Finance and Misallocation: Evidence from Plant-Level Data*

Virgiliu Midrigan† Daniel Yi Xu‡

February 2013

Abstract

We use producer-level data to evaluate the role of financial frictions in determining total factor productivity (TFP). We study a model of establishment dynamics in which financial frictions reduce TFP through two channels. First, finance frictions distort entry and technology adoption decisions. Second, finance frictions generate dispersion in the returns to capital across existing producers and thus productivity losses from misallocation. Parameterizations of our model consistent with the data imply fairly small losses from misallocation, but potentially sizable losses from inefficiently low levels of entry and technology adoption. We provide support for our model's implications using producer-level data for several countries that differ in the degree of financial development, as well as by studying producer-level data during the Korean financial crisis.

Keywords: productivity, technology adoption, misallocation, finance frictions.

JEL classifications: O1, O4.

*We thank Vivian Yue for many useful conversations during an early stage of this project. We thank our discussants, Simon Gilchrist, Jan de Loecker, Ben Moll, Richard Rogerson, and Manuel Santos; our editor, Penny Goldberg; and three anonymous referees for valuable comments and suggestions. We have also benefited from conversations with Andrew Atkeson, Susanto Basu, Francisco Buera, Ariel Burstein, Andres Rodriguez-Claire, Mark Gertler, Boyan Jovanovic, Joe Kaboski, Patrick Kehoe, Timothy Kehoe, Robert Lucas, Yongseok Shin and Mark Wright. Jiwoon Kim, Fernando Leibovici and Matthias Lux provided excellent research assistance.

†New York University, and NBER, virgiliu.midrigan@nyu.edu.

‡Duke University, and NBER, daniel.xu@duke.edu.

1 Introduction

Differences in GDP per capita across countries are large and mostly accounted for by differences in total factor productivity. A key challenge is to identify the sources of these large differences in TFP. Since financial markets are much less developed in poor countries, a hypothesis that has received much attention in recent years is that financial frictions are an important source of aggregate TFP losses.[1]

Financial frictions can reduce aggregate productivity via two channels. First, they may distort *entry* and *technology adoption* decisions and thus reduce the productivity of individual producers.[2] Second, financial frictions may generate differences in the returns to capital across individual producers, and thus efficiency losses due to *misallocation*.[3] Our goal in this paper is to evaluate the strength of these two channels quantitatively, using establishment-level data for the manufacturing sectors of South Korea, a country with a relatively well-developed financial system, as well as China and Colombia, two countries with relatively low levels of financial development.

We study a model of establishment dynamics in which producers can operate in one of two sectors. Producers in the unproductive, *traditional* sector, only use labor and do not require financing in order to operate. Producers in the productive, *modern* sector, require two forms of capital investment. First, entry into the modern sector requires a one-time investment in a sunk cost. Second, production in the modern sector requires physical capital. Financial frictions, that take the form of simple constraints on the amount of debt and equity producers can issue, generate TFP losses by preventing productive traditional-sector producers from joining the modern sector, as well as by preventing the reallocation of capital in response to productivity shocks in the modern sector.

We use establishment-level data from Korean manufacturing to quantitatively evaluate these two sources of inefficiency. We show that a parameterized version of our model accounts well for a number of salient features of the micro data: the variability and persistence of establishment-level output, capital and employment, difference in the returns to capital and

[1]See Buera, Kaboski and Shin (2011) and the reference therein.

[2]See Cole, Greenwood and Sanchez (2012).

[3]See Banerjee and Duflo (2005), Restuccia-Rogerson (2008) and Hsieh and Klenow (2009). See also Guner, Ventura, Xu (2008), Hopenhayn and Rogerson (1993), Lagos (2006), Angeletos (2008) and Castro, Clementi, MacDonald (2009) who study the role of various frictions that generate misallocation.

output growth rates for young and old plants, as well as statistics describing the level of development of Korea's debt and equity markets.

We find that financial frictions can reduce substantially (up to 40%) the level of TFP, output and consumption in our model economy. The bulk of these losses arise due to the distortions associated with the decision to enter the modern sector and the technology adoption decisions. In contrast, the TFP losses from misallocation of capital among modern-sector producers are a lot smaller (5% to 10%) and account for only a fraction of the overall efficiency losses associated with a tightening of the borrowing constraints.

The mechanism that undoes the losses from misallocation among modern-sector producers is *self-financing*. Relatively more efficient producers accumulate internal funds over time and quickly grow out of their borrowing constraints. Although transitory productivity shocks can indeed temporarily distort a producer's capital relative to its efficient level, the data show that the time-series variability in a producer's productivity is not nearly large enough for such distortions to be quantitatively important.

In contrast, entry and adoption decisions entail large long-lived investments that pay off only gradually over time and are thus difficult to finance using internal funds. Consider the problem of a traditional-sector producer that contemplates entering the modern sector. Although the sunk cost of entering may be relatively small relative to the present value of future profits expected in the modern sector, the producer may be unable to finance this cost internally, out of the much more modest profits it earns in the traditional sector. Ability to borrow is thus critical for such a producer to enter the modern sector.

The Benchmark model we study is a parsimonious extension of the model of establishment dynamics in Hopenhayn (1992). We introduce an important role for finance by assuming that the number of producers that operate grows over time. Immediately upon entry, all new producers operate in the traditional sector. Over time, these producers can choose to enter the modern sector by paying a one-time sunk cost. Producers can finance this cost either by accumulating internal funds or externally, by issuing uncontingent debt or equity claims to future dividends. We study the extent to which constraints on how much debt and equity producers can issue distort entry decisions and therefore aggregate efficiency.

We have conducted a number of exercises in order to gauge the robustness of our Benchmark model's results. We have explicitly introduced a technology adoption decision, a decision to temporarily shut down production in the modern sector, capital adjustment costs, variable markups, capital-specific productivity shocks, and additional sources of heterogeneity in producers' production technologies and borrowing constraints. We found that our results are robust to all these modifications. All versions of our model predict fairly modest aggregate efficiency losses from capital misallocation among producers in the modern sector, but potentially large losses due to distortions along the extensive margins.

In our empirical analysis we associate the modern sector with the official manufacturing sector and the traditional sector with various forms of non-market activity that are not covered by the government surveys we study. Moreover, we do not observe the technology adoption decisions of producers in the manufacturing sectors we study. For these reasons, we mostly focus on measuring the losses from misallocation among producers in the modern sector, as opposed to those arising due to distortions along the extensive margin. Our approach is thus closely related to that of Hsieh and Klenow (2009). In contrast to Hsieh and Klenow, who document large (about 40%) overall losses from misallocation in the manufacturing sectors of China and India, we focus solely on the losses from capital misallocation generated by financial frictions and show that these are fairly small. Overall, the open– and closed–economy versions of our model predict that the maximal losses from misallocation are about 1/8th and 1/4th as large as those documented by Hsieh and Klenow.

Capital misallocation in our model arises from two main channels. First, age differences across producers generate differences in these producers' net worth and thus their marginal product of capital. We refer to this first channel as the *age channel*. Second, constrained producers cannot fully change their capital stocks in response to productivity shocks so that the latter cause dispersion in the producers' marginal product of capital. We refer to this second channel as the *adjustment channel*.

We find, consistent with what our quantitative model predicts, that both of these channels are weak in the data. First, even though the average product of capital is highly dispersed across producers, differences in age account for little of this dispersion, both in Korea, as well as in the much less financially developed manufacturing sectors of Colombia and China. Our model interprets this finding as evidence against the hypothesis that differences in the net worth across young and old producers induce large differences in returns to capital and thus efficiency losses. Second, we find, both in our calibration, as well as when directly estimating production functions at the industry level, that the productivity of individual producers does not fluctuate over time nearly enough for capital adjustment frictions to distort allocations much. Indeed, even if the capital stocks of individual producers were to not respond at all to changes in productivity, the losses from lack of reallocation would be at most 2-3%.

Our paper is related to a number of recent studies that quantitatively examine the impact of financing frictions on the level of economic development.[4] Our contribution, relative to the existing work, is to discipline the quantitative analysis using a richer set of cross-sectional and time-series observations from establishment-level data, in order to isolate the two distinct channels through which financial frictions may lower TFP. We find that a model that replicates the dynamics of output and productivity at the producer level predicts fairly small losses from misallocation across producers. Our results thus suggest that it is difficult to attribute the bulk of the large TFP losses from misallocation documented by Hsieh and Klenow (2009) to financial frictions. In contrast, financial frictions have potentially sizable negative effects on the number of producers that operate as well as the level of technology that these producers adopt. Thus, as Jeong and Townsend (2006) and Buera, Kaboski and Shin (2011) do, we emphasize the role financial constraints have on the extensive margin. In contrast to these studies, we focus on the role of financial frictions in distorting long-lived investments and find a potentially important role for such distortions.

2 Benchmark Model

We first discuss the setup of the model, the decision rules, the definition of an equilibrium, and finally describe how we calculate TFP and the first-best allocations in our economy.

2.1 Setup

The economy is populated by a measure one of workers and a measure N_t of producers. The efficiency of labor and the measure of producers grows over time at a constant rate γ. Producers operate in one of two sectors: a *traditional* sector that uses only labor and an unproductive technology, and a *modern* sector that uses capital and labor and a more productive technology. We associate the modern sector with the official manufacturing sector

[4]See Jeong and Townsend (2006), Amaral and Quintin (2010), Buera and Shin (2011), Moll (2012), Greenwood, Sanchez and Wang (2010), Cole, Greenwood and Sanchez (2012).

and the traditional sector with various forms of non-market activity.[5]

Entry into the modern sector requires an upfront investment in a sunk entry cost. Producers can borrow and save with financial intermediaries. The amount a producer can borrow is subject to a collateral constraint. Workers face uninsurable idiosyncratic labor income risk and have access to financial markets. There are two types of financial instruments available: a one-period uncontingent security, as well as equity claims to producers' profits.

2.1.1 Producers

A measure $(\gamma - 1)N_t$ of producers enter the economy at the end of period t. All these producers operate in the traditional sector upon entry. Over time, these producers may choose to enter the modern sector by paying the sunk entry cost.

Traditional Sector. Producers in this sector face a decreasing returns technology that produces output Y_t using labor L_t as the only factor of production:

$$Y_t = \exp\left(z + e_t\right)^{1-\eta} L_t^{\eta}. \tag{1}$$

Here $\eta < 1$ is the degree of returns to scale, z is a permanent component of the producer's productivity, while e_t is a transitory productivity component that evolves over time according to a finite-state Markov process on $E = \{e_1, ..., e_T\}$ with transition probabilities $f_{i,j} = \Pr\left(e_{t+1} = e_j | e_t = e_i\right)$. We assume that entrants draw their initial productivity component e_i from the stationary distribution associated with f, which we denote with $\bar{f}_i$. Similarly, entrants draw the permanent productivity component z from some distribution $G(z)$, whose mean we normalize to unity. All entering producers have zero wealth.

Let D_t denote the producer's debt position. The problem of producers in the traditional sector is to maximize their life-time utility given by

$$E_0 \sum_{t=0}^{\infty} \beta^t \log\left(C_t\right).$$

The budget constraint that producers in the traditional sector face depends on whether they decide to remain in the traditional sector or switch to the modern sector. Producers who

[5]See Jeong and Townsend (2006) who also studying the role of financing frictions in preventing the flow of resources from the traditional to the modern sector, and Jeong and Kim (2006) for a taxonomy of different occupations into the two sectors. Notice that we could also associate the traditional sector with home production or even wage employment: most of our analysis goes through under this alternative interpretation.

stay in the traditional sector earn profits $Y_t - WL_t$, and choose how much of their income to save and to consume. Their budget constraint is

$$C_t = Y_t - WL_t - (1+r)\,D_t + D_{t+1}, \tag{2}$$

where W and r are the equilibrium wage and interest rate in this economy. These producers are unable to borrow and so $D_{t+1} \leqslant 0$.

Consider next the problem of traditional sector producers that enter the modern sector. Entering the modern sector requires an upfront investment equal to $\exp(z)\,\kappa$ units of output. We assume that this sunk cost is proportional to the permanent productivity component so that even the most productive producers face a non-trivial cost of entering the modern sector.[6]

The producer who enters the modern sector finances expenditures on its physical capital, K_{t+1}, and intangible capital, $\exp(z)\,\kappa$, using either its internal funds, by borrowing using one-period risk-free debt or by issuing equity claims to a fraction of its future profits. The amount the producer can borrow is limited by a collateral constraint that requires that its debt does not exceed a fraction of its capital stock:

$$D_{t+1} \leqslant \theta\left(K_{t+1} + \exp(z)\,\kappa\right), \tag{3}$$

where $\theta \in [0,1]$ governs the strength of financial frictions in this economy. We assume that both the tangible and non-tangible capital components are pledgeable as collateral.

Let P_t be the price of a claim to the entire stream of profits of a producer in the modern sector, where profits are defined as output net of spending on labor and the interest and depreciation cost of capital:

$$\Pi_t^m = Y_t - WL_t - (r+\delta)\,K_t.$$

We assume that producers can only issue claims to a fraction $\theta\chi$ of their future profits, where $\chi \in [0,1]$, and can only do so once, upon entering the modern sector. Note that a low θ depresses both the producer's ability to borrow and to issue equity. We think of θ as characterizing the degree of financial development of the economy.

The budget constraint of a producer that enters the modern sector is therefore

$$C_t + K_{t+1} + \exp(z)\,\kappa = Y_t - WL_t - (1+r)\,D_t + D_{t+1} + \theta\chi P_t. \tag{4}$$

[6] We have also studied an economy in which the sunk cost does not scale with the producer's productivity and found it difficult to match the size distribution of producers in the data given that only the most productive producers enter the modern sector in such an environment.

The producer uses its internal funds, as well as new borrowing and the proceeds from issuing equity, in order to finance consumption and expenditure on the two types of capital.

Modern Sector. The technology with which producers in the modern sector operate is

$$Y_t = \exp\left(z + e_t + \phi\right)^{1-\eta}\left(L_t^{\alpha} K_t^{1-\alpha}\right)^{\eta},$$

where α governs the share of labor in production, K_t is the amount of capital installed in the previous period and $\phi \geqslant 0$ determines the relative productivity of the modern sector.

Producers in this sector can save and borrow at the risk-free rate r, subject to the collateral constraint (3). Their budget constraint is

$$C_t + K_{t+1} - (1-\delta) K_t = Y_t - W L_t - (1+r) D_t - \theta\chi\Pi_t^m + D_{t+1}. \tag{5}$$

This constraint states that consumption and investment are financed out of existing operating income, net of repayment of existing financial obligations – the one-period loan and payments to equity holders, as well as by borrowing from financial intermediaries.

We assume, as is standard in the investment literature, that output at date $t+1$ is produced using capital installed in period t. The choice of how much to invest at the end of period t is, however, measurable with respect to e_{t+1}. This assumption conveniently simplifies our analysis by reducing the dimensionality of the state-space[7] and allows us to focus solely on the role of financial frictions in distorting the allocation of capital among producers.

2.1.2 Workers

The economy is also inhabited by a unit measure of workers, each of whom supplies $\gamma^t \nu_t$ efficiency units of labor, where ν_t is the worker's idiosyncratic efficiency and evolves over time according to a finite-state Markov process.

Let a_t denote a worker's holdings of the risk-free asset and ω_t^i denote the number of shares it owns of producer i. The worker has identical log preferences as producers do, and chooses how much to save and consume subject to a budget constraint given by:

$$c + a_{t+1} + \int P_t^i \omega_{t+1}^i di = W\gamma^t \nu_t + (1+r) a_t + \int \left(P_t^i + \Pi_t^{m,i}\right)\omega_t^i di.$$

[7]See Moll (2012) and Buera and Moll (2012) who illustrate the equivalence of this setup to the setup with rental markets for capital studied by Evans and Jovanovic (1989) and Buera, Kaboski and Shin (2011).

Workers cannot borrow, so their asset holdings, $a_{t+1} + \int P_t^i \omega_{t+1}^i di$, are nonnegative.[8]

Since there is no aggregate risk in this economy, no-arbitrage implies that the return on the risk-free security is equal to the expected return to holding equity:

$$(1+r) = \frac{E_t \left[P_{t+1}^i + \Pi_{t+1}^{m,i}\right]}{P_t^i}.$$

2.2 Recursive Formulation and Decision Rules

Producers in the Modern Sector. Let $A = K - D$ be the producer's net worth relative to its permanent productivity. Our measurability assumption on capital implies that producer profits are a function solely of its net worth, not of capital and debt in isolation. Moreover, profits, output, and the optimal choice of capital and labor are all homogeneous of degree one in $(A, \exp(z))$ so we can rescale all variables by $\exp(z)$.

The Bellman equation along a balanced growth path with constant prices W and r of a producer with rescaled net worth $a = A/\exp(z)$ and productivity e_i is given by:

$$V^m(a, e_i) = \max_{a',c} \log(c) + \beta \sum_m f_{i,j} V^m(a', e_j). \tag{6}$$

The budget constraint of the producer is

$$c + a' = (1 - \theta\chi)\, \pi^m(a, e) + (1+r)\, a \tag{7}$$

where

$$\pi^m(a, e) = \max_{k,l} \exp(e + \phi)^{1-\eta} \left(l^\alpha k^{1-\alpha}\right)^\eta - Wl - (r + \delta)\, k. \tag{8}$$

The borrowing constraint reduces to:

$$k \leq \frac{1}{1-\theta} a + \frac{\theta}{1-\theta} \kappa. \tag{9}$$

Expressions (7)-(9) simply rewrite the budget constraint (5) and the borrowing constraint (3) of producers in the modern sector given the new notation.

The net worth accumulation decision of the producer is characterized by

$$\frac{1}{c(a, e_i)} = \beta \sum f_{i,j} \left[(1+r) + \frac{1}{1-\theta} \mu(a', e_j)\right] \frac{1}{c(a', e_j)}, \tag{10}$$

[8] This restriction does not bind for most of the experiments we consider, since our parameterization assumes that one of the elements of the worker's efficiency, ν_t, is equal to 0, so that the natural borrowing limit is also equal to zero.

where $\mu(a,e)$ is the multiplier on the borrowing constraint (9). Notice how the expectation that the borrowing constraint will bind in future periods raises the producer's return to savings and thus the amount of net worth that the producer accumulates.

Finally, the choice of capital and labor reduce to

$$\alpha\eta\frac{y(a,e)}{l(a,e)} = W \tag{11}$$

and

$$(1-\alpha)\eta\frac{y(a,e)}{k(a,e)} = r+\delta+\mu(a,e). \tag{12}$$

Dispersion in the net worth and productivity of entrepreneurs, in the presence of borrowing constraints, leads to dispersion in the marginal product of capital of individual producers and generates TFP losses from misallocation. Notice that the producer's permanent productivity component, z, does not appear anywhere in the rescaled formulation of the problem and thus does not have an independent effect on allocations. A producer that is twice more productive and has twice more assets is thus equally constrained.

Panel A of Figure 1 illustrates how the modern sector producers' *shadow cost of funds*, $r+\mu(a,e)$, varies with their net worth and productivity. Clearly, more productive producers are more constrained for any given level of net worth. Panel B of Figure 1 illustrates the savings decision of producers. Rich producers dissave as long as they are sufficiently impatient relative to the interest rate, while poor producers save to relax future borrowing constraints.

The decision rules in Figure 1 imply that producer entry and transitory productivity shocks are the only source of dispersion in the producers' shadow cost of funds. Since poor producers save and rich producers dissave, absent productivity shocks and producer entry the distribution of net worth across producers would converge to a mass point.[9] If, however, entering producers start with insufficient net worth or if productivity shocks are large, financial frictions generate dispersion in the shadow cost of funds and efficiency losses.

Producers in the Traditional Sector. Consider next the problem of producers in the traditional sector. Let $a=-d$ denote these producers' net worth. The Bellman equation of such producers is:

$$V^{\tau}(a,e_i) = \max_{a',c}\log(c) + \beta\max\left\{\sum_j f_{i,j}V^{\tau}(a',e_j),\ \sum_j f_{i,j}V^{m}(a',e_j)\right\},$$

[9] See Banerjee and Moll (2009) who make a related point.

subject to

$$c + x = \pi^{\tau}(e) + (1 + r)\, a, \tag{13}$$

where

$$\pi^{\tau}(e) = \max_{l} \exp(e)^{1-\eta} l^{\eta} - Wl$$

are the profits of a producer in the traditional sector, and x are its savings.

The producer's continuation value is the envelope over the expected value of the two options it has: staying in the traditional sector, or switching to the modern sector. The evolution of its net worth is a function of whether the producer switches. A producer that stays in the traditional sector simply inherits its past savings, $a' = x$. In contrast, a producer that enters the modern sector has

$$a' = x - \kappa + \theta\chi p(a', e_i), \tag{14}$$

where $p(a', e_i)$ is the price (rescaled by $\exp(z)$) of a claim to the entire stream of the producer's future profits and satisfies

$$p(a, e_i) = \frac{1}{1+r} \sum_{j} f_{i,j} \left[p(a', e_j) + \pi^{m}(a', e_j) \right]. \tag{15}$$

The law of motion in (14) and the budget constraint in (13) simply restate the original budget constraint (4) of a producer that switches to the modern sector given the new notation. A producer that decides to switch must pay the entry cost κ, and receives an injection $\theta\chi p(a', e_i)$ from selling claims to a fraction $\theta\chi$ of its entire stream of future profits.

The fact that producers in the modern sector can borrow against their intangible capital implies that their net worth can be negative. The collateral constraint is not, however, the only constraint that the producer faces. Since debt is uncontingent here, the natural borrowing constraint,

$$a > a_{\min} = -\frac{(1 - \theta\chi)\, \pi^{m}(a_{\min}, e_1)}{r}, \tag{16}$$

which requires that the producer be able to repay its debt under the worst-possible sequence of productivity shocks, may be more stringent than the collateral constraint. Hence, even absent a collateral constraint, a producer may choose not to enter the modern sector until it accumulates enough savings to maintain a level of net worth above the borrowing limit. Ability to issue equity and introduce state-contingency into the repayment schedule is thus critical for this economy's ability to achieve an efficient rate of entry into the modern sector. Figure 2 illustrates the producer's entry decision.

2.3 Equilibrium

We define next the equilibrium of this economy. Let $n_t^m(a,e)$ be the measure of modern-sector producers and $n_t^\tau(a,e)$ be the measure of traditional-sector producers. Clearly, the measures of producers in the two sectors must add up to $N_t = \gamma^t$:

$$\int_{A\times E} dn_t^m(a,e) + \int_{A\times E} dn_t^\tau(a,e) = N_t.$$

To characterize the evolution of these measures, let $\xi(a,e)$ be an indicator for whether a producer in the traditional sector switches to the modern sector. Let $A = [\underline{a}, \overline{a}]$ denote the compact set of values a producer's net worth can take and $\mathcal{A}$ denote a family of its subsets.

The measure of producers in the modern sector evolves over time according to:

$$n_{t+1}^m(\mathcal{A}, e_j) = \int_A \sum_i f_{i,j} \mathrm{I}_{\{a^m(a,e_i)\in\mathcal{A}\}} dn_t^m(a,e_i) + \int_A \sum_i f_{i,j} \mathrm{I}_{\{\xi(a,e_i)=1,\ a^{\tau,s}(a,e_i)\in\mathcal{A},\}} dn_t^\tau(a,e_i), \tag{17}$$

where $a^m(.)$ is the savings decision of a producer in the modern sector and $a^{\tau,s}(.)$ is the amount of net worth a producer that switches sectors carries into the next period. The law of motion (17) simply adds up producers in the modern sector and those producers in the traditional sector that decide to switch.

Similarly, the measure of producers in the traditional sector evolves according to:

$$n_{t+1}^\tau(\mathcal{A}, e_j) = \int_A \sum_i f_{i,j} \mathrm{I}_{\{\xi(a,e_i)=0,\ a^\tau(a,e_i)\in\mathcal{A}\}} dn_t^\tau(a,e_i) + (\gamma - 1) N_t \mathrm{I}_{\{0\in\mathcal{A}\}} \bar{f}_j, \tag{18}$$

where $\bar{f}_j$ is the stationary distribution of the transitory productivity and $a^\tau(.)$ is the savings decision of a producer that remains in the traditional sector. This last expression simply adds up producers that stay in the traditional sector and newly entering producers.

A *balanced growth equilibrium* is a set of prices W, r and $p(a,e)$, policy functions for workers, $c_t^w(a,\nu)$ and $a_{t+1}^w(a,\nu)$, for producers, $c_t^j(a,e)$ and $a_{t+1}^j(a,e)$, where $j \in \{\tau, \tau s, m\}$, a switching decision $\xi(a,e)$ for producers in the traditional sector, measures $n_{t+1}^\tau(a,e)$ and $n_{t+1}^m(a,e)$, as well as output, labor and capital decisions by the producers, $y^\tau(e)$, $l^\tau(e)$, $y^m(a,e), l^m(a,e), k^m(a,e)$ that satisfy (i) the labor market clearing condition

$$L_t = \int_{A\times E} l^\tau(e)\, dn_t^\tau(a,e) + \int_{A\times E} l^m(a,e)\, dn_t^m(a,e),$$

where $L_t = \gamma^t$ is the total amount of efficiency units of labor supplied by workers (we normalize the mean of ν to unity), (ii) the asset market clearing condition:

$$A^w_{t+1} + \sum_{i=m,\tau} \int_{A\times E} \sum a^i_{t+1}(a,e)\, dn^i_{t+1}(a,e) = \int_{A\times E} k^m_{t+1}(a,e)\, dn^m_{t+1}(a,e), \tag{19}$$

as well as (iii) producer and worker optimization, (iv) the no-arbitrage condition (15), and (v) the laws of motion for the measures in (17) and (18). The asset market clearing condition can also be rewritten as:

$$C_t + K_{t+1} - (1-\delta) K_t + X_t = Y_t, \tag{20}$$

which states that total consumption and investment in both types of capital is equal to the total amount of output produced by the two sectors.

All variables that we have indicated with time subscripts, such as the consumer decision rules and the measures of producers, grow at a constant rate γ along a balanced growth path. All other variables, such as producer decision rules and the equity pricing functions, are time-invariant. To solve for the balanced growth equilibrium, we rescale all variables that grow over time by γ^t and solve the resulting stationary system.

2.4 Efficient Allocations

Financial frictions reduce TFP in this economy via two channels, by distorting entry into the modern sector, as well as by generating losses from misallocation in the modern sector. We measure the strength of these two channels by conducting two separate calculations. The first calculation computes the size of TFP losses in the modern sector that arise due to misallocation of capital across existing producers, *taking as given* the stationary measure n^m that characterizes the equilibrium of our model economy. We think of this calculation as answering a similar question to that posed by Hsieh and Klenow (2009). Our second calculation computes the levels of consumption, output and TFP, as well as measures of producers that characterize the solution to the problem of a planner that faces no restrictions on how to allocate labor and capital across productive units. This calculation answers a broader question: by how much is total consumption in this economy reduced by the distortions financial frictions induce along both the extensive and intensive margin?

TFP Losses from Misallocation in the Modern Sector. Let i index producers, M be the set of all producers operating in the modern sector, and L and K denote the total amount of labor and capital used in that sector. Integrating the decision rules (11) and (12) across producers gives the following expression for the total amount of output produced by the modern sector:

$$Y = \underbrace{\exp(\phi)^{1-\eta} \frac{\left(\int_{i \in M} \exp\left(e_i\right)\left(r+\delta+\mu_i\right)^{-\frac{(1-\alpha)\eta}{1-\eta}} di\right)^{1-\alpha\eta}}{\left(\int_{i \in M} \exp\left(e_i\right)\left(r+\delta+\mu_i\right)^{\frac{\alpha\eta-1}{1-\eta}} di\right)^{(1-\alpha)\eta}}}_{=TFP} \left(L^{\alpha} K^{1-\alpha}\right)^{\eta}, \tag{21}$$

The first term of this expression gives the TFP of the modern sector, which reflects the exogenous productivity gap, ϕ, and an endogenous component that depends on the measure of producers operating, their efficiency, and the extent to which they are constrained.

To compute the efficient level of TFP given the set M of producers that operate in the original economy, consider the problem of allocating capital and labor across these producers in order to maximize total output in the modern sector,

$$\max_{k_i, l_i} \int_{i \in M} \exp\left(e_i + \phi\right)^{1-\eta} \left(l_i^{\alpha} k_i^{1-\alpha}\right)^{\eta} di,$$

subject to the constraint that the planner uses the same amount of aggregate labor and capital as in the original economy. The solution to this problem requires that the marginal product of capital and labor is equalized across producers, and the efficient level of output is given by

$$Y^e = \underbrace{\exp(\phi)^{1-\eta} \left(\int_{i \in M} \exp\left(e_i\right) di\right)^{1-\eta}}_{=TFP^e} \left(L^{\alpha} K^{1-\alpha}\right)^{\eta} \tag{22}$$

Note that the decreasing returns to scale we have assumed at the producer level generate a love-for-variety effect: TFP increases with the number of producers operating in the modern sector, under both the original and the efficient allocations.

Comparing (21) and (22) and using the fact that the shadow cost of capital, $r + \delta + \mu$, is proportional to its average product, as in (12), the TFP losses from misallocation are:

$$\text{TFP losses} = \log\left(\int_{i \in M} \exp\left(e_i\right)\right)^{1-\eta} - \log \frac{\left(\int_{i \in M} \exp\left(e_i\right)\left(\frac{y_i}{k_i}\right)^{-\frac{(1-\alpha)\eta}{1-\eta}}\right)^{1-\alpha\eta}}{\left(\int_{i \in M} \exp\left(e_i\right)\left(\frac{y_i}{k_i}\right)^{\frac{\alpha\eta-1}{1-\eta}}\right)^{(1-\alpha)\eta}}. \tag{23}$$

To build intuition for (23), suppose that the logarithm of y_i/k_i and e_i are jointly normally distributed. Equation (23) then reduces to

$$\text{TFP losses} = \frac{1}{2}\frac{(1-\alpha\eta)(1-\alpha)\eta}{1-\eta}\text{var}\left(\log(y_i/k_i)\right),$$

so that the TFP losses are proportional to the variance of the average product of capital. Intuitively, the efficient allocations entail equalization of the marginal (and here average) product of capital. Dispersion in the average product of capital thus generates TFP losses.

Clearly, the fact that the dispersion in the average product of capital maps one-for-one into the TFP losses from financial frictions reflects our stark assumption that there are no other sources of variation in the average product of capital, either efficient (for example, differences in technology) or inefficient (for example, differences in markups). In richer environments that allow for such sources expression (23) does not reflect the TFP losses from misallocation induced by financial frictions and must be modified accordingly.

Efficient (First-Best) Allocations. To compute the efficient allocations we must also characterize the optimal allocation of producers across the two sectors. We do so by solving the problem of a planner that is only constrained by the aggregate resource constraint in (20) and the production technologies we have assumed. The planner's problem is to choose the stock of capital, K, the measures of producers in the two sectors, n_i^τ and n_i^m, and the allocation of labor across sectors, L^τ and L^m, to maximize

$$\left(\sum_i \exp(e_i)\, n_i^\tau\right)^{1-\eta}(L^\tau)^\eta + \left(\sum_i \exp(e_i+\phi)\, n_i^m\right)^{1-\eta}\left((L^m)^\alpha (K)^{1-\alpha}\right)^\eta \qquad (24)$$
$$-\left(\delta+\frac{\gamma}{\beta}-1\right)K - \frac{\sum_i n_i^m}{\beta}(\gamma-1)\,\kappa,$$

subject to the labor resource constraint, $L^\tau + L^m = 1$, and the restrictions on the measures implied by Markov transition probabilities, $f_{i,j}$. The planner's objective in (24) adds up the output of the two sectors and subtracts the user cost of capital and the sunk cost of entering the modern sector. In deriving (24) we use the assumption that the planner can freely reallocate consumption across all agents, and thus faces a discount factor equal to β/γ.

3 Quantitative Analysis

We parameterize the model to ensure that its microeconomic implications accord with those of the establishment-level data in Korean manufacturing, an environment with relatively well-functioning credit markets. Our Appendix discusses the dataset we use. Briefly, the survey provides information, for each plant with more than five workers, on total revenue, wage bill, intermediate inputs, as well as investment and its capital stock. The dataset covers the years 1991 to 1999. We focus on the years of 1991 to 1996 for most of our analysis, and study the years of Korea's financial crisis of 1997-1998 in the empirical section below. We next discuss how we used these data to parameterize the model and then our results.

3.1 Parameterization

We group parameters into two categories. The first category includes preference and technology parameters that are difficult to identify using our data. We assign these parameters values that are common in existing work. The second category includes parameters that determine the process for entrepreneurial productivity as well as the size of the financing frictions. We pin down these parameters by requiring that the model accounts for the salient features of the Korean data. Table 2 summarizes the parameter values we used in our experiments.

Assigned Parameters. The period is one year. Real output in Korean manufacturing grew at an annual real rate of 8% in the years we study. We consequently set $\gamma = 1.08$. We choose a value of β equal to 0.92γ, consistent with the choice of Buera, Kaboski and Shin (2010), implying that agents are fairly impatient.[10] Capital depreciates at a rate $\delta = 0.06$. The span-of-control parameter is set equal to $\eta = 0.85$, as in Basu and Fernald (1997) and Atkeson and Kehoe (2007). The elasticity of labor in production is set equal to $\alpha = 2/3$.

The worker's efficiency follows a two-state Markov process with $\nu_i \in \{0, 1\}$. We assume that the probability of staying in the zero state is equal to $\lambda_0 = 0.5$ and choose the probability of remaining in the unit state equal to $\lambda_1 = 0.79$, so that the fraction of workers that supply labor in any given period is equal to 70%, a number consistent with Korea's employment to population ratio. The process for worker efficiency pins down the precautionary savings motive and thus the equilibrium interest rate (we assume that our Benchmark economy is a closed economy and thus the equilibrium interest rate satisfies (19)), which, as we discuss below, lies in the neighborhood of 4-5% for the economies parameterized to Korea's level of financial development. These numbers are consistent with the data and the work of Buera,

[10] Since we have assumed logarithmic preferences and consumption grows at a rate γ along a balanced growth path, the discount factor is equal to $\beta/\gamma = 0.92$.

Kaboski and Shin (2011).

Consider next our choice of the relative efficiency of producers in the modern and traditional sector, ϕ. Given that we associate the traditional sector with various forms of non-market activity not covered by government surveys, we cannot use our data to pin down parameters describing this sector.[11] We start by assuming that $\phi = 0.2/(1-\eta)$, so that a producer's efficiency in the modern sector is on average 20% larger than the efficiency of the traditional sector. We then report how our results vary for alternative values of ϕ. We note that when ϕ is equal to $0.2/(1-\eta)$, the profits and output of producers in the modern sector are on average 8 times greater than those of a producer in the traditional sector, while employment is about 5 times greater. These numbers are greater than the size differentials that La Porta and Shleifer (2008) document when comparing formal and informal firms in more than 100 countries (a size ratio of producers in the formal and informal sectors of 1.5 to 2), but smaller than the 15-fold ratio in Mexico and 40-fold ratio in India documented by Hsieh and Klenow (2012). Below we study an alternative parameterization of our model that is consistent with these latter numbers and find that our results are robust to this modification.

Calibrated Parameters. The rest of the parameters are jointly pinned down by the requirement that the model accounts for the establishment-level facts in Korean manufacturing. Panel A of Table 1 lists the moments we used to calibrate the parameters. Table 2 reports the parameter values that achieve the best fit.

To pin down the process for producer-level productivity, we require that the model matches salient features of the output data.[12] Since we abstract from intermediate inputs in our model, the measure of output that most closely relates to that in our model is value added, which we compute by subtracting payments to intermediate inputs from a plant's total sales. We assume that the process for transitory productivity evolves according to an AR(1) process with Gaussian disturbances, which we then discretize using the Rouwenhorst method. We choose σ_ε, the volatility of the transitory shocks, and ρ, the persistence of the transitory component, as well as the variance of the permanent component, σ_z, to simultaneously match the standard deviation of output and output growth rates in the data of 1.31

[11] A similar difficulty arises when researchers attempt to calibrate the value of non-market activity in models of the labor market. See Hagedorn and Manovskii (2008). See also the work of Jeong and Kim (2006) who use cross-sectional earnings data in Thailand to divide occupations into 'modern' and 'traditional' and document large differences in productivity growth across the two sectors.

[12] Many of these statistics have been already documented. See, e.g., Rossi-Hansberg and Wright (2007).

and 0.59, as well as the autocorrelation of output of horizons of one, three and five years of 0.90, 0.87 and 0.85, respectively.

Table 2 reports that the implied persistence of the transitory component is very low, $\rho = 0.25$, while shocks to the transitory component are fairly volatile, $\sigma_\varepsilon = 0.50$. The variance of the permanent component, σ_z^2, is equal to 1.47. These numbers imply that 85% of the cross-sectional variance of productivity is accounted for by the permanent component. The reason for this result is that the autocorrelation of output decays very slowly with the horizon in the data, much slower than the geometric decay of an AR(1) process. The model thus requires a large permanent source of dispersion in producer-level productivity to account for the low degree of mean-reversion in output observed in the data.

We pin down θ and χ, the parameters governing the amount of debt and equity producers can issue, by requiring that the model matches the debt-to-output ratio in Korean manufacturing of 1.2 reported by the Bank of Korea Financial Statement Analysis (FSA)[13] and the 0.3 equity to GDP ratio reported by Beck et. al. (2000) for the years we study.

Since the sunk cost of entering the modern sector, κ, is the only source of investment in an intangible factor in our model, we choose its value to ensure that the ratio of investment in intangibles to value added is equal to 4.6%, a number that the FSA reports for Korean manufacturing. Investment in the sunk cost accounts for about 11% of the total amount of investment along the balanced growth path of our model. The sunk cost is about 30 times larger than the traditional-sector profits and four times larger than the modern-sector profits.

Additional moments. Panel B of Table 1 reports several additional statistics. Notice that the Benchmark model accounts well for the variability of the levels and growth rates of employment and capital in the data. In the model employment and capital are, absent financial constraints, proportional to output and thus equally volatile. This pattern is consistent with the data in which all output moments are broadly similar for capital and employment.

A second set of moments we study are those describing the share of producers, output and factor use of producers in various age groups. A single parameter, γ, determines the rate at which producers enter the modern sector along the balanced growth path of the model. Given that we have chosen γ independently to match the aggregate growth rate of

[13] The FSA reports a debt to sales ratio of 0.5 for Korean manufacturing plants in the mid-90s, which implies a ratio of debt to value-added of 1.2 given that the share of value added in revenue in our data is equal to about 40 percent.

output in Korean manufacturing, the model predicts too few young producers: the fraction of producers younger than five years is equal to 51% in the data, greater than the 32% in the model. Young producers are smaller, however, in the data compared the model: they account for about 20% of all output in the data and 28% in the model.

The last set of statistics we report are those that characterize how establishment growth rates vary with producer age. The model accounts well for this dimension in the data: the youngest establishments (ages 1 to 5) grow about 11% faster than the oldest ones (11 years and older) in both the model and in the data. Our assumption that producers can issue equity at entry is critical for this result. Absent equity financing the youngest establishments would experience annual output (capital) growth rates in excess of 30% (45%).

3.2 Aggregate Implications

We next discuss the effect of financial frictions on aggregate efficiency. We first contrast the aggregate implications of our Benchmark economy with the first-best allocations. We then consider a number of experiments in which we reduce the producer's ability to borrow and issue equity, in both open and closed economies.

Benchmark Economy. The column labeled "Korea" of Table 3 reports the key aggregate statistics of the Benchmark economy. Financial constraints play a negligible role here as only 17% of producers in the modern sector are constrained. The capital-output in the modern sector is equal to 2.59, close to that prevailing in the absence of financial frictions ($(1-\alpha)\,\eta/(r+\delta) = 2.65$). The TFP losses from misallocation in the modern sector are small as well, about 0.3%.

Financial frictions do not affect the extensive margin either. All new producers finance the sunk cost of entry by issuing equity and enter the modern sector immediately. The fraction of producers in the modern sector is thus equal to $1/\gamma = 0.93$, the maximum attainable given that entry into the modern sector occurs with a period delay.

Comparison to First-Best Allocations. We next compare the allocations in our Benchmark economy with those under the first-best allocations. The TFP of the modern sector is only 0.3% higher under the first-best allocations, reflecting the small misallocation losses in our Benchmark economy. As in the Benchmark model, all producers enter the modern sector after a one-period delay.

One dimension along which the Benchmark model differs from the first-best allocations is the level of consumption and investment. Since markets are incomplete, agents save for precautionary reasons and the interest rate in the Benchmark economy is too low relative to the rate of time preference (4.7% in the model compared to $(\beta/\gamma)^{-1} - 1 = 8.7\%$). The Benchmark model is thus characterized by over-investment: the capital-output ratio is about 35% larger than under the efficient allocations. As a result of this inefficiency, consumption is about 2% lower in the Benchmark model than under the first-best allocations.

Effect of tightening the collateral constraint. Open Economy. Panel A of Table 3 reports the effect of lowering θ, the collateral constraint, from unity to zero in an open economy setting in which the interest rate remains unchanged at its value of 4.7%. We leave χ, the equity issuance constraint, at its value of 0.10 in the Benchmark model.

Clearly, as θ declines, so does the debt-to-output ratio. Absent a financial constraint the modern sector is a net borrower: its aggregate debt to output ratio is equal to 1.3. In contrast, when $\theta = 0$, the modern sector is a net lender: its debt-to-output ratio is equal to -0.6. Since the amount of equity producers can issue is equal to $\theta\chi p(a, e)$, the decline in θ also reduces the equity to output ratio of the modern sector from about 30% to 0. The decline in θ raises the fraction of modern-sector producers that are constrained from 17% under the Korean parameterization to 83% when θ is equal to zero. The increase in the severity of the borrowing constraints lowers the capital-output ratio from about 2.6 to 2.

Tighter borrowing constraints also manifest themselves in a reduced TFP of the modern sector. TFP declines from about 1 in the absence of a borrowing constraint to 0.83 when producers cannot borrow. The losses from misallocation are equal to 4.7% when θ is equal to zero and account for only about one quarter of the decline in TFP. The bulk of the TFP decline is thus due to the considerable drop in the fraction of modern-sector producers, from 93% absent a borrowing constraint to 35% when producers cannot borrow.

The decline in the number of producers in the modern sector associated with a tightening of the borrowing constraint leads to an increase in the level of TFP and output of the traditional sector. Nevertheless, since that sector is less efficient, tighter borrowing constraints substantially reduce aggregate consumption and output. Aggregate consumption drops by about 18% when we reduce θ from 1 to 0, while aggregate output drops by about 40%.

Effect of eliminating equity issuance. Open economy. Panel B of Table 3 reports the aggregate implications of economies in which producers cannot issue equity. The aggregate implications of economies with and without equity issuance are very similar for extreme values of θ of 1 and 0. Inability to issue equity does, however, have sizable consequences for intermediate values of θ. Consider, for example, an economy in which θ is equal to 0.75. In this case both the economies with and without equity issuance have similar debt to output ratios of about 0.90. The measure of modern-sector producers is, however, much greater in the economy with equity issuance (0.93) than in the economy without (0.61). Consequently, the TFP of the modern sector is about 7% lower absent equity issuance, as is aggregate consumption. Losses from misallocation account for a small fraction of this gap: they are equal to 1.4% in the economy with equity issuance and increase to only 2.7% in the economy without equity.

Effect of financial frictions in a closed economy. Table 4 reports the effect of reducing θ and χ in a closed economy setting in which the interest rate declines.

Note that the TFP losses from misallocation are now twice larger relative to those in the corresponding open economy experiments. The maximal misallocation losses in economies with no external finance are now equal to about 10%, compared to 5% in the open economy experiments. Also notice that the debt to output and capital to output ratio of producers in the modern sector declines much more gradually as we reduce θ, especially in the environment without equity issuance, reflecting the decline in the interest rate.[14]

Overall, we conclude that closed-economy versions of the model predict greater TFP losses from misallocation across producers in the modern sector. Intuitively, the interest rate decreases in a closed economy in response to a tightening of financial constraints, thus leading to a greater desired level of capital stock for unconstrained producers. The lower the interest rate is, the longer it therefore takes for relatively poor young producers to catch up to the capital stock of the relatively wealthy old producers, and the greater the dispersion in the marginal product of capital. For example, the variance of the marginal product of capital is only equal to 0.14 in the open-economy version of our model with no external finance, and it increases to 0.30 in the closed-economy version in which the interest rate is much lower.

Notice finally that, as earlier, the bulk of the drop in consumption and output in economies with tight financial constraints arise due to distortions along the extensive margin. Only

[14]See also Buera and Moll (2012) who derive a related result.

about one-third of producers operate in the modern sector in an economy without external finance, and these jointly account for less then half of the overall output.

Role of ϕ. Since financing frictions can severely distort entry into the modern sector, the gap between the productivity of the two sectors plays an important role for the model's implications for TFP. We next explore how the losses from financing frictions vary with the size of this gap. We study two additional experiments. In the first experiment we eliminate the productivity gap between the two sectors altogether by setting $\phi = 0$. In the second experiment we assume a 40% productivity gap, by setting $\phi = 0.4/\left(1-\eta\right)$. [15] In this latter latter experiment the relative size of producers in the modern to traditional sectors is equal to 40, a number consistent with the evidence from Hsieh and Klenow (2012) on the relative size of the formal and informal establishments in India.

Table 5 reports the results of these experiments. Absent a productivity gap, the model predicts very small losses from financial frictions. The maximal TFP losses from misallocation in the modern sector are only 0.4% in an open economy experiment in which $\theta = 0$. Although financial frictions prevent most producers from entering the modern sector, aggregate consumption in this economy declines little in response to a tightening of the collateral constraint since the losses from a suboptimal mix of producers are negligible.

In contrast, when the productivity gap is equal to 40%, the model predicts larger losses from misallocation (9% in an open economy with no external finance), but even greater losses from distortions along the extensive margin. Consumption in an economy with no external finance is about 35% below its level in the economy calibrated to Korea's level of financial development, mostly reflecting the fact that the share of producers in the modern sector is inefficiently low (28%).

Summary. To summarize, financial frictions can reduce substantially the level of TFP, output and consumption in our model economy. The bulk of these losses arise due to the distortions associated with the decision to enter the modern sector. The larger the gap in productivity between the traditional and the modern sector, the more difficult it is for producers in the traditional sector to accumulate funds to finance entry into the modern sector and thus the larger the aggregate efficiency losses.

[15] We use the parameter values from the Benchmark experiment here and solve the the new equilibrium wage and interest rate.

4 Extensions of the Model

We next consider several extensions of our Benchmark model and discuss these models' aggregate and micro-economic implications. We introduce (i) a technology adoption decision and (ii) a fixed cost of operating in the modern sector which generates producer exit. Both of these extensions reinforce the conclusions we derive using our Benchmark model.

4.1 Economy with technology adoption

We now suppose that producers in the modern sector have the option to adopt a more productive technology by paying a fixed cost, κ_p. The more productive technology is

$$Y_t = \exp\left(z + e_t + \phi + \phi_p\right)^{1-\eta} \left(L_t^{\alpha} K_t^{1-\alpha}\right)^{\eta},$$

where $\phi_p > 0$. That is, the firm's productivity increases by $\exp\left(\phi_p\right)^{1-\eta}$ upon paying the fixed cost of adoption.

We choose parameters for this model using the same strategy we used in our Benchmark model. We set $\phi_p = 0.27/\left(1-\eta\right)$, implying that the producer's productivity grows by 27% on average over its lifetime, a number that we calculate using the establishment-level data for Korea. We assume that the sunk cost of adopting the productive technology, κ_p is proportional to the cost of entering the modern sector and scales with the productivity gap, $\kappa_p = \exp\left(\phi_p\right)\kappa$. We set κ as earlier, to ensure that the total amount spent on investment in intangibles (including both the cost of entry and that of technology upgrading) is equal to 4.6% of total output in the modern sector.

Tables 1 and 2 present the full set of moments and parameters in this set of experiments. The model does a good job at accounting for the features of the data that we explicitly target, with the exception of the higher-order autocorrelations which now decay faster with the horizon. As for the moments that we have not targeted, the model does a better job at accounting for the fact that young producers are relatively small in the data, but overstates the extent to which young producers grow. Growth now occurs not only because producers accumulate internal funds, but also because of the technology improvements which are, in the model, are less gradual than in the data.

Table 6 (columns labeled 'Adoption') reports the effect of eliminating external finance by setting $\theta = 0$ in an open economy setting. Doing so has sizable consequences for TFP, consumption and output. Consumption declines by about 0.35 log-points relative to its level in the economy that reproduces Korea's financial statistics, output drops by about 0.47 log-points and TFP in the modern sector declines by about 0.26 log-points. As earlier, most of these losses arise due to the distortions along the extensive margin. While in the economy with relatively developed financial markets most producers adopt the productive technology, only 18% of producers do so in the economy with no external finance. Note also that the TFP losses from misallocation are slightly larger (6.3%) than in the economy without technology adoption and no external finance (4.7%), but fairly modest relative to the losses arising from the distortions along the extensive margin.

Overall, our results based on the model with technology adoption reinforce our earlier conclusions that financial frictions can have sizable effects on aggregate efficiency. These frictions mostly operate through the extensive (entry and technology adoption) margins and have a relatively modest impact on the amount of capital misallocation within a sector.

4.2 Economy with Producer Exit

In our Benchmark model producers operating in the modern sector never exit. As a result the model cannot account for the large number of young producers in the Korean establishment-level data. We next ask whether explicitly allowing for producer exit changes the model's predictions. We assume that producers operating in the modern sector face a fixed operating cost per period. As with the sunk cost, we assume that the fixed cost is proportional to a producer's permanent productivity component.

In any given period a producer in the modern sector must decide whether to pay the fixed cost and use the modern technology or use instead the traditional technology which requires no fixed cost. The producer's problem is similar to that in the Benchmark setup, except that its budget constraint is

$$c + a' = \max\left[\pi^m\left(a, e_i\right) - WF, \pi^\tau\left(e_i\right)\right] + (1 + r)\, a,$$

reflecting the additional fixed cost F required to operate in the modern sector, and the choice of the sector in which to operate. We assume that a producer pays the cost of entering the modern sector only once, the first time it enters, and can switch at no cost in future periods.

We calibrate the model to match the salient features of the Korean data in Table 1. One notable difference relative to our Benchmark model is that we now require much more volatile productivity shocks (with a standard deviation of 0.96 compared to 0.50 earlier) to account for the variability of output in the data. Intuitively, the distribution of output growth rates is now truncated – the least efficient producers exit the modern sector, and more volatility in the underlying efficiency is required to reproduce the same volatility of output growth rates.

We include an additional moment, the fraction of young (ages 1 to 10) producers in order to pin down the size of the fixed cost of operating. Given that the fixed cost we calibrate is fairly high (9.4% of the overall amount of labor employed by the modern sector), 26% of producers in the modern sector choose to exit in any given period. The model is thus capable of reproducing the large fraction (78%) of young producers in the data.

The column labeled 'Exit' in Table 6 reports the aggregate implications of this model. Notice that, absent external finance, the losses from misallocation in the modern sector are somewhat smaller than those in an economy without exit (4.7% in our Benchmark model compared to 4.1% in the model with exit). The reason misallocation declines, despite the increase in the variability of productivity shocks, is that the most constrained producers in the modern sector now choose to exit, thus lowering the dispersion in the average product of capital of those producers that survive. For this reason misallocation once again accounts for a relative small fraction of the overall efficiency losses induced by financial frictions.

4.3 Microeconomic Implications

Table 6 also reports the implications for several microeconomic statistics of tightening financial frictions in the various models that we have studied. (See our Appendix for additional statistics that we report.)

A first implication of the model is that financial frictions act like an adjustment cost by preventing constrained firms from adjusting their capital in response to changes in productivity. To see this, notice that the standard deviation of output growth declines as we tighten the borrowing constraint. For example, in the Benchmark model the standard deviation of output growth falls from 0.58 in the economy calibrated to Korea's financial statistics to 0.32 in the economy without external finance.

The Benchmark model also predicts that more severe borrowing constraints tend to disproportionately affect young producers who have not yet accumulated internal funds. To see this, note that the average product of capital of young (ages 1-5) producers is only about

0.08 log-points greater than that of old (ages 11 and above) producers in an economy with Korea's level of financial development. Eliminating external finance altogether increases the relative average product of capital of the young producers to 0.73 log-points. The fact that the borrowing constraints are more severe for young producers also shows up in their relative growth rates. In the Benchmark model young producers grow 8% faster than old producers in the economy calibrated to Korea, and 12% faster when we eliminate external finance.[16]

Importantly, this last set of implications of the Benchmark model is not robust across the different versions of the model we considered. Consider first the economy with technology adoption. In this environment financial frictions reduce, rather than increase, the relative growth rate of young producers and their average product of capital since they prevent the adoption of the more efficient technology early in the life-cycle. This model can thus rationalize the observation of Hsieh and Klenow (2012) that plants in less developed economies grow slower than those in the U.S.[17]

The economy with exit makes similar predictions. Differences in the strength of financial frictions have much smaller effects here on the gap between the average product of capital of young and old producers since the most constrained young producers choose to exit. This selection effect also implies that tighter financial frictions reduce, rather than increase, the relative growth rate of young producers.

5 Capital Misallocation in Economy without Entry

We study next an economy without entry in which all producers operate in the modern sector. We then conduct a number of additional experiments to further gauge the robustness of our results about the effect of financial frictions on capital misallocation.

5.1 Baseline Model

We set $\gamma = 0$ to eliminate producer entry and adjust θ, as well as the parameters describing the process for producer productivity, to match the debt-to-output ratio in Korean manufacturing as well as the variability and persistence of producer-level output in the data. In

[16] See also Cooley and Quadrini (2001) who discuss this implication of the model.

[17] See the work of Cole, Greenwood and Sanchez (2012) who explicitly model the frictions that prevent producers in developing countries from adopting the high-growth technologies adopted in the U.S. and account for the pattern of plant growth in Mexico, India and the U.S.

Table 7 (rows labeled 'Baseline') we see that the model predicts fairly small losses from misallocation, equal to 2.5% for the economy calibrated to Korea's financial statistics and 3.4% in the open economy version of the model with no external finance. The reason the losses for the Korean calibration are somewhat greater than those in the economy with entry is that matching Korea's debt-to-output ratio requires now a tighter collateral constraint, $\theta = 0.57$ (0.86 earlier), and more volatile productivity shocks, $\sigma_\varepsilon = 0.83$ (0.50 earlier).

The requirement that the model replicates the variability of output growth in the data is critical to our finding of small productivity losses from misallocation. To see this, suppose we triple the volatility of productivity shocks. When we do so (Table 7, rows labeled 'Volatile productivity shocks'), the TFP losses from misallocation increase to 5.6% for an economy with Korea's debt to output ratio, 20% for an open economy with no external finance and as much as 30% for a closed economy with no external finance. Intuitively, financial frictions act like an adjustment cost on capital and can severely distort allocations if changes in productivity are large. Large fluctuations in a producer's productivity generate, however, much more volatility in output compared to the data.

We next explore the role of ρ, the persistence of productivity shocks, in determining the size of the losses from misallocation. We increase ρ to 0.9, three times its value in the Baseline model, and report the results of this experiment in the rows labeled 'Persistent productivity' of Table 7. We find that the losses from misallocation are greater now compared to those in our baseline setup with more transitory shocks: 8.2% in an open economy with no external finance compared to 3.4% earlier. Intuitively, a more persistent shock lasts for a larger number of periods, and since it takes time for the producer to grow out of the borrowing constraint, misallocation persists. Once again, however, the model with persistent transitory shocks cannot account for the rate at which the autocorrelation of output decays with the horizon in the data.[18]

One way to bound the size of the TFP losses from misallocation arising from the producer's inability to change its capital in response to productivity shocks is to calculate the TFP losses in an environment in which the capital stock does not respond at all to such

[18] See also the work of Buera and Shin (2011) and Moll (2012) who study in more detail the role of persistence in this class of models.

shocks. In this case the TFP losses from (23) simplify to

$$\text{worst TFP losses} = (1-\eta)\log\int \exp(e_i) - (1-\alpha\eta)\log\int \exp(e_i)^{\frac{1-\eta}{1-\alpha\eta}} \tag{25}$$

and are equal to

$$\frac{1}{2}\frac{(1-\alpha)\,\eta}{1-\alpha\eta}\,(1-\eta)\,\sigma_e^2$$

when e_i is log-normally distributed with an unconditional variance equal to σ_e^2.

In our baseline model without producer entry the unconditional variance of the transitory productivity component is equal to 0.76 ($0.83^2/(1-0.3^2)$), so (25) implies an upper bound on the TFP losses from frictions that prevent capital reallocation of 3.7%. These losses are nearly as large as in the version of the model without external finance (3.4%), suggesting that financial frictions do indeed severely distort producers' ability to change their capital stocks in response to changes in productivity. The reason such frictions do not generate much larger TFP losses is that the transitory productivity shocks are simply not large enough to generate much misallocation. In contrast, in the 'Volatile productivity shocks' economy the variance of productivity is 9 times larger, and so are the worst-case TFP losses (33%). In this latter environment financial frictions have the potential to generate much larger losses from misallocation, and they do so indeed.

5.2 Robustness Extensions

We next discuss several additional robustness experiments we have conducted using the model without producer entry. The extensions, which are discussed in more detail in the Appendix, study the role of physical restrictions on capital adjustment, variable markups, as well as capital-specific productivity shocks. We recalibrate parameters in all these experiments to reproduce the same set of moments in the data as we have done in the baseline economy without entry. For each economy, we report the results from an economy in which θ is chosen to match Korea's debt-to-output ratio of 1.2, as well as an economy with no external finance and a constant interest rate.

Predetermined capital Our baseline model assumes that borrowing constraints are the only friction that prevents capital from responding to productivity shocks. Empirical evidence suggests, however, that physical adjustment costs are also non-negligible.[19]

[19] See, for example, Cooper and Haltiwanger (2006).

A simple way to introduce capital adjustment frictions is to assume that the capital stock in period t is chosen before the producer learns its productivity in that period. We do so next and recalibrate the model to account for the variability and persistence of output in the data. Since capital can no longer respond to contemporaneous productivity shocks, the model requires a much larger volatility of shocks, $\sigma_\varepsilon = 1.45$ (compared to 0.83 in the baseline model) to account for the variability of output growth rates in the data.

As for its implications for the TFP losses from misallocation, Table 7 shows that the model's efficiency losses due to financial frictions are less than 1%. The reason these losses are small is that financial frictions act much like adjustment frictions do and their role is offset by the technological constraints that prevent reallocation.

Notice that with capital adjustment frictions we can no longer use (23) to compute the TFP losses due to financial frictions. This expression interprets all dispersion in the average product of capital across producers as inefficient and ignores the additional technological restriction that we now impose. Instead, we compute the efficiency losses due to financial frictions by comparing the level of TFP in our economy with the level of TFP that a planner can achieve subject to an identical technological constraint. Equation (23) does predict substantial TFP losses (we refer to these as *measured TFP losses*), of about 10%, but these simply reflect the constraints on the physical environment that a planner also faces.

Also notice that the model with predetermined capital no longer implies that a tightening of the financial constraint reduces the variability of output. Incidentally, this prediction of the model is consistent with the data. As we document in the Appendix, the extent to which capital and output respond to productivity shocks is largely independent of a country's degree of financial development. Individual producers' capital stocks are indeed irresponsive to shocks to productivity in the data, but this is true for all countries.

Variable Markups We next introduce variable markups and argue that our results are robust to this modification. We assume that each producer sells an imperfectly substitutable variety, faces an iso-elastic demand for its goods and produces output uses a Cobb-Douglas technology with constant returns to scale. We introduce variable markups by assuming that producers choose their prices prior to observing their productivity in any given period. This assumption implies that producers cannot decrease prices when faced with positive productivity shocks and so markups positively comove with productivity.

Table 7 shows that this version of the model requires even greater productivity shocks, with a standard deviation of 1.84, to account for the variability of output in the data. Since quantities are demand-determined and prices do not respond to contemporaneous productivity shocks, output responds gradually to changes in productivity. Once again, however, the model predicts small losses from misallocation: 0.3% for Korea's level of financial development and 1.1% for an economy with no external finance. As was the case in the model with predetermined capital, frictions that hinder the producer's ability to respond to shocks imply a smaller role for financial frictions in distorting the reallocation of capital among producers.

Low elasticity of substitution between capital and labor We next argue that our results are also robust to reducing the elasticity of substitution between capital and labor. We modify the production function to

$$y_i = \exp(z + e_i)^{1-\eta} \left[\alpha (l_i)^{\frac{\vartheta-1}{\vartheta}} + (1-\alpha)(k_i)^{\frac{\vartheta-1}{\vartheta}}\right]^{\frac{\vartheta}{\vartheta-1}\eta},$$

set the elasticity of substitution between capital and labor equal to $\vartheta = 0.25$, and choose the weight on labor, α, to ensure that payments to labor are twice as large as payments to capital, as in the baseline model. Table 7 shows that our results are robust: the losses from misallocation range from 1.5% to 3.2% as we tighten the borrowing constraint.

Capital-specific productivity shocks We next assume that productivity shocks are capital-specific rather than Hicks-neutral and modify the production function to

$$y_i = \exp(z)^{1-\eta} \left[\alpha (l_i)^{\frac{\vartheta-1}{\vartheta}} + (1-\alpha)(\exp(e_i) k_i)^{\frac{\vartheta-1}{\vartheta}}\right]^{\frac{\vartheta}{\vartheta-1}\eta},$$

where we maintain the assumption that $\vartheta = 0.25$. Our conclusions based on the baseline model are unchanged: the TFP losses from misallocation in an economy with no producer borrowing are only equal to 1.1%.

5.3 Role of Heterogeneity

We next show that our results are robust to introducing various forms of heterogeneity in production function parameters, as well as in producers' ability to access external finance.

Heterogeneity in labor intensity, α We assume that producers differ in their labor intensity. There are three equally-sized groups of producers (sectors), with labor elasticity given by 0.44, 0.66 and 0.89, respectively. We choose these numbers in order to match the average capital-labor ratio in the Korean data, as well as its 25th and 75th percentiles.

As Table 8 (column labeled 'Labor Share') shows, the more capital-intensive sector is more distorted: the within-sector misallocation losses are about three times as larger than in the most labor-intensive sector. Overall, however, allowing for heterogeneity in α does not change the model's implications much. The TFP losses (which arise from both within- and across-sector misallocation) are equal to 2.6% in the economy with Korea's debt-to-output ratio and increase to only 2.9% in an economy with no external finance. Notice that simply using the dispersion in returns to capital to compute TFP losses from misallocation according to (23) gives, incorrectly, much greater loses from misallocation, about 8%. Such a calculation ignores the fact that most dispersion in the average product of capital in this economy is efficient and simply reflects production function differences.

Heterogeneity in returns to scale, η Consider next the role of heterogeneity in the span of control parameter, η. We assume that producers are uniformly distributed across three sectors, with $\eta_1 = 0.55$, $\eta_2 = 0.85$ and $\eta_3 = 0.95$, numbers chosen to match the 25th and 75th percentile of the cost shares in value added in the Korean data. Table 8 shows that heterogeneity in the span of control parameter does not greatly increase the TFP losses from misallocation: these increase from 1.9% to 2.5% as we move from an the economy with Korea's debt-to-output ratio to an economy with no external finance.

Heterogeneity in collateral constraints, θ We next study the role of heterogeneity in the collateral constraint, θ. We assume that producers are equally divided across three groups, with $\theta_1 = 0.15$, $\eta_2 = 0.58$ and $\eta_3 = 0.85$. We choose these numbers in order to match the 25th and 75th percentile of the debt-to-output ratio across producers in the Korean data, in addition to the aggregate debt-to-output ratio. Heterogeneity in θ has little effect on our results. The most constrained producers accumulate more internal funds, while the least constrained producers accumulate less internal funds, so that in the steady state financial frictions induce small differences in the returns to capital across these groups of producers. The TFP losses from misallocation are only equal to 1.8% in an economy with Korea's level of financial development, thus even smaller than those in the economy without heterogeneity.

Heterogeneity in borrowing rates, r We next assume away the collateral constraints, but that firms differ in the rates at which they can borrow. We think of this experiment as capturing the financial environment in China, in which state-owned enterprises can borrow at much lower rates from state-owned banks than private enterprises can.[20] We assume three sets of producers who can borrow at $r_1 = 0.05$, $r_2 = 0.10$ and $r_3 = 0.15$, respectively, numbers chosen to reproduce the dispersion in borrowing rates in China documented by Qian, Strahan and Yang (2010). All producers can save at a rate equal to 0.05. We parameterize the model to replicate the salient features of China's manufacturing sector documented in the Appendix. In this environment output is somewhat more volatile (the standard deviation of output growth rates is equal to 0.89) and less persistent (the autocorrelation of output is equal to 0.80), while the debt-to-output ratio is about half as large as that of Korean producers (0.7 for producers in the Chinese firm-level data we study).

Table 8 shows that the TFP losses from misallocation are equal to 1.6%. Intuitively, producers that face the higher borrowing rates find it optimal to accumulate more internal funds and avoid borrowing altogether. These producers thus face a much lower shadow cost of funds (about 8%) than the 15% borrowing rate. As a result, the model produces a fairly small gap of about 23% between the average product of capital across the sectors with the highest and lowest borrowing rates. Incidentally, this number is consistent with the data from the Chinese manufacturing sector in which the average product of capital of state-owned enterprises is only about 25% greater than that of privately-owned enterprises.

6 Evidence on Losses from Capital Misallocation

We next use establishment-level data from several developing economies to test the model's predictions about the relationship between the strength of financial frictions and the TFP losses from misallocation. We mostly focus on the losses from misallocation, as opposed to those arising due to distortions along the extensive margin, since we do not observe producers operating in the traditional sector in the data, nor their technology adoption decisions.

Misallocation in our model arises from two channels. First, age differences across producers reflect in differences in these producers' net worth and thus their marginal product of capital. We refer to this source of dispersion as the *age channel*. Second, constrained producers cannot fully change their capital stocks in response to productivity shocks so that the latter cause dispersion in the marginal product of capital. We refer to this second channel as the *adjustment channel*. We next discuss the strength of these channels in the model, and

[20]See Song, Storesletten and Zilibotti (2011).

then in the data. We find, consistent with what our model predicts, that both the age and adjustment channels are weak in the data, and roughly independent of a country's degree of financial development. We finally study data from the Korean financial crisis of 1997-98 and show that our model accounts well for the dynamics of TFP in that episode.

6.1 Losses from Misallocation in the Model

To measure the strength of age channel in our Benchmark model, recall first that in that model the average product of capital is proportional to a producer's shadow cost of funds, implying that the TFP losses from misallocation are summarized by the dispersion in the average product of capital. We next ask: what fraction of the variance of the average product of capital is accounted for by differences in age across producers? To answer this question, we project the logarithm of the average product of capital on a full set of age dummies,

$$\log(Y_i/K_i) = \sum_a \gamma_a D_{a,i} + \varepsilon_i, \tag{26}$$

and isolate the variation in the average product of capital accounted for by differences in age. We then compute the TFP losses in (23) using data on the fitted values in (26).

As Table 9 shows, the bulk (3.7%) of the overall 4.7% TFP losses from misallocation in our Benchmark model with no external finance are accounted for by the age channel, reflecting the fairly large difference in the average product of capital between young and old producers. For example, the average product of capital of young producers is 73% greater than that of old producers in the economy without external finance.

The adjustment channel, in contrast, is very weak in our Benchmark model. Absent external finance, the variance of the residuals in (26) is equal to only about 15% of the overall variance of the average product of capital. Hence, the losses from misallocation within a given age group are fairly small: 1.3% for young producers and 0.8% for old producers. The reason these losses are small, despite the fact that most producers are constrained absent external finance, is that the productivity shocks are simply too small in our Benchmark model.

All the extensions of the Benchmark model we have considered predict fairly small losses from misallocation among modern-sector producers, but disagree on the decomposition of these losses into the two channels. Consider, for example, the model with exit. As Table 9 shows, the overall losses from misallocation are equal to 4.1% in the version of the model without external finance. The age channel is fairly modest (0.7%), reflecting the exit of the most constrained young producers. In contrast, the adjustment channel is more potent, reflecting the much more volatile productivity shocks: the losses from misallocation within a given age group are equal to 4.7% for young producers and 2.5% for old producers.

6.2 Losses from Misallocation in the Data

We next provide evidence from establishment-level panels in China (1998-2007) and Colombia (1985-1990), two countries with relatively weak levels of financial development, on the strength of the age and adjustment channels.[21] Our evidence suggests that both channels are relatively weak in the data, even in environments with poorly developed financial markets.

To construct our measures of losses from misallocation, we use data on output, employment and the producer's capital stock, together with sector-specific information on capital and labor shares, to construct a Solow residual-based measure of producer-level productivity. We then isolate the transitory productivity component for each producer by subtracting the time-series average of each producer's productivity. We use the implied transitory productivity component, $\hat{e}$, together with each producer's average product of capital, y_i/k_i, to compute the *measured TFP losses* using equation (23).[22] As we have shown in some of our experiments equation (23) may overstate the TFP losses from misallocation due to financial frictions, since differences in the average product of capital may reflect differences in technologies, technological barriers to capital reallocation, or other inefficiencies such as taxes or markups. Nevertheless, we find equation (23) useful as it provides an upper bound on the losses from capital misallocation.

As Table 9 shows, the measured TFP losses predicted by (23) are fairly large in the data, consistent with the findings of Hsieh and Klenow (2009), in all datasets we have studied. These losses are somewhat larger in China (22.4%) and Colombia (17.7%) than they are in Korea (16.2%), but the differences are not very large, despite the fact that these countries differ greatly in their level of financial development.[23] These numbers thus suggest that it is

[21] See our Appendix for a detailed description of the datasets we study.

[22] Our Appendix shows that our results are robust to using the Blundell-Bond (1998) method to identify the transitory productivity shocks and estimate the production function parameters.

[23] Recall that the debt to value added ratio in Korean manufacturing is equal to 1.2. Beck et. al. (2000) report that the ratio of external borrowing to GDP in Colombia was equal to about 0.2 in the years we study. The debt to value added ratio of producers in our Chinese dataset is equal to 0.7.

difficult to attribute the bulk of the measured TFP losses in the data to differences in the level of financial development.

Consider next the relative strength of the age channel. We compute the size of this channel using the same approach as in the model, by projecting the average product of capital of individual producers on age dummies and using the projected values to calculate the TFP losses in (23). The data shows little dispersion in the average product of capital across producers of various ages in the countries we study. The youngest producers' average product of capital capital is about 15% greater than that of old producers in China and 25% smaller in Colombia, numbers comparable to the 21% gap in the average product of capital in Korea. Because differences in the average product of capital accounted for by age are small, the TFP losses accounted for by the age channel are small as well, ranging from 0.2% in Korea and 0.3% in China to about 2.7% in Colombia.

Consider next the adjustment channel. As we have argued earlier, the fact that the transitory component of producer productivity is not very volatile in the data implies a very tight bound on the maximal losses from misallocation that can be explained by adjustment frictions. As Table 9 shows, the variance of the transitory productivity component ranges from about 0.24 in Colombia to 0.30 in China and 0.35 in Korea, implying that the worst-case TFP losses in (25) range from about 2 to 3% in the three countries we study.

Given that simply subtracting the time-series average to isolate the transitory productivity component is problematic in small samples, we have also estimated the persistence and standard deviation of the transitory component by fitting an AR(1) model with fixed effects for the Solow residuals computed from the data. When we do so, we find that the implied variance of productivity shocks is only slightly greater than that found by simply subtracting the time-series average from each producer's productivity. For example, Table 9 shows that the autocorrelation of the transitory productivity component in Korea is equal to 0.11, and the standard deviation of its innovations is equal to 0.68. These numbers imply a variance of the transitory productivity component equal to 0.47, thus not much larger than the 0.35 we estimate directly, and also imply very small losses from the adjustment channel.

Finally, Table 9 also reports the measured TFP losses from misallocation within groups of young and old producers. The average product of capital is almost equally dispersed for both young and old producers in all countries we study. For this reason, the measured TFP losses are very similar across age groups in China and Korea, and in fact larger for older producers in Colombia. This feature of the data suggests that adding additional sources of heterogeneity in entering producers' net worth to raise the dispersion of their marginal products of capital is not an empirically promising avenue to generate more misallocation.

Overall, we conclude that our model's predictions are in line with the data. The variability of the transitory productivity that we estimate directly is in the range of what we have calibrated in the various versions of our model and thus not very large. For this reason the data suggests that the costs of having individual producers' capital stocks not adjust to changes in productivity are small. Moreover, we found small differences in the average product of capital across young and old producers, suggesting that plant entry generates small differences in the returns to capital in the data as well.

6.3 Korean Financial Crisis of 1997-1998

The crisis of 1997-1998 in Korea allows us to further test the predictions of the model, as it was associated with a sharp deleveraging of the Korean Manufacturing sector. For example, the debt to equity ratio of Korean Manufacturing producers decreased from about 4 at the beginning of 1997 to 2 by the end of 1998.

Figure 3 reports how our Benchmark model responds to a permanent credit tightening (decline in θ), chosen to reproduce the decline in the leverage ratio in Korea, in an open-economy version of our model without equity issuance.[24] The model implies a fairly large initial increase in the TFP losses from misallocation of about 5%. These losses are reversed, though not fully, in subsequent periods as producers accumulate internal funds. In addition, TFP in the modern sector declines because of a large, though gradual, drop in the number of producers operating in the modern sector. In the new state state with tighter borrowing constraints the number of producers operating in the modern sector is about 30% lower. Overall, TFP declines by about 5% in the immediate aftermath of the credit tightening, and by about 6.5% in the steady state. As the lower-left panel of Figure 3 illustrates, the initial TFP drop is mostly accounted for by an increase in misallocation, while the bulk of the steady-state TFP losses arises due to the drop in the number of producers operating. This

[24] We assume that the shock is unanticipated and use a shooting method to solve for the equilibrium wages and producer decision rules along the transition path. The figure reports deviations from the balanced growth path for variables that grow over time.

extensive margin effect implies a 4.2% drop in the first-best level of TFP.

Consider next what happened in the data. Figure 4 reports the evolution of TFP in the Korean Manufacturing sector in the aftermath of the crisis. The Figure shows an 8% decline in TFP from 1996 to 1998, with the bulk of this decline (6%) accounted for by a decline in the first-best (efficient) level of TFP caused by the 20% decline in the number of producers operating.[25] The data also shows an increase in the amount of misallocation at the beginning of 1999 (reflecting the investment decisions made in 1998, during the peak of the crisis) which brings the overall TFP losses from misallocation to about 5% by the end of our sample. The number of producers quickly recovers in 1999, thus bringing up the first-best level of TFP.

Overall, therefore, our model is capable of generating sizable TFP losses in response to a credit crunch, similar in magnitude to those observed in the data. These losses arise, as in the data, from a combination of capital misallocation and a reduction in the number of producers that operate.

7 Conclusions

We use producer-level data to evaluate the role of financial frictions in reducing aggregate productivity. We study a model of establishment dynamics in which financial frictions may distort aggregate productivity through two channels. First, finance frictions distort entry and technology adoption decisions, thus reducing the productivity of individual producers. Second, finance frictions generate misallocation among existing producers, by inducing inefficient dispersion in their marginal product of capital. Parameterizations of our model consistent with the data predict fairly modest losses from misallocation, but potentially large losses from inefficiently low levels of entry and technology adoption.

Intuitively, financial frictions cannot generate large losses from misallocation because relatively more productive producers accumulate internal funds over time and quickly grow out of their borrowing constraints. In contrast, entry and adoption decisions entail large long-lived investments that pay off only gradually over time and are thus difficult to finance using internal funds. Well-developed financial markets are thus critical in generating efficient

[25]We compute the actual level of TFP using (21) and the first-best level using (22), but modify those equations to include both the permanent and transitory productivity components, $z_i + e_{i,t}$, to explicitly account for the possibility that the distribution of z_i across producers change over time.

levels of entry and technology adoption and increasing aggregate productivity.

References

[1] Amaral, Pedro S. and Erwan Quintin, 2010, "Limited Enforcement, Financial Intermediation, and Economic Development: A Quantitative Analysis *International Economic Review*, 51(3), 785-811.

[2] Angeletos, Marios, 2008, "Uninsured Idiosyncratic Investment Risk and Aggregate Saving," forthcoming, *Review of Economic Dynamics*

[3] Atkeson, Andrew and Patrick Kehoe, 2007, Modeling the transition to a new economy: lessons from two technological revolutions," *American Economic Review*, 97(1): 64-88.

[4] Banerjee, Abhijit V. and Esther Duflo, 2005. "Growth Theory through the Lens of Development Economics,"in: Philippe Aghion & Steven Durlauf (ed.), Handbook of Economic Growth, edition 1, volume 1, chapter 7, pages 473-552.

[5] Banerjee, Abhijit and Benjamin Moll, 2009, "Why Does Misallocation Persist?" forthcoming, *American Economic Journal: Macroeconomics.*

[6] Basu, Susanto and John Fernald, 1997, "Returns to Scale in U.S. Production: Estimates and Implications," *Journal of Political Economy*, 105(2): 249-283.

[7] Beck, Thorsten, A. Demirguc-Kunt, and Ross Levine, 2000, "A New Database on the Structure and Development of the Financial Sector." *WB Economic Review*, 14: 597-605.

[8] Blundell, Richard and Stephen Bond, 1998. "Initial Conditions and Moment Restrictions in Dynamic Panel Data Models," *Journal of Econometrics*, 87, 115-143.

[9] Buera, Francisco J. and Yongseok Shin, 2011. "Self-insurance vs. Self-financing: A Welfare Analysis of the Persistence of Shocks," *Journal of Economic Theory*, 76: 845-862.

[10] Buera, Francisco J., Joseph P. Kaboski and Yongseok Shin, 2011. "Finance and Development: A Tale of Two Sectors," *American Economic Review*, 101: 1964-2002.

[11] Buera, Francisco J., and Benjamin Moll, 2012, "Aggregate Implications of a Credit Crunch,"mimeo.

[12] Castro, Clementi, MacDonald, 2009, "Legal Institutions, Sectoral Heterogeneity and Economic Development," *Review of Economic Studies*, 76: 529-561.

[13] Cole, Harold, Jeremy Greenwood and Juan Sanchez, 2012. "Why Doesn't Technology Flow from Rich to Poor Countries?" mimeo.

[14] Cooley, Thomas and Vincenzo Quadrini, 2001. "Financial Markets and Firm Dynamics," *American Economic Review*, 91(5): 1286-1310.

[15] Cooper, Russell and John Haltiwanger, 2006. "On the Nature of Capital Adjustment Costs,"*Review of Economic Studies*, 73(3): 611-633.

[16] Evans, D. and Boyan Jovanovic, 1989. "An Estimated Model of Entrepreneurial Choice Under Liquidity Constraints," *Journal of Political Economy*, 97(4): 807-827.

[17] Greenwood, Jeremy, Juan Sanchez, and Cheng Wang, 2010, "Quantifying the Impact of Financial Development on Economic Development," mimeo.

[18] Guner, Nezih, Gustavo Ventura and Yi Xu, 2008. "Macroeconomic Implications of Size Dependent Policies," *Review of Economic Dynamics*, 11(4): 721-744.

[19] Hagedorn, Marcus and Iourii Manovskii, 2008. "The Cyclical Behavior of Equilibrium Unemployment and Vacancies Revisited," *American Economic Review*, 98(4): 1692-1706.

[20] Hopenhayn, Hugo, 1992. "Entry, Exit, and Firm Dynamics in Long Run Equilibrium," *Econometrica*, 60(5), 1127-1150.

[21] Hopenhayn, Hugo and Richard Rogerson, 1993. "Job Turnover and Policy Evaluation: A General Equilibrium Analysis," *Journal of Political Economy*, 101(5), 915-938.

[22] Hsieh, Chang-Tai and Peter Klenow, 2009. "Misallocation and Manufacturing TFP in China and India," *Quarterly Journal of Economics*, 124(4): 1403-1448.

[23] Hsieh, Chang-Tai and Peter Klenow, 2012. "The Life Cycle of Plants in India and Mexico," mimeo.

[24] Jeong, Hyeok and Kim, Yong, 2006. "Complementarity and Transition to Modern Economic Growth," Working Paper.

[25] Jeong, Hyeok and Townsend, Robert M., 2006. "Sources of TFP growth: occupational choice and financial deepening," *Economic Theory*, 32(1): 179-221

[26] Lagos, Ricardo, 2006. "A Model of TFP," *Review of Economic Studies*, 73(4), 983-1007.

[27] La Porta, Rafael and Andrei Shleifer, 2008. "The Unofficial Economy and Economic Development," NBER Working Paper 14520.

[28] Moll, Benjamin, 2012. "Productivity Losses from Financial Frictions: Can Self-Financing Undo Capital Misallocation," mimeo.

[29] Qian Jun, Philip Strahan and Zhishu Yang, 2010. "The Impact of Organizational and Incentive Structures on Soft Information: Evidence from Bank Lending, " mimeo.

[30] Restuccia, Diego and Richard Rogerson, 2008. "Policy Distortions and Aggregate Productivity with Heterogeneous Plants," *Review of Economic Dynamics*, 11(4), 707-720.

[31] Rossi-Hansberg, Esteban and Mark L. J. Wright, 2007. "Establishment Size Dynamics in the Aggregate Economy," *American Economic Review*, 97(5), 1639-1666.

[32] Song, Zheng, Kjetil Storesletten, and Fabrizio Zilibotti, 2011. "Growing Like China," *American Economic Review*, 101(1): 202-241.

Table 1: Moments

	Data. Korea	Benchmark	Adoption	Exit
		A. Used to calibrate model		
S.D. output growth	0.59	0.58	0.58	0.59
S.D. output	1.31	1.30	1.37	1.30
1-year autocorrelation	0.90	0.90	0.89	0.91
3-year autocorrelation	0.87	0.87	0.83	0.87
5-year autocorrelation	0.85	0.86	0.80	0.86
Intangibles invest. to output, %	4.6	4.6	4.6	4.6
Output growth rate, %	8.0	8.0	8.0	8.0
Debt to output	1.2	1.2	1.2	1.2
Equity to output	0.3	0.3	0.3	0.3
		B. Additional Moments		
S.D. employment growth	0.49	0.58	0.58	0.59
S.D. capital growth	0.57	0.57	0.53	0.52
S.D. employment	1.21	1.30	1.37	1.30
S.D. capital	1.44	1.30	1.40	1.30
1-year autocorr. employm.	0.92	0.90	0.89	0.91
5-year autocorr. employm.	0.86	0.86	0.80	0.86
1-year autocorr. capital	0.92	0.90	0.92	0.92
5-year autocorr. capital	0.86	0.86	0.79	0.88
Share producers, ages 1-5	0.51	0.32	0.32	0.64
Share producers, ages 6-10	0.27	0.22	0.22	0.12
Share output, ages 1-5	0.20	0.28	0.16	0.57
Share output, ages 6-10	0.20	0.23	0.23	0.12
Share employm., ages 1-5	0.21	0.28	0.16	0.57
Share employm., ages 6-10	0.20	0.23	0.23	0.12
Share capital, ages 1-5	0.22	0.26	0.13	0.55
Share capital, ages 6-10	0.21	0.23	0.23	0.12
Rel. output growth 1-5 vs. 11+	0.11	0.09	0.28	0.10
Rel. output growth 6-10 vs. 11+	0.05	0.01	0.08	0.04
Rel. employm. growth 1-5 vs. 11+	0.09	0.09	0.28	0.10
Rel. employm. growth 6-10 vs. 11+	0.02	0.01	0.08	0.04
Rel. capital growth 1-5 vs. 11+	0.09	0.13	0.27	0.12
Rel. capital growth 6-10 vs. 11+	-0.03	0.02	0.11	0.06

Table 2: Parameter values

		Benchmark	Adoption	Exit
Assigned parameters				
labor elasticity	α	0.67	0.67	0.67
span of control	η	0.85	0.85	0.85
capital depreciation	δ	0.06	0.06	0.06
discount factor	$\beta(1+\mu)^{-1}$	0.92	0.92	0.92
growth rate	γ	1.08	1.08	1.08
persistence unit worker state	λ_1	0.79	0.79	0.79
persistence zero worker state	λ_0	0.50	0.50	0.50
relative efficiency in modern sector	$(1-\eta)\phi$	0.20	0.20	0.20
Calibrated parameters				
collateral constraint	θ	0.86	0.78	0.68
equity issuance constraint	χ	0.10	0.08	0
stand. dev. transitory shocks	σ_ε	0.50	0.50	0.96
persistence transitory shocks	ρ	0.25	0.11	0.40
cost of entering modern sector	κ	1.19	0.30	2.66
variance exogenous permanent component	$var(z)$	1.47	1.43	1.44
relative efficiency of productive technology	$(1-\eta)\phi_p$	-	0.27	-
cost of adopting productive technology	κ_p	-	1.83	-
fixed cost of operating in modern sector	F	-	-	0.27

Table 3: Aggregate implications of finance frictions. Open economy

	Efficient	"Korea"	θ = 1	θ = 0.75	θ = 0.50	θ = 0.25	θ = 0
			A. With equity issuance (χ = 0.10)				
Debt to output (modern)		1.18	1.30	0.92	0.35	-0.14	-0.60
Equity to output (modern)		0.29	0.32	0.30	0.26	0.14	0
Interest rate		0.047	0.047	0.047	0.047	0.047	0.047
Fraction constrained		0.17	0	0.44	0.69	0.78	0.83
Capital to output (modern)	1.93	2.59	2.65	2.46	2.25	2.14	2.05
TFP (modern)	1.003	1.000	1.003	0.989	0.926	0.869	0.827
Loss misallocation, %	0	0.3	0.0	1.4	3.9	4.4	4.7
Fraction producers modern	0.93	0.93	0.93	0.93	0.70	0.48	0.35
Fraction output modern	0.99	0.99	0.99	0.99	0.90	0.73	0.58
Consumption	1.02	1.00	1.01	0.98	0.90	0.85	0.82
Output	1.50	1.68	1.70	1.62	1.41	1.24	1.13
			B. Without equity issuance (χ = 0)				
Debt to output (modern)			1.59	0.85	0.34	-0.13	-0.60
Interest rate			0.047	0.047	0.047	0.047	0.047
Fraction constrained			0	0.50	0.68	0.77	0.83
Capital to output (modern)			2.65	2.42	2.27	2.15	2.05
TFP (modern)			1.003	0.918	0.878	0.849	0.827
Loss misallocation, %			0.0	2.7	3.8	4.4	4.7
Fraction producers modern			0.93	0.61	0.49	0.41	0.35
Fraction output modern			0.99	0.88	0.78	0.67	0.58
Consumption			1.01	0.91	0.87	0.84	0.82
Output			1.70	1.42	1.29	1.20	1.13

Table 4: Aggregate implications of finance frictions. Closed economy

	$\theta = 1$	$\theta = 0.75$	$\theta = 0.50$	$\theta = 0.25$	$\theta = 0$
			A. With equity issuance ($\chi = 0.10$)		
Debt to output (modern)	1.21	1.07	0.84	0.58	0
Equity to output (modern)	0.30	0.32	0.43	0.58	0
Interest rate	0.049	0.042	0.033	0.019	-0.060
Fraction constrained	0	0.42	0.77	0.94	1.00
Capital to output (modern)	2.60	2.57	2.49	2.42	2.18
TFP (modern)	1.003	0.990	0.957	0.925	0.766
Loss misallocation, %	0.0	1.2	4.7	7.3	9.8
Fraction producers modern	0.93	0.93	0.93	0.87	0.29
Fraction output modern	0.99	0.99	0.98	0.96	0.45
Consumption	1.00	0.99	0.94	0.91	0.71
Output	1.69	1.65	1.55	1.46	1.06
			B. Without equity issuance ($\chi = 0$)		
Debt to output (modern)	1.51	1.49	1.51	0.80	0
Interest rate	0.049	0.031	0.010	-0.060	-0.060
Fraction constrained	0	0.59	0.93	1.00	1.00
Capital to output (modern)	2.60	2.76	2.83	2.87	2.18
TFP (modern)	1.003	0.902	0.841	0.782	0.766
Loss misallocation, %	0.0	3.7	7.2	10.3	9.8
Fraction producers modern	0.93	0.58	0.46	0.33	0.29
Fraction output modern	0.99	0.90	0.80	0.64	0.45
Consumption	1.00	0.91	0.87	0.78	0.71
Output	1.69	1.47	1.33	1.19	1.06

Table 5: Role of productivity gap. Open economy

	$(1-\eta)\phi_u = 0$		$(1-\eta)\phi_u = 0.2$		$(1-\eta)\phi_u = 0.4$	
	"Korea"	No finance	"Korea"	No finance	"Korea"	No finance
Debt to output (modern)	1.5	-1.6	1.2	-0.6	1.1	-0.3
Equity to output (modern)	0.3	0	0.3	0	0.3	0
Consumption	0.77	0.77	1	0.82	1.32	0.92
Output	1.21	0.93	1.68	1.13	2.29	1.35
TFP (modern)	0.80	0.61	1	0.83	1.22	0.94
Loss misallocation, %	0.1	0.4	0.3	4.7	0.2	9.0
TFP (traditional)	0.66	0.81	0.56	0.78	0.56	0.79
Fraction producers modern	0.78	0.13	0.93	0.35	0.93	0.28
Fraction output modern	0.84	0.16	0.99	0.58	1.00	0.77
Fraction employment modern	0.77	0.11	0.99	0.48	1.00	0.69

Table 6: Extensions of the Benchmark Model

	Benchmark		Adoption		Exit	
	"Korea"	No finance	"Korea"	No finance	"Korea"	No finance
Debt to output (modern)	1.2	-0.6	1.2	-0.2	1.2	-0.6
Equity to output (modern)	0.3	0	0.3	0	0.3	0
Consumption	1.00	0.82	1.41	0.97	0.86	0.79
Output	1.68	1.13	2.41	1.47	1.30	1.08
TFP modern sector	1	0.83	1.29	0.99	0.91	0.79
Loss misallocation, %	0.3	4.7	1.2	6.3	2.1	4.1
Fraction producers modern	0.93	0.35	0.93	0.39	0.36	0.25
Fraction productive producers modern	-	-	0.86	0.18	-	-
Fraction modern producers operating	1	1	1	1	0.67	0.44
Std. dev. output growth	0.58	0.32	0.58	0.26	0.59	0.40
Average product of capital, 1-5 vs. 11+	0.08	0.73	0.27	0.22	0.13	0.19
Relative output growth, 1-5 vs. 11+	0.09	0.12	0.28	0.08	0.10	0.08

Table 7: Economy Without Entry

		S.D. product. shocks	S.D. output growth	Misallocation loss, %	Measured TFP losses, %
Data		0.83	0.59		23.5
Baseline	"*Korea*"	0.83	0.57	2.5	2.5
	No finance		0.38	3.4	3.4
Volatile productivity shocks	"*Korea*"	2.49	2.94	5.6	5.6
	No finance		2.03	20.3	20.3
Persistent productivity	"*Korea*"	0.83	0.69	2.8	2.8
	No finance		0.48	8.2	8.2
Predetermined capital	"*Korea*"	1.45	0.59	0.9	10.0
	No finance		0.61	0.8	9.9
Variable markups	"*Korea*"	1.84	0.59	0.3	2.7
	No finance		0.43	1.1	2.5
Low elasticity of substit.	"*Korea*"	0.73	0.59	1.5	0.6
	No finance		0.23	3.2	1.2
Capital-specific shocks	"*Korea*"	0.62	0.59	0.3	7.1
	No finance		0.58	1.1	9.3

Table 8: Role of Heterogeneity

	Labor Share		Span of Control		Collateral Constraint		Borrowing Rates
	"Korea"	No finance	"Korea"	No finance	"Korea"	No finance	"China"
Sector 1	$\alpha_1 = 0.44$		$\eta_1 = 0.55$		$\theta_1 = 0.15$	$\theta_1 = 0$	$r_1 = 0.05$
Sector 2	$\alpha_2 = 0.66$		$\eta_2 = 0.85$		$\theta_2 = 0.58$	$\theta_2 = 0$	$r_2 = 0.10$
Sector 3	$\alpha_1 = 0.89$		$\eta_1 = 0.95$		$\theta_1 = 0.85$	$\theta_1 = 0$	$r_3 = 0.15$
Misallocation loss, %	2.6	2.9	1.1	1.5	1.8	2.3	1.6
Sector 1 TFP losses, %	2.7	3.2	1.0	2.0	2.2	2.3	0.0
Sector 2 TFP losses, %	1.9	2.4	1.5	2.3	1.5	2.3	1.0
Sector 3 TFP losses, %	0.8	1.0	1.1	1.2	0.7	2.3	2.2
Measured TFP losses, %	8.2	8.2	1.9	2.5	1.8	2.3	1.6

Table 9: Cross-Country Evidence

		Benchmark Model		Model w/ Exit		Data		
		"Korea"	No finance	"Korea"	No finance	Korea	China	Colombia
Measured TFP losses, %	overall	0.3	4.7	2.1	4.1	16.2	22.4	17.7
	due to age	0.1	3.7	0.1	0.7	0.2	0.3	2.7
	if K fixed	1.3	1.3	5.4	5.4	2.4	2.9	1.9
	among 1-5	0.5	1.3	2.6	4.7	16.2	22.8	11.4
	among 11+	0.0	0.8	0.7	2.5	15.7	21.7	18.6
var e		0.27		1.10		0.35	0.30	0.24
ρ_e		0.25		0.40		0.11	0.21	0.29
σ_e		0.50		0.96		0.68	0.58	0.49
avg(Y/K)	1-5 vs. 11+	0.08	0.73	0.13	0.19	0.21	0.15	-0.25

Figure 1: Decision Rules. Modern Sector

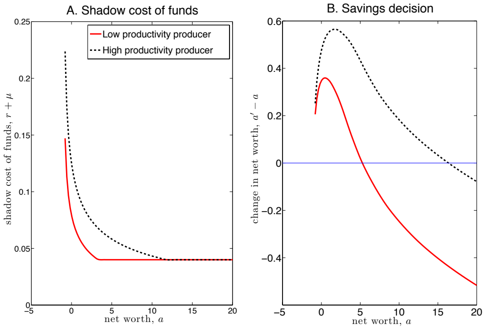

Figure 2: Decision to Enter Modern Sector

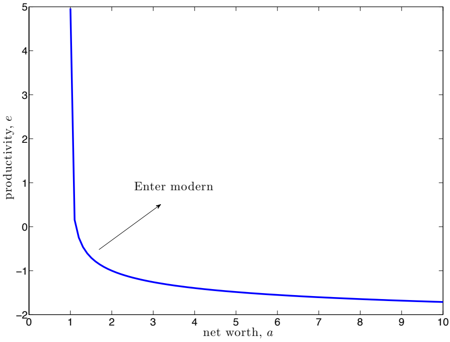

Figure 3: Response to a Credit Shock. Benchmark Model

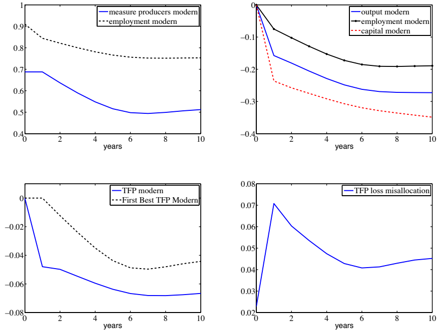

Figure 4: TFP during the 1997-98 Korean Financial Crisis