantifying aggregate productivity loss due to financial frictions. As in the literature, I use aggregate external-financing-to-GDP ratio to discipline the plegeability of assets in the restricted calibration. These restricted calibrations produce counterfactual relationship between firm leverage and firm output-to-capital ratio. I find aggregate productivity loss is about 2% in the restricted estimation that assumes no earnings-based borrowing and 0% in the restricted estimation that assumes earnings have the same plegeability as assets. That is, assuming firms cannot borrow against earnings overstates TFP loss by two-folds relative to the loss that is consistent with my empirical findings, while an approach that ties the plegeability of revenue to that of assets understates the TFP loss.

I also explore the implications of my findings for the contribution of financial frictions to TFP differences across countries. I calculate the contribution of financial frictions to the TFP gap between China and Japan by reducing the plegeability of assets and/or revenue in the model calibrated to Japanese data to match the aggregate external-financing-to-GDP ratio in China. I compare the resulting decline in TFP in the model to the empirical gap in TFP between China and Japan. I find that when China's lower aggregate leverage is due to lower asset pledgeability and zero revenue pledgeability, the model generates 13 to 25% of the TFP gap. In contrast, when China's lower aggregate leverage is only coming from lower asset pledgeability and China has the same revenue pledgeability as Japan, financial frictions generate only 1.5 to 6% of the TFP gap. These numbers are very different from each other and also different from inferences that restrict the pledgeability of revenue. Hence, my findings suggest that understanding the availability of earning-based financing in poorer countries may be important for quantifying the contribution of financial frictions to TFP gap between countries.

There is an extensive literature on the impact of financial frictions on aggregate output and productivity. However, there does not appear to be a consensus on the relationship between productivity and borrowing capacity. For example, recent articles such as Khan and Thomas (2013), Gopinath, Kalemli-zcan, Karabarbounis and Villegas-Sanchez (2017), Buera and Shin (2013) and Midrigan and Xu (2014) assume a firm's borrowing capacity is constant with respect to its productivity while other articles such as Cooley and Quadrini (2001), Arellano, Bai and Zhang (2012), Buera, Kaboski and Shin (2011) and Buera, Kaboski and Shin (2021) allow borrowing capacity to rise with firm productivity. Well-known theoretical papers (e.g. Kehoe and Levine (1993) and Albuquerque and Hopenhayn (2004)) that give micro-foundations to borrowing capacity are agnostic about whether borrowing capacity should rise with firm productivity. This paper contributes to the literature by providing empirical evidence consistent with borrowing capacity rising with productivity through earning-based borrowing and showing the quantitative importance of this empirical pattern.

Outside of the context of aggregate productivity, several recent papers have also emphasized earning-based borrowing. In trade, Brooks and Dovis (2019) argues that borrowing limits are forward looking for Colombia and, as a result, aggregate gains from trade liberalization is similar to a perfect credit market economy. In corporate finance, Lian and Ma (2021) shows that 80% of U.S. non-financial firms' debt is collateralized by cash flows from firms operations. The survey article of Eisfeldt and Shi (2018) conjectures that output based borrowing could be important for capital misallocation. In business cycle studies, Greenwald (2018) emphasizes the role of debt-to-income ratio in the mortgage lending and the transmission of monetary policy while Drechsel (2019) provides empirical support for earnings-based borrowing for U.S. firms and shows that aggregate output responds to fiscal and monetary policy shocks differently than when borrowing is based on assets alone. I complement these papers by showing the implication of earning-based borrowing for capital misallocation and aggregate productivity.

In the following, Section 1 presents a general equilibrium model of aggregate TFP loss due to financial frictions where borrowing constraints depend on the plegeability of assets and earnings. Section 2 calibrates this model using, among others, evidence on aggregate leverage and the relationship between firm leverage and output-to-capital ratio. Section 3 compares the impact of financial frictions on TFP in the benchmark calibration to those in calibrations with parameter restrictions on the plegeability of earnings. Section 4 concludes.

1 Theory

This section lays out a model of TFP loss due to financial frictions where borrowing capacities can depend on firm productivity through earning-based borrowing. It is an extension of Moll (2014) and nests the original specification of asset-based borrowing. I use the model to derive moments that inform the extent of earning-based borrowing and show that controlling for aggregate leverage, TFP losses are smaller when borrowing capacity increases with firm productivity. Furthermore, I show that for two countries with the same aggregate leverage, their TFP can differ one country's borrowing capacity increases less with firm productivity than the other.

1.1 Model

Consider an economy populated with a continuum of infinitely lived entrepreneurs born with wealth a_0 and productivity z_0 drawn from a distribution $G(a, z)$. Each entrepreneur's productivity post birth is governed by an AR(1) process with persistence parameter ρ and iid normal innovation shock with mean μ_e and standard deviation σ_e. Using x' to denote the next period value of variable x, the relationship between productivity z in the current period and productivity z' in the next period is given by

$$\ln z' = \rho \ln z + \epsilon, \quad \epsilon \overset{iid}{\sim} N(\mu_e, \sigma_e^2). \tag{1}$$

Under this law of motion, the marginal distribution of productivity z in the equilibrium is log normal $\Gamma(z) \equiv LN\left(\frac{\mu_e}{1-\rho}, \frac{\sigma_e^2}{1-\rho^2}\right)$. The economy also has L

measure of hand-to-mouth workers each supplying one unit of labor.

The entrepreneurs can save with financial intermediaries for a net rate of return r. The financial intermediaries in turn lend capital to entrepreneurs. I assume the financial intermediaries are perfectly competitive and that there are no aggregate risks. Under these assumptions, if there are no defaults, the equilibrium lending rate is equal to the return to savings plus depreciation, $r + \delta$. For illustration, I will first discuss an analytical example with an exogenous borrowing limit and assume no default. In the quantitative exercise, I will model the borrowing limit using limited enforcement of contracts as in Buera, Kaboski and Shin (2011). In this case, the equilibrium endogenously has no default.

An entrepreneur with productivity z, capital input k and labor input l can produce output

$$y = f(z, k, l) = z(k^\alpha l^{1-\alpha})^\eta \tag{2}$$

where α controls the capital intensity and $\eta \in (0, 1]$ controls the returns-to-scale.[3] When $\eta = 1$, production is constant-returns-to-scale.

In each period, the entrepreneur maximizes profit by choosing capital and labor inputs after observing current period productivity z. Namely, the entrepreneur solves the following problem

$$\pi(a, z) := \max_{k,l} \{f(z, k, l) - (r + \delta)k - wl, \quad \text{s.t.} \quad k \le \bar{k}(a, z)\} \tag{3}$$

where $\bar{k}(a, z)$ denotes the borrowing capacity or the maximum amount of capital the entrepreneur can raise. This capacity depends on the entrepreneurs asset collateral a and current period productivity z. The dependence of the borrowing capacity on a captures "asset-based-lending" and z captures "cash-flow-based-lending" in loan contracts documented by Lian and Ma (2021). A common assumption in the literature is that $\partial\bar{k}(a, z)/\partial z = 0$. That is, firms with the same collateral a have the same borrowing capacity regardless of their

[3] When $\eta < 1$, the solution to the firm's problem is the same as a model where firms have constant-returns-to-scale production technology but face CES demand with elasticity of substitution $\frac{1}{1-\eta}$.

productivity. In contrast, $\partial\bar{k}(a,z)/\partial z > 0$ holds under cash-based borrowing or earning-based borrowing, because more productive firms have higher output.

Let $\underline{z}$ denote the productivity level of the least productive firm among the active firms. When $\eta < 1$, $\underline{z}$ is the lower support of the productivity distribution because all firms are active. When $\eta = 1$, some entrepreneurs are inactive and $\underline{z}$ is the productivity level when profit equals zero. $\pi(a,z) = 0$ for inactive entrepreneurs.

The entrepreneur's dynamic problem can be written recursively as

$$V(a,z) = \max_{a',c}\; u(c) + \beta\,\mathbb{E}\left[V(a',z')|z\right]$$

subject to

$$c + a' \leq a(1+r) + \pi(a,z).$$

There are two markets that need to clear. First, capital market clearing requires aggregate capital demand to equate total wealth

$$K := \int_{a,z\geq\underline{z}} k(a,z)\;\; dG(a,z) = \int_{a,z} a\;\; dG(a,z) =: A \tag{4}$$

Second, the labor market clearing condition requires labor supply to equate labor demand

$$L = \int_{a,z\geq\underline{z}} l(a,z)\;\; dG(a,z). \tag{5}$$

Furthermore, at the equilibrium, the evolution of wealth and productivity distribution must be consistent with the law of motion of the entrepreneurs' productivity and savings policy functions, denoted by $S(a,z)$. That is,

$$dG(a',z') = \int_{a,z} Prob(z'|z)\,\mathbf{1}\{a' = S(a,z)\}\,dG(a,z) \tag{6}$$

where $Prob(z'|z)$ denotes the probability that next period productivity is z' when the current period productivity is z and $\mathbf{1}\{\}$ is an indicator function that equals one when the condition in the braces is true.

Having laid out the ingredients of the model, I next define the equilibrium.

Steady state equilibrium definition: A stationary competitive equilibrium consists of labor demand $l(a,z)$, capital demand $k(a,z)$, productivity cutoff level $\underline{z}$, savings policy $S(a,z)$, interest rate r, wage w, asset and productivity distribution $G(a,z)$ such that

1. given prices, $l(a,z)$, $k(a,z)$, $\underline{z}$ and $S(a,z)$ solve the entrepreneur's problem
2. $\underline{z}$, $l(a,z)$, $k(a,z)$, $G(a,z)$ satisfy (4) and (5) to clear the markets
3. $G(a,z)$ and $S(a,z)$ satisfy the law of motion in (6)

I also need to define TFP loss due to financial frictions to prepare for analysis. Since firms produce the same product, aggregate output equals the sum of output across firms

$$Y = \int_{a,z} f(z, k(a,z), l(a,z))\, dG(a,z),$$

and aggregate productivity (TFP) is defined as

$$Z := \frac{Y}{(K^\alpha L^{1-\alpha})^\eta}. \tag{7}$$

Efficient aggregate productivity, Z^{fb}, is given by equation (7) when $\bar{k}(a,z)$ exceeds the optimal capital demand for all (a,z). This is the no financial frictions scenario. Without financial friction and when $\eta = 1$, only the most productive firm produces and Z^{fb} is just the upper bound of the exogenous productivity distribution $\Gamma(z)$. When $\eta < 1$, as shown in Midrigan and Xu (2014),

$$Z^{fb} := \left[\, \mathbb{E}_\Gamma\, z^{\frac{1}{1-\eta}} \right]^{1-\eta}$$

where the expectation is taken with respect to $\Gamma(z)$. Regardless of η, the first best TFP does not depend on the distribution of a.

TFP loss due to financial frictions is the gap between the first best TFP and

TFP in the market equilibrium expressed as a percent of the first best

$$\text{TFP loss relative to the first best} := \frac{Z^{fb} - Z}{Z^{fb}} \times 100,$$

or relative to the equilibrium TFP

$$\text{TFP loss relative to the equilibrium} := \frac{Z^{fb} - Z}{Z} \times 100.$$

My analysis below does not depend on which definition I use. Going forward, TFP loss refers to loss as a percent of the first best.

The next sections examine how this loss changes with the shape of the borrowing capacity $\bar{k}(a, z)$. I first assume production technology is constant-returns-to-scale in order to provide intuitions with analytical solutions. In section 2, I conduct quantitative analysis by numerically solving and calibrating the model allowing for decreasing-returns-to-scale.

1.2 An analytical example

Here, I analyze the model when the production function is constant- returns-to-scale ($\eta = 1$) as this version of the model can be solved analytically. I will also assume that the borrowing capacity $\bar{k}(a, z)$ can be written as $\lambda(z)a$, the entrepreneurs have log utility and z is iid ($\rho = 0$). These assumptions ensure relatively simple analytical solutions which allows me to illustrate why borrowing capacity rising with firm productivity, or $\partial\bar{k}(a, z)/\partial z \geq 0$, may be important for quantifying aggregate productivity losses from financial frictions. I will relax the assumptions on $\bar{k}(a, z)$, η and ρ and model $\lambda(z)$ through earning-based borrowing when I take the model to the data.

When the production technology is constant-returns-to-scale, all active entrepreneur borrow to the limit or $k(a, z) = \bar{k}(a, z)$ because the marginal increase in profit from scaling up production is constant. Hence, the entrepreneur's profit function (3) becomes

$$\pi(a,z) := \bar{k}(a,z)\max\{\bar{\pi}z^{\frac{1}{\alpha}} - r - \delta,\, 0\} \tag{8}$$

where $\bar{\pi} = \left(\frac{1-\alpha}{w}\right)^{\frac{1-\alpha}{\alpha}}$ and the productivity cutoff is given by $\bar{\pi}z^{\frac{1}{\alpha}} - r - \delta = 0$ or

$$\underline{z} \equiv \left(\frac{r+\delta}{\bar{\pi}}\right)^{\frac{1}{\alpha}}. \tag{9}$$

The cutoff increases with input costs $r+\delta$ and w. Entrepreneurs with current period productivity below $\underline{z}$ do not operate.

Let $A(z) \equiv 1 + r + \lambda(z)\max\{\bar{\pi}z^{\frac{1}{\alpha}} - r - \delta,\, 0\}$ summarize the return to wealth a. The entrepreneur's savings problem can be written as

$$V(a,z) = \max_{a'} \log(A(z)a - a') + \beta\, \mathbb{E}_{\Gamma}\, V(a', z')$$

where $A(z)a - a'$ equals the consumption of the entrepreneur. Note that the distribution of next period's productivity is $\Gamma(z')$ because productivity is iid. Then following the proof in Moll (2014), it can be shown that the optimal savings policy is linear in current period cash-on-hand

$$a' = S(a,z) = \beta A(z)a. \tag{10}$$

Substituting this and $Prob(z'|z) = \Gamma(z')$ into the law of motion for $G(a,z)$ in (6) implies that the wealth and productivity joint distribution $G(a,z)$ is separable in a and z

$$dG(a',z') = \Gamma(z')\int_{a,z} \mathbf{1}\left\{a = \frac{a'}{\beta A(z)}\right\} dG(a,z) \equiv \Gamma(z')W(a'). \tag{11}$$

where $W(a')$ denotes the marginal distribution of a.

The separability in (11) implies that the wealth share of entrepreneurs with productivity z is just $\Gamma(z)$ and the wealth share of active entrepreneurs is $E = 1-$

$\Gamma(\underline{z})$. Since total wealth equals K due to the capital market clearing condition, the aggregate leverage is the inverse of the wealth share of active entrepreneurs

$$\frac{K}{E} = \frac{1}{1-\Gamma(\underline{z})}. \tag{12}$$

Furthermore, since K/E is also the wealth weighted average of active entrepreneur's leverage $\lambda(z)$, aggregate leverage is also equal to the average $\lambda(z)$ of active entrepreneurs

$$\frac{K}{E} = \mathbb{E}_\Gamma\left[\lambda(z) | z \geq \underline{z}\right]. \tag{13}$$

With $\eta = 1$, aggregate TFP in (7) can be decomposed into the aggregate output-to-capital and capital-to-labor ratios

$$TFP = \frac{Y}{K^\alpha L^{1-\alpha}} = \frac{Y}{K}\left(\frac{K}{L}\right)^{1-\alpha}. \tag{14}$$

Since an entrepreneur's output is $\bar{\pi} z^{\frac{1}{\alpha}} \lambda(z) a$ and $K = \int_a aW(a)da$, the aggregate output-to-capital ratio is equal to

$$\frac{Y}{K} = \bar{\pi}\, \mathbb{E}_\Gamma\left[\lambda(z) z^{\frac{1}{\alpha}} | z \geq \underline{z}\right][1-\Gamma(\underline{z})] \tag{15}$$

Also, since $l(a,z) = \bar{\pi}^{\frac{1}{1-\alpha}} z^{\frac{1}{\alpha}} \lambda(z) a$, the labor market clearing condition implies

$$L = \bar{\pi}^{\frac{1}{1-\alpha}}\, \mathbb{E}_\Gamma\left[\lambda(z) z^{\frac{1}{\alpha}} | z \geq \underline{z}\right](1-\Gamma(\underline{z}))K. \tag{16}$$

Substituting (15) and (16) into (14) yields the following expression for aggregate productivity

$$Z = \mathbb{E}_\Gamma\left[\lambda(z) z^{\frac{1}{\alpha}} | z \geq \underline{z}\right]^\alpha (1-\Gamma(\underline{z}))^\alpha.$$

To understand how the relationship between $\lambda(z)$ and z affects aggregate productivity, I decompose aggregate TFP into two components

$$Z^{\frac{1}{\alpha}} = \mathbb{E}_{\Gamma}\left[z^{\frac{1}{\alpha}}|z \geq \underline{z}\right] + Cov_{\Gamma}[\lambda(z), z^{\frac{1}{\alpha}}|z \geq \underline{z}](1 - \Gamma(\underline{z})). \tag{17}$$

where I have invoked $1 = \mathbb{E}_{\Gamma}\left[\lambda(z)|z \geq \underline{z}\right](1 - \Gamma(\underline{z}))$ from (12) and (13). The first component is the average level of productivity of active entrepreneurs while the second component is the covariance between leverage capacity $\bar{k}(a, z)/a$ and productivity. Higher average $\lambda(z)$ pushes up the productivity cutoff $\underline{z}$ and raises the first component. Holding fixed average $\lambda(z)$, the second component increases with the covariance between $\lambda(z)$ and productivity z because more capital is allocated to more productive entrepreneurs.

Next I use the decomposition in (17) and three stylized examples to illustrate the implications of borrowing capacity varying with firm productivity for TFP losses from financial frictions.

Example 1. TFP is larger if more productive firms have higher borrowing capacity Consider two economies that have identical parameters except $\lambda(z)$. In economy 1, $\lambda_1(z)$ rises with productivity z while in economy 2, $\lambda_2(z) = \bar{\lambda}$ where $\bar{\lambda}$ is the aggregate leverage in the first economy. From (13), aggregate leverage is the same in the two economies. From (12), the economies also have the same productivity cutoff $\underline{z}$. Therefore, applying (17), the difference in TFP in the two economies is

$$Z_1^{\frac{1}{\alpha}} - Z_2^{\frac{1}{\alpha}} = Cov_{\Gamma}[\lambda_1(z), z^{\frac{1}{\alpha}}|z \geq \underline{z}](1 - \Gamma(\underline{z})) > 0 \tag{18}$$

That is, economy 1 has higher TFP even though the two economies have the same aggregate leverage. Since the first best TFP is the same in the two economies by construction, the loss from financial frictions is higher in the economy 2.

Intuitively, this is because economy 2 has a constant $\lambda(z)$ which prevents firms who are more productive relative to their wealth level to borrow more. In the constant-returns-to-scale case, all operating firms borrow up to the limit and $\lambda(z)a$ is the capital input. Since more productive entrepreneurs have higher marginal return to capital, the efficient allocation gives them more capital regardless of their wealth level. A constant $\lambda(z)$ prevents entrepreneurs with the same wealth level but different productivity from having different capital input.

Example 2. Measuring $\lambda(z)$ correctly is important for quantifying TFP losses due to financial frictions Consider the first economy with $\lambda_1(z)$. Due to constant-returns-to-scale production, TFP is maximized by having only the firm with the highest productivity producing. Hence the first best Z^{fb} equals z_{max}. TFP loss due to financial frictions is given by

$$\text{true loss} = \frac{Z^{fb} - Z_1}{Z^{fb}} \tag{19}$$

Suppose measurement of misallocation in this economy uses a model that assumes borrowing capacity is constant at $\hat{\lambda}$ and calibrates $\hat{\lambda}$ to match the aggregate leverage which equals $\bar{\lambda}$. The measured TFP loss from misallocation is then

$$\text{measured loss} = \frac{Z^{fb} - Z_2}{Z^{fb}} \tag{20}$$

Since $Z_2 < Z_1$, measured loss is larger than the true loss

$$\text{measured loss} - \text{true loss} = \frac{Z^{fb} - Z_2}{Z^{fb}} - \frac{Z^{fb} - Z_1}{Z^{fb}} > 0 \tag{21}$$

Hence, for economies where $\lambda(z)$ positively correlate with z, assuming $\lambda(z)$ is constant and calibrating to aggregate leverage can overstate TFP losses from financial frictions.

Example 3. Measuring $\lambda(z)$ correctly is important for quantifying the contribution of financial frictions to TFP gaps across countries A standard method for quantifying the contribution of financial frictions is to calibrate model parameters to one economy and then calculate a counterfactual TFP when the borrowing capacity parameter is changed to match the aggregate leverage in another economy. Since aggregate leverage is the same in the two economies in example 1, such a method would wrongly conclude that financial frictions contribute 0% to the TFP differences between the two economies even though it generated 100% to the TFP differences by construction.

1.3 Earning-based borrowing capacity

The analytical examples demonstrate that in theory, the relationship between borrowing capacity and firm productivity is relevant for understanding TFP losses from financial frictions. In Section 2, I consider the empirical relevance of this channel by calibrating a model with decreasing-returns-to-scale ($\eta < 1$) to data in Japan and China. To do so, I give more structure to $\bar{k}(a, z)$ using the limit enforcement model in Buera, Kaboski and Shin (2011), where borrowing capacity depends on firm productivity through earning-based borrowing. This allows me to calibrate the relationship between borrow capacity and firm productivity and gauge its quantitative importance.

Under the limited enforcement of contracts model in Buera, Kaboski and Shin (2011), an entrepreneur who defaults can keep $1 - \phi_y$ fraction of revenue minus labor costs and $1 - \phi_k$ fraction of depreciated capital but loses all of her wealth $a(1+r)$. In other words, ϕ_y and ϕ_k are the fractions of earnings and capital that are pledgeable. Entrepreneurs who default can use the financial market after one period without further penalties. In this setting, $\bar{k}(a, z)$ is the maximum capital level k that satisfies the following incentive compatibility constraint so that there is no default in the equilibrium

$$\max_l \{f(z,k,l)-wl\}+(1+r)a-(r+\delta)k \geq (1-\phi_y)\max_l \{f(z,k,l)-wl\}+(1-\phi_k)(1-\delta)k.$$

This constraint simply says what the entrepreneurs receive by repaying the debt must exceed what they receive by defaulting.

This parsimonious borrowing capacity nests the standard borrowing constraint $\bar{k}(a,z) = \lambda a$. When $\phi_y = 0$, the borrowing limit reduces to

$$\bar{k}(a,z) = \frac{1+r}{r+\delta+(1-\phi_k)(1-\delta)}\, a$$

and higher ϕ_k raises the borrowing capacity. When $\phi_y > 0$, the net benefit of repaying increases with productivity z because revenue net of labor costs is increasing in z, or $\max_l \{f(z,k,l) - wl\} \propto \left(\frac{zk^{\alpha\eta}}{w^{(1-\alpha)\eta}}\right)^{\frac{1}{1-(1-\alpha)\eta}}$. Hence, when $\phi_y > 0$, borrowing capacity $\bar{k}(a,z)$ increases with productivity z, controlling for a.

Existing approaches tend to either assume $\phi_y = 0$ or $\phi_y = \phi_k$ and use measures of aggregate leverage to calibrate ϕ_k. In order to infer the quantitative relevance of earning-based borrowing, I need to relax these restriction on ϕ_y and identify ϕ_y separately from ϕ_k. The elasticity of leverage with respect to the output-to-capital ratio for constrained firms is closely tied to ϕ_y in the model and will be used as a target in the calibration.

To see why this moment is informative of ϕ_y, the capital demand and output-to-capital ratio of an unconstrained entrepreneur with productivity z and asset a are given by

$$k^u(a,z) \propto z^{\frac{1}{1-\eta}} \qquad \eta\alpha\frac{y^u(a,z)}{k^u(a,z)} = r+\delta.$$

An entrepreneur's optimal capital demand is the smaller of $k^u(a,z)$ and $\bar{k}(a,z)$. An entrepreneur is constrained if $k^u(a,z) > \bar{k}(a,z)$. In that case, her capital demand and output-to-capital ratio are given by

$$k^c(a,z) = \bar{k}(a,z) \qquad \eta\alpha\frac{y^c(a,z)}{k^c(a,z)} \propto \left(\frac{z}{\bar{k}(a,z)^{1-\eta}}\right)^{\frac{1}{1-(1-\alpha)\eta}} > r+\delta$$

Therefore, the output-to-capital ratio rises with firm productivity for constrained firms. On the other hand, the debt of an entrepreneur in the model is $d \equiv \max\{0, k(a,z) - a\}$ and the leverage $k/(k-d)$ is equal to $\frac{k(a,z)}{\min(a,k(a,z))}$. For constrained firms, $k(a,z) = \bar{k}(a,z)$ and the leverage is $\bar{k}(a,z)/a$, which rises more quickly with productivity z for higher ϕ_y.

Hence, when $\phi_y = 0$, $\bar{k}(a,z)/a$ is constant and leverage of constrained firms do not correlate with their output-to-capital ratio. Higher ϕ_k raises the average leverage but does not affect this correlation. However, when $\phi_y > 0$, the correlation is positive because both the output-to-capital ratio and leverage rise with firm productivity z. Hence, the elasticity of firm leverage with respect to the output-to-capital ratio for constrained firms is informative of ϕ_y.

In the data, I do not have a variable to identify constrained firms. The model says that constrained firms have higher capital-to-output ratio. Hence, I will calibrate ϕ_y so that the elasticity of leverage with respect to the output-to-capital ratio of firms with above median output-to-capital ratio in the model matches the empirical elasticity for firms with above median output-to-capital ratio.

2 Calibration

This section calibrates the model laid out in the previous section to gauge the potential quantitative importance of earning-based borrowing. Since identifying the extent of earning-based borrowing, ϕ_y, is the novel part of the exercise, I first describe the evidence I use to infer this parameter and then describe the evidence used calibrate the remaining parameters.

2.1 Calibration target for earning-based borrowing

I use firm balance sheet information in Orbis where I have access to data for Japan from 2004 to 2013. Table 1 displays the data variables I use and the mapping to model variables. In particular, I use the ratio of total asset to shareholders fund to measure firm leverage $k/(k-d)$ and the ratio of total asset to revenue to measure the firm's output-to-capital ratio. Appendix A provides details of the data variable definitions and cleaning procedure.

I run the following regression to estimate the elasticity of firm leverage with

Table 1: Map of model to data

Variable	Model	Data
capital	k	book value of capital stock (total asset)
revenue	y	operating revenue
labor	l	number of employees
equity	$k-d$	shareholders fund

respect to firm output-to-capital ratio

$$\ln \frac{k_{f,i,t}}{k_{f,i,t}-d_{f,i,t}} = \gamma \ln \frac{y_{f,i,t}}{k_{f,i,t}} + IndustryFE + YearFE + v_{f,i,t} \tag{22}$$

where an observation is a firm f in industry i and year t. The sample is restricted to firms with above median output-to-capital ratio in their NAICS 3 digit industry in a year. I use year and firm fixed effects to control for elements in the data that are outside of my model such as aggregate fluctuations, industry and firm heterogeneity. As is well known, firm level data likely contains measurement error which can lead to bias in an OLS regression. First there may be division bias due to capital appearing in the denominator of the output-to-capital ratio and the numerator of the leverage ratio. This tends to make the OLS coefficient negative. Second, there may be attenuation bias which can bias the OLS coefficient towards zero. To address these, I use the log number of employees as an instrument for log output-to-capital ratio as employment rises with output-to-capital ratio for constrained firms in the model. This strategy relies on measurement errors in employment to be independent of measurement errors in the output-to-capital ratio.

Table 2 displays the regression results. The first column shows that the OLS regression yields a slightly negative coefficient while the IV regression yields a coefficient of 3.2, which says that one percent increase in firm output-to-capital ratio is associated with about 3 percent increase in firm leverage. The last two

Table 2: Empirical elasticity of leverage with respect to the output-to-capital ratio for firms with above median output-to-capital ratio

	OLS	IV	OLS winsorized	IV winsorized
Elasticity	-0.336***	3.198***	-0.355***	2.333***
	(0.005)	(0.871)	(0.004)	(0.398)
Observations	606,261	606,261	606,227	606,227
Number of firms	140,731	140,731	140,724	140,724
Firm/Year FE	YES	YES	YES	YES

Note: the table displays the coefficient on log output-to-capital ratio when regressing log leverage on log output-to-capital ratio controlling for year and firm fixed effects. The IV columns instrument log output-to-capital with log employment. The logs of leverage, output-to-capital ratio, and employment are winsorized at the tails at 5% for the winsorized columns. The models are estimated using $reghdfe$ by Correia (2017) for OLS and $ivreghdfe$ by Correia (2018) for IV designs. Robust standard errors, clustered at firm level, in parentheses, *** p <0.01, ** p <0.05, * p <0.1.

columns use a winsorized sample where the logs of leverage, output-to-capital ratio, and, for the IV design, employment, are winsorized at the tails at 5%. Similar to the unwinsorized sample, OLS regression yields a coefficient close to zero while the IV regression yields a slightly lower coefficient of 2.3. I will use 3.2 for my benchmark calibration but also conduct robustness checks that calibrate to a target of 2.3. When matching the model to the data, I choose ϕ_y so that the covariance of log leverage growth and log output-to-capital ratio growth divided by the variance of log output-to-capital growth in the model matches these regression coefficients.

2.2 Other calibration targets

I normalize μ_e, the mean of log productivity, to 0 and calibrate the remaining parameters. Column “Data” in Panel A of Table 3 presents the calibration targets. Target 1 and 2 are the aggregate cost and capital shares calculated from the 2021 JIP growth accounting table.[4] The data estimate the rental rate of capital to construct the cost share of capital and labor (Fukao, Hamagata, Inui, Ito, Kwon, Makino, Miyagawa, Nakanishi and Tokui, 2007). I calculate the aggregate cost share by dividing the sum of capital and labor costs by nominal value added. The data provide estimates for different sectors of the economy. I use the values for the macro economy excluding housing and activities not elsewhere classified).[5] The aggregate cost share is 84.6% while the cost share of capital is around 29.5%.

Moments 3 and 4 are the persistence of sales and the RMSE of sales which are useful for calibrating ρ and σ_e in the productivity AR(1) process. I calculates these moments using the Orbis firm level data. Let i denote industry, t year and f firm. I run an AR(1) regression of the log of firm revenue deflated by the GDP deflator [6]

$$\ln(sales)_{f,i,t} = \rho_y \ln(sales)_{f,i,t-1} + FE_i + FE_t + v_{f,i,t}. \tag{23}$$

Target 3 is ρ_y in the above regression while target 4 is RMSE. As in previous studies, sales is quite persistent with an one year AR(1) coefficient of 0.97. There is also significant variation in size, with a RMSE of about 0.4. I choose ρ and σ_e so the corresponding regression for sales in the model match these moments. In the model, when there are no financial frictions, ρ_y matches ρ because log sales is proportional to log productivity. This relationship breaks down in the presence of financial friction. Nonetheless, all else equal, higher ρ and higher σ_e results in higher ρ_y and RMSE in the model.

Target 5 is the aggregate external-financing-to-GDP ratio that is informative of ϕ_k, the plegeability of assets. I calculated this moment as in Buera, Kaboski and Shin (2021) but exclude lending unrelated to firms such as lending to

[4]JIP is a growth accounting database produced by researchers in collaboration with Japanese government, World KLEMS and EU KLEMS projects.

[5]For manufacturing, JIP reports a cost share of 0.845, which is close to the 0.85 used in Midrigan and Xu (2014)'s study of the manufacturing sector.

[6]World Bank's World Development Indicators series NY.GDP.DEFL.KD.ZG.

household mortgages. The data sources are the World Bank Financial Structure and Development Dataset ver 2019 of Beck, Demirgüç-Kunt and Levine (2000) and the Bank for International Settlements Long Series on Credit to the Non-financial Sector. The debt-to-GDP ratio is the sum of private credit and private bond market capitalization divided by GDP. I construct private credit using the "private credit by deposit money banks and other financial institutions to GDP" in the World Bank data multiplied by one minus the share of private credit to households in the BIS data. The latter is calculated as "Credit to households and NPISHs from all sectors at market value" divided by "Credit to private non-financial sector from all sectors at market value". The resulting debt-to-GDP ratio averages to about 1.73 over 2004-2013.

Moment 6 is the elasticity of leverage with respect to the output-to-capital ratio described above. Target 7 is the depreciation rate in Bureau of Economic Analysis (BEA) Tables 1.3 divided by net capital stock in BEA Table 1.1 for fixed assets. The BEA depreciation rates are used by the JIP growth accounting data. The average depreciation rate over 2004-2013 is about 5 percent per year. This disciplines the depreciation rate in the model. Target 8 is the short term nominal interest rate for Japan from the OECD minus Japan's inflation rate from World Bank's World Development Indicators. Nominal rates were close to zero in Japan over 2004-2013 and lower than the real rate of about 1.4% because Japan experienced deflation during this period. This moment is informative of the discount factor β. All else equal, the equilibrium interest rate declines with β in the model. Finally, target 9 is the average number of persons engaged in Table III-1 of the published tabulations of the Economic Census, which was conducted in 2009 and 2012 during 2004-2013. The value is 9.9 for 2009 and 10.2 for 2012. The target is the average of these two values and is used to pin down L in the model.

2.3 Calibrated parameters

I carry out three calibrations 1) calibrate ϕ_k and ϕ_y to match the aggregate debt-to-GDP ratio and the elasticity of firm leverage with respect to firm output-to-capital ratio 2) restrict $\phi_y = 0$ and calibrate ϕ_k to match the aggregate debt-to-GDP ratio 3) restrict $\phi_y = \phi_k$ and and calibrate ϕ_k to match the aggregate debt-to-GDP ratio. Calibrations 2) and 3) mimics common practices in the literature and do not target the elasticity of leverage with respect to the output-to-capital ratio. In all three calibrations, the other parameters are calibrated to match the same moments so that the only difference between the calibrations is the restriction on ϕ_y.

Panel A of Table 3 displays the model fit for each calibration and Panel B displays the corresponding parameters. The "Benchmark" column is calibration 1). This calibration yields $\phi_k = 1$ and $\phi_y = 0.191$, which implies that firms are able to pledge all of their assets and about one-fifth of their earnings. The calibrated capital intensity and returns-to-scale parameters are close to the observed capital and cost shares and are close to the 85% and 33% used in Midrigan and Xu (2014) and others in the literature. The persistence of productivity is slightly lower than the observed persistence of sales and the standard deviation of productivity shocks is close to $(1 - \eta)$ times the observed RMSE of log sales. This is because log sales of unconstrained firms in the model is $\frac{1}{1-\eta}$ times log productivity (plus a constant).

When I restrict $\phi_y = 0$ or $\phi_k = \phi_y$, the model also asks for $\phi_k = 1$ and similar values for other parameters. These two calibrations, however, do not match the elasticity of leverage with respect to the output-to-capital ratio. The calibration with $\phi_y = 0$ yields an elasticity of zero while the $\phi_k = \phi_y$ specification yields an infinite elasticity because the variance of output-to-capital ratio is zero.

All three specifications do not match the interest rate well. It turns out that the model has difficulty matching the level of aggregate leverage in conjunction with other moments. Aggregate debt-to-GDP ratio in the model increases when many high productivity entrepreneurs have low wealth. The aggregate debt-to-GDP can also increase with β because the aggregate capital-to-output ratio increases with lower interest rate. To make the three calibrations comparable, I sacrifice matching the interest rate to match the aggregate debt-to-GDP ratio.

I run an alternative calibration in Table 4 to check that the poor fit of the interest rate does not affect my results. Namely, I match the interest rate and miss the aggregate leverage target. Calibration 1) yields a slightly higher ϕ_y of 0.195 while the pledgeability of asset ϕ_k is still 1 in all three calibrations. Since I am matching the real interest rate, β is lower than the calibration in Table 3. The model generates an aggregate debt-to-GDP ratio of about 1.50 for calibration 1) and with the $\phi_k = \phi_y$ restriction and about 1.4 when ϕ_y is restricted to be zero. In the last column of Table 4, I show that the $\phi_k = 0$ specification can also generate an aggregate debt-to-GDP of 1.50 if I sacrifice the fit of the interest rate slightly.

Finally, I run calibration 1) with a lower elasticity target of 2.333. Table 5 shows that targeting this more conservative estimate yields a ϕ_y of about 0.14, regardless of the calibrated value of β. Overall, the model fits the data the best when about one-seventh to one-fifth of earnings is pledgeable.

3 Implications of earning-based borrowing

The previous section shows that calibrating the model to Japanese data suggest that firms in Japan are able to borrow again earnings but not to the same extent as assets. Is this quantitatively meaningful? This section shows the answer is yes by comparing the TFP loss due to financial frictions implied by the three calibration specification. It also conducts a counterfactual of matching the aggregate debt-to-GDP ratio in China to see how earning-based borrowing affects inferences of the contribution of financial frictions to TFP differences between China and Japan.

Table 3: Model fit and calibrated parameters by pledgeability restrictions

Panel A. Model fit

Target moments	Data	Bench-mark	Assume $\phi_y = 0$	Assume $\phi_k = \phi_y$
1. aggregate cost share (%)	84.6	84.6	84.7	84.6
2. aggregate capital share (%)	29.5	29.5	29.6	29.5
3. persistence of log sales	0.97	0.97	0.97	0.97
4. RMSE of log sales	0.41	0.41	0.41	0.41
5. aggregate debt-to-GDP ratio	1.73	1.73	1.74	1.74
6. elast of lev. wrt sales/capital	3.20	3.19	0.00	inf
7. annual depreciation rate (%)	5.14	5.14	5.14	5.14
8. annual real interest rate (%)	1.41	0.62	0.38	0.69
9. average worker per firm	10.1	10.1	10.1	10.1

Panel B. Parameters

		Bench-mark	Assume $\phi_y = 0$	Assume $\phi_k = \phi_y$
production returns-to-scale	η	0.848	0.849	0.846
production capital intensity	α	0.297	0.297	0.295
depreciation rate	δ	0.051	0.051	0.051
worker per firm	L	10.05	10.05	10.05
discount factor	β	0.964	0.970	0.964
productivity AR(1) persistence	ρ	0.956	0.971	0.970
productivity AR(1) residual stde	σ_e	0.065	0.055	0.063
pledgability of assets	ϕ_k	1	1	1
pledgability of revenue	ϕ_y	0.191	0	1

Source: 1 and 2 are from JIP 2021. 3, 4 and 6 are the author's calculations based on Orbis data. 5 is calculated using World Bank and BIS data on external financing to GDP ratios. 7 is from BEA Tables 1.1 and 1.3. 8 is from the OECD and the World Bank. 9 is from the Economic Census in Japan. All values are averages over 2004–2013.

Table 4: Model fit and calibrated parameters, lower β

Panel A. Model fit

Target moments	Data	Fit elast	$\phi_y = 0$	$\phi_k = \phi_y$	$\phi_y = 0$ same D/Y
1. aggregate cost share (%)	84.6	84.7	84.7	84.5	84.7
2. aggregate capital share (%)	29.5	29.5	29.6	29.6	29.6
3. persistence of log sales	0.97	0.97	0.97	0.97	0.97
4. RMSE of log sales	0.41	0.41	0.41	0.41	0.41
5. aggregate debt-to-GDP ratio	1.73	1.50	1.41	1.52	1.49
6. elast of lev. wrt sales/capital	3.20	3.19	-0.01	inf	0.00
7. annual depreciation rate (%)	5.14	5.14	5.14	5.14	5.14
8. annual real interest rate (%)	1.41	1.41	1.41	1.42	1.14
9. average worker per firm	10.1	10.1	10.1	10.1	10.1

Panel B. Parameters

		Fit elast	$\phi_y = 0$	$\phi_k = \phi_y$	$\phi_y = 0$ same D/Y
production returns-to-scale	η	0.849	0.849	0.845	0.849
production capital intensity	α	0.297	0.297	0.296	0.297
depreciation rate	δ	0.051	0.051	0.051	0.051
worker per firm	L	10.05	10.05	10.05	10.05
discount factor	β	0.953	0.956	0.955	0.959
productivity AR(1) persistence	ρ	0.955	0.971	0.970	0.971
productivity AR(1) residual stde	σ_e	0.065	0.055	0.064	0.055
pledgability of assets	ϕ_k	1	1	1	1
pledgability of revenue	ϕ_y	0.195	0	1	0

Source: 1 and 2 are from JIP 2021. 3, 4 and 6 are the author's calculations based on Orbis data. 5 is calculated using World Bank and BIS data on external financing to GDP ratios. 7 is from BEA Tables 1.1 and 1.3. 8 is from the OECD and the World Bank. 9 is from the Economic Census in Japan. All values are averages over 2004–2013.

Table 5: Model fit and calibrated parameters, lower elasticity target

Panel A. Model fit

Target moments	Data	Fit D/Y	Lower β
1. aggregate cost share (%)	84.6	84.7	84.7
2. aggregate capital share (%)	29.5	29.5	29.5
3. persistence of log sales	0.97	0.97	0.97
4. RMSE of log sales	0.41	0.41	0.41
5. aggregate debt-to-GDP ratio	1.73	1.73	1.49
6. elast of lev. wrt sales/capital	3.20	2.35	2.31
7. annual depreciation rate (%)	5.14	5.14	5.14
8. annual real interest rate (%)	1.41	0.58	1.41
9. average worker per firm	10.1	10.1	10.1

Panel B. Parameters

		Fit D/Y	Lower β
production returns-to-scale	η	0.849	0.849
production capital intensity	α	0.297	0.297
depreciation rate	δ	0.051	0.051
worker per firm	L	10.05	10.05
discount factor	β	0.965	0.954
productivity AR(1) persistence	ρ	0.952	0.952
productivity AR(1) residual stde	σ_e	0.064	0.064
pledgability of assets	ϕ_k	1	1
pledgability of revenue	ϕ_y	0.143	0.144

Source: 1 and 2 are from JIP 2021. 3, 4 and 6 are the author's calculations based on Orbis data. 5 is calculated using World Bank and BIS data on external financing to GDP ratios. 7 is from BEA Tables 1.1 and 1.3. 8 is from the OECD and the World Bank. 9 is from the Economic Census in Japan. All values are averages over 2004–2013.

Table 6: TFP loss due to financial frictions

	Assume $\phi_y = \phi_k$	Benchmark $\phi_y = 0.191$	Conservative $\phi_y = 0.143$	Assume $\phi_y = 0$
TFP loss as % of first best	0.0	0.7	1.0	2.0
Equilibrium debt-to-GDP ratio	1.74	1.73	1.73	1.74

Table 7: TFP loss due to financial frictions, lower β

	Assume $\phi_y = \phi_k$	Benchmark $\phi_y = 0.195$	Conservative $\phi_y = 0.144$	Assume $\phi_y = 0$
TFP loss as % of first best	0	0.8	1.1	2.2
Equilibrium debt-to-GDP ratio	1.52	1.50	1.49	1.49

3.1 TFP loss due to financial frictions

First, Table 6 displays the TFP loss due to financial frictions implied by the calibrations in Table 3 and Table 5, when all calibrations match the observed aggregate debt-to-GDP ratio in Japan. Matching the elasticity in the data yields a loss of 0.7 to 1% depending on the elasticity target used. In contrast, restricting $\phi_k = \phi_y$ yields no loss while restricting $\phi_y = 0$ overstates the loss by two-folds.

Table 7 displays the same comparison but for calibrations in Table 4 and Table 5 when all calibrations fit the interest rate and generate an aggregate debt-to-GDP ratio of about 1.5. TFP loss when matching the elasticity in the data is 0.8 to 1%. Again, restricting $\phi_k = \phi_y$ yields no loss while restricting $\phi_y = 0$ overstates the loss by two-folds. These results show that correctly calibrating ϕ_y is important for inferring TFP loss from financial frictions.

3.2 Japan-China TFP gap due to financial frictions

Next, to gauge the potential quantitative relevance of earning-based borrowing for cross-country TFP differences, I change the values of ϕ_k and ϕ_y in the benchmark calibration to match the aggregate debt-to-GDP ratio in China and compare the resulting change in TFP with the actual TFP gap between China and Japan. The aggregate debt-to-GDP ratio for China is calculated in the same way as for Japan and stands at about 1.2. The gap in TFP is calculated using the Penn World Table data and the method in Boppart and Li (2021) which augments Hall and Jones (1999) with investment specific technology. For 2004-2013, China has on average 82% lower TFP than Japan.

Table 8 shows the results when the counterfactuals are created from the calibrations in Table 3, where the model fits the Japanese debt-to-GDP ratio of 1.73. If I assume China has the same ϕ_y as Japan but lower ϕ_k, the model needs China's ϕ_k to be 0.32 to match China's debt-to-GDP ratio. This lower ϕ_k generates 1.5% of the TFP gap between China and Japan. In contrast, if I assume ϕ_y in China is zero, the model requires ϕ_k to be 0.50 to match the aggregate debt-to-GDP ratio. In this case, the model can generate one quarter of the TFP gap.

Table 9 conducts two robustness checks by using the calibrations in Table 4 and Table 5 to construct the counterfactuals. The contribution of financial frictions to the TFP gap still depends crucially on whether China has lower plegeability of earnings. These show that the aggregate debt-to-GDP ratio alone do not fully capture the contribution of financial frictions to cross-country TFP differences. It is important to also know the pledgeability of earnings.

Finally, Table 10 shows what one would have inferred if one assumes $\phi_y = 0$ for both China and Japan or $\phi_y = \phi_k$ for both China and Japan. The table shows that such inferences can be quite different from each other and from the contribution when China and Japan have different plegeability of earnings. This further highlights the importance of correctly measuring the plegeability of earnings across countries.

Table 8: Japan-China TFP differences due to financial frictions

	Japan	China data	Assume $\phi_y^{CN} = \phi_y^{JP}$	Assume $\phi_y^{CN} = 0$
Debt-to-GDP ratio	1.73	1.20	1.20	1.20
Calibrated China ϕ_k			0.32	0.50
TFP loss rel to Japan (%)	0	82.1	1.2	20.7
Fin Friction contrib. (%)			**1.5**	**25.2**

TFP loss is the difference between TFP calibrated to Japanese data and counterfactual TFP if ϕ_y and ϕ_k change to match the debt-to-GDP ratio of China. Contribution of financial friction is this TFP loss divided by the loss in the data, expressed as a percent.

4 Conclusion

When inferring the effects of financial frictions on TFP across countries, existing approaches tend to assume that the borrowing limits of firms depend only on their assets. More recent studies incorporate earning-based borrowing but assume that the plegeability of revenue is the same as assets. These approaches discipline the extent of financial frictions using evidence on aggregate leverage such as the aggregate external-financing-to-GDP ratio.

Using firm-level data in Japan, this paper shows that such approaches may lead to the wrong inference about TFP losses from financial frictions because firms are able to pledge revenue but not to the same degree as assets. In particular, the TFP loss from financial frictions in Japan is likely to be lower than an inference that rules out earning-based borrowing and higher than an inference that assumes revenue is as plegeable as assets.

The paper also shows that the contribution of financial frictions to the TFP gap between Japan and China depends crucially on whether China has lower plegeability of revenue than Japan. Conditional on aggregate leverage in Japan and China, financial frictions contribute significantly more to their TFP differ-

Table 9: Japan-China TFP differences due to financial frictions, robustness checks

Panel A. lower beta

	Japan	China data	Assume $\phi_y^{CN} = \phi_y^{JP}$	Assume $\phi_y^{CN} = 0$
Debt-to-GDP ratio	1.50	1.20	1.19	1.20
Calibrated China ϕ_k			0.46	0.60
TFP loss rel to Japan (%)	0	82.1	2.5	11.7
Fin Friction contrib. (%)			**3.1**	**14.3**

Panel B. lower beta and lower elasticity target

	Japan	China data	Assume $\phi_y^{CN} = \phi_y^{JP}$	Assume $\phi_y^{CN} = 0$
Debt-to-GDP ratio	1.49	1.20	1.19	1.20
Calibrated China ϕ_k			0.46	0.60
TFP loss rel to Japan (%)	0	82.1	4.7	10.3
Fin Friction contrib. (%)			**5.7**	**12.5**

TFP loss is the difference between TFP calibrated to Japanese data and counterfactual TFP if ϕ_y and ϕ_k change to match the debt-to-GDP ratio of China. Contribution of financial friction is this TFP loss divided by the loss in the data, expressed as a percent.

Table 10: Inference of Japan-China TFP differences due to financial frictions

Panel A. Using benchmark Japan calibration

Assumption about ϕ_y	Both $\phi_y = 0$	Both $\phi_y = \phi_k$	$\phi_y^{CN} = \phi_y^{JP}$	$\phi_y^{CN} = 0$
China debt-to-GDP ratio	1.20	1.20	1.20	1.20
Calibrated China ϕ_k	0.39	0.33	0.32	0.50
TFP loss rel to Japan (%)	8.6	2.1	1.2	20.7
Fin Friction contrib. (%)	**10.5**	**2.6**	**1.5**	**25.2**

Panel B. lower β in Japan calibration

Assumption about ϕ_y	Both $\phi_y = 0$	Both $\phi_y = \phi_k$	$\phi_y^{CN} = \phi_y^{JP}$	$\phi_y^{CN} = 0$
Debt-to-GDP ratio	1.20	1.20	1.19	1.20
Calibrated China ϕ_k	0.66	0.45	0.46	0.60
TFP loss rel to Japan (%)	6.1	2.4	2.5	11.7
Fin Friction contrib. (%)	**7.5**	**2.9**	**3.1**	**14.3**

TFP loss is the difference between TFP calibrated to Japanese data and counterfactual TFP if ϕ_y and ϕ_k change to match the debt-to-GDP ratio of China. Contribution of financial friction is this TFP loss divided by the loss in the data, expressed as a percent.

ences when China has zero pledgeability of revenue versus when China has the same plegeability of revenue as Japan. Therefore, it may be fruitful for future studies to investigate the availability of earning-based borrowing in less developed countries.

References

Albuquerque, Rui and Hugo A Hopenhayn, "Optimal lending contracts and firm dynamics," *The Review of Economic Studies*, 2004, *71*, 285–315.

Arellano, Cristina, Yan Bai, and Jing Zhang, "Firm dynamics and financial development," *Journal of Monetary Economics*, 2012, *59* (6), 533–549.

Beck, Thorsten, Asli Demirgüç-Kunt, and Ross Levine, "A new database on the structure and development of the financial sector," *The World Bank Economic Review*, 2000, *14* (3), 597–605.

Boppart, Timo and Huiyu Li, "Productivity slowdown: reducing the measure of our ignorance," *Federal Reserve Bank of San Francisco Working Paper*, 2021.

Brooks, Wyatt and Alessandro Dovis, "Credit Market Frictions and Trade Liberalizations," *Journal of Monetary Economics*, 2019.

Buera, Francisco J and Yongseok Shin, "Financial Frictions and the Persistence of History: A Quantitative Exploration," *Journal of Political Economy*, 2013, *121* (2), 221–272.

_ , Joseph P Kaboski, and Yongseok Shin, "Finance and Development: A Tale of Two Sectors," *American Economic Review*, 2011, *101* (5), 1964–2002.

_ , _ , and _ , "The Macroeconomics of Microfinance," *The Review of Economic Studies*, 2021, *88* (1), 126–161.

Cooley, Thomas F and Vincenzo Quadrini, "Financial markets and firm dynamics," *American Economic Review*, 2001, pp. 1286–1310.

Correia, Sergio, "Linear models with high-dimensional fixed effects: An efficient and feasible estimator," *Unpublished manuscript, http://scorreia. com/research/hdfe. pdf (last accessed 25 October 2019)*, 2017.

_ , "IVREGHDFE: Stata module for extended instrumental variable regressions with multiple levels of fixed effects," 2018.

Drechsel, Thomas, "Earnings-Based Borrowing Constraints and Macroeconomic Fluctuations," Technical Report, working paper 2019.

Eisfeldt, Andrea L and Yu Shi, "Capital reallocation," *Annual Review of Financial Economics*, 2018, *10*, 361–386.

Fukao, Kyoji, Sumio Hamagata, Tomohiko Inui, Keiko Ito, Hyeog Ug Kwon, Tatsuji Makino, Tsutomu Miyagawa, Yasuo Nakanishi, and Joji Tokui, "Estimation Procedure and TFP Analysis of the JIP Database 2006 (revised)," Technical Report, Research Institute of Economy, Trade and Industry (RIETI) Discussion Paper Series 2007.

Gopinath, Gita, ebnem Kalemli-zcan, Loukas Karabarbounis, and Carolina Villegas-Sanchez, "Capital Allocation and Productivity in South Europe," *The Quarterly Journal of Economics*, 06 2017, *132* (4), 1915–1967.

Greenwald, Daniel, "The mortgage credit channel of macroeconomic transmission," *MIT Sloan Research Paper No. 5184-16*, 2018.

Hall, Robert Ernest and Charles Jones, "Why Do Some Countries Produce So Much More Output Per Worker Than Others?," *The Quarterly Journal of Economics*, 1999, *114* (1), 83–116.

Kehoe, Timothy J and David K Levine, "Debt-constrained asset markets," *The Review of Economic Studies*, 1993, *60* (4), 865–888.

Khan, Aubhik and Julia K Thomas, "Credit Shocks and Aggregate Fluctuations in an Economy with Production Heterogeneity," *Journal of Political Economy*, 2013, *121* (6), 1055–1107.

Lian, Chen and Yueran Ma, "Anatomy of corporate borrowing constraints," *The Quarterly Journal of Economics*, 2021, *136* (1), 229–291.

Midrigan, Virgiliu and Daniel Yi Xu, "Finance and Misallocation: Evidence from Plant-Level Data," *The American Economic Review*, 2014, *104* (2), 422–458.

Moll, Benjamin, "Productivity Losses from Financial Frictions: Can Self-Financing Undo Capital Misallocation?," *The American Economic Review*, 2014, *104* (10), 3186–3221.

A Data

Table 11 displays the Orbis data version information for each variable and the extraction condition (in addition to the condition “World region/Country/Region in country: Japan”). From the raw data, I keep firm-years with positive values for all four variables and have a NAICS 3-digit industry code. Since the regression for elasticity includes firm fixed effects, I exclude firms that appear for only one year in the data. The final panel has contains 243,329 firms and 1,285,093 firm-year observations.

Table 11: Data version and extraction conditions

Variable	Update nbr	Update date	Condition
Total asset	124	June 12, 2014	Total assets: All companies with a known value, 2013, 2012, 2011, 2010, 2009, 2008, 2007, 2006, 2005, 2004, for at least one of the selected periods
Shareholder’s fund	123	May 8th, 2014	Capital: All companies with a known value, 2013, 2012, 2011, 2010, 2009, 2008, 2007, 2006, 2005, 2004, for at least one of the selected periods
Employment	124	June 12, 2014	Number of employees: All companies with a known value, 2013, 2012, 2011, 2010, 2009, 2008, 2007, 2006, 2005, 2004, for at least one of the selected periods
Sales	125	July 25, 2014	Sales: All companies with a known value, 2013, 2012, 2011, 2010, 2009, 2008, 2007, 2006, 2005, 2004, for at least one of the selected periods