The Pennsylvania State University
The Graduate School

THREE ESSAYS ON MISALLOCATION AND PRODUCTIVITY

A Dissertation in
Economics
by
Minsoo Han

© 2013 Minsoo Han

Submitted in Partial Fulfillment
of the Requirements
for the Degree of

Doctor of Philosophy

August 2013

The dissertation of Minsoo Han was reviewed and approved* by the following:

Neil Wallace
Professor of Economics
Dissertation Advisor, Chair of Committee, Acting Head of the Department of Economics

Saroj Bhattarai
Assistant Professor of Economics

James R. Tybout
Professor of Economics

David Abler
Professor of Agricultural, Environmental and Regional Economics and Demography

*Signatures are on file in the Graduate School.

Abstract

CHAPTER 1: Plant-Level Worker Flows and the Losses from Financial Frictions

Buera and Shin (2013) (BS) study the effect of financial frictions on total factor productivity (TFP). To do so, they develop a growth model in which output is produced by producers with heterogeneous productivity and there are entry and exit of producers. Their financial frictions are in the form of a collateral constraint, so that the amount of capital which producers can rent in the capital rental market is limited to some multiple of producers' individual wealth. But plant-level worker flows predicted by their model are not consistent with data on such flows. In this paper, I recalibrate the model to match these additional data. The main finding is that TFP effect of financial frictions is smaller under the revised calibration. For the tightest collateral constraint (a producer can only employ the capital he owns), TFP is 5.6% lower than in perfect capital market, while it is 15.9% lower for the replication of BS calibration.

CHAPTER 2: Capital Account Openness and the Losses from Financial Frictions

The goal of this paper is to isolate the role of openness to international financial markets (capital account openness) on the total factor productivity (TFP) effect of financial frictions. To do so, I formulate a model in which individual households are either workers or entrepreneurs, can only save in the form of capital, and entrepreneurs are subject to a collateral constraint. Using this structure, I compare two steady states of a calibrated model numerically: one in which the capital rental rate must clear a domestic capital rental market (closed economy), and one in which that rate is given by the world (small open economy). The model predicts that a small open economy is affected less by financial frictions than a closed economy: for the tightest collateral constraint, TFP in a small open economy is only about 1% lower than in the economy without a collateral constraint, while it is 15% lower in a closed economy. TFP losses in a small open economy reflect factor misallocation among incumbent entrepreneurs (intensive margin), not distortions along entry-exit margin, whereas for a tight financial frictions, there are distortions on both intensive and

entry-exit margins in a closed economy. Using macro data, I find that a 1% rise in openness is associated with 0.196% decline in the effect of financial frictions on TFP. Running the same regression on subsamples, I also find that this empirical result mainly comes from a group of low income countries.

CHAPTER 3: The Losses from Tax-type Distortions in a Model with Innovation

In this paper, I assess total factor productivity (TFP) losses from tax-type distortions. To do so, I introduce firm-specific tax-type distortions into a model like that of Luttmer (2007) and Atkeson and Burstein (2010), both of which have firms entering and exiting and engaging in costly process innovation that raises the probability of receiving higher future productivity. Then I compare the TFP gain from removing the tax-type distortions in this model with the TFP gain from their removal in a static model like that of Hsieh and Klenow (2009). The main finding is that both kinds of models make the similar prediction for the gains from removing the distortions. This happens because removing the distortions in the first kind of model gives rise to two offsetting effects on the incentive to engage in costly process innovation: the absence of distortions increases that incentive, while the induced greater entry increases competition and, thereby, reduces that incentive.

Table of Contents

List of Figures

List of Tables

Acknowledgments

I am deeply indebted to my advisor, Neil Wallace, for my professional development. Since I started my own research, he has provided the best advising I can imagine in many generously long discussions. He has taught me how to address research questions and express ideas in a rigorous way. I find his influence in every page of this dissertation.

I also would like to thank Saroj Bhattarai and James Tybout for their time and suggestions. They carefully read the second and third chapters of this dissertation and provided detailed comments. I should have talked to them more often and tried to learn more. I am also grateful to David G. Abler for his comments on the first chapter of this dissertation.

Last but not the least, I thank my mother, Woongsik Kim, my father, Jungnam Han, and my brother, Minkoo, who taught me the opposite of disappearing.

Chapter 1

Plant-Level Worker Flows and the Losses from Financial Frictions

1.1 Introduction

Buera and Shin (2013) (BS) argue that financial frictions in the form of a collateral constraint can reduce total factor productivity (TFP) by 24%[1]. In this paper, I recalibrate their model to match the additional U.S. plant-level dynamics and compare TFP losses of my alternative calibration to that of BS.

The model in BS is a growth model, in which output is produced by producers with heterogeneous productivity. An agent either supplies homogeneous labor (is a worker) or is a producer using a span-of-control-type production function at each period. The agent can only save in the form of capital and a producer is subject to a collateral constraint which limits the amount of capital he can employ to a multiple of his own capital. The agent's productivity at each period can either equal to the past productivity with a contant probability parameter or otherwise be a new productivity draw from Pareto distribution.

Since the U.S. is a financially developed country reletive to the rest of the world, BS consider the model without a collateral constraint to represent the U.S. and calibrate it to match the U.S. plant-level data. In particular, they pin down the probability of retaining

[1]There are previous studies to consider this form of financial frictions, for example, Evans and Jovanovic (1989), Holtz-Eakin, Joulfaian, and Rosen (1994), Banerjee and Duflo (2005), Paulson, Townsend, and Karaivanov (2006), Jeong and Townsend (2007), Moll (2012), Moll, Townsend, and Karaivanov (2013), and Midrigan and Xu (forthcoming).

the past productivity and the tail index for Pareto distribution to match the exit rate and the employment share of the largest 10% of plants. Because BS did not look at the plant-level dynamics, I recalibrate their model and examine whether their prediction is consistant with data. Accoriding to two empirical studies by Davis and Haltiwanger (1990) and Lee and Mukoyama (2012), plant-level entry and exit account for about 20% of annual gross job destruction and creation in the U.S. However, 94% in BS's model without a collateral constraint is explained by plant-level entry and exit. I also try different values for the probability parameter of retaining the past productivity, which is the primary factor to influence the plant-level dynamics in BS. But with BS's productivity process, it is difficult for the model to be consistent with the plant-level worker flows.

To match the additional U.S. plant-level dynamics, I deviate from BS in only one dimension: productivity process. In particular, depending on the current productivity, which could be 0, smaller, or greater than the median of the set of possible productivity realizations, the next-period productivity follows the different productivity process. With the alternative productivity process, I calibrate the model without a collateral constraint to match additional data in the U.S. In particular, my calibration targets are the exit (entry) rate, the autocorrelation parameter for AR(1) process for employment, job creation by startups, job creation by continuers, job destruction by shutdowns, and job destruction by continuers (all from Lee and Mukoyama (2012)), and the employment share of the largest 10% of plants (from BS). After that, taking as given the calibrated parameters, I vary a parameter for the collateral constraint and compare the steady state properties in my alternative calibration to those predicted by BS.

The main finding is that TFP losses of financial frictions in my alternative calibration are significantly smaller than in BS. For the tightest collateral constraint (a producer can only employ the capital he owns), TFP is 5.6% lower than in an economy without a collateral constraint, while it is 15.9% lower for BS's calibration. To further analyze TFP effect of financial frictions, I conduct TFP decomposition. In both BS and my alternative calibration, TFP losses from financial frictions are mainly due to the effect on the intensive margin: financial frictions distort the allocation of factors across incumbent producers while the distortion on the entry and exit of producers is not substantial. Consistent with the difference in TFP losses between my calibration and BS, the dispersion in marginal product of capital in BS is greater than in my alternative calibration.

1.2 Model and Equilibrium

This section introduces the model, defines an equilibrium, and describes how I solve an equilibrium.

1.2.1 Model

Time is discrete and denoted by t. There is one (produced) good per date. The economy consists of a continuum of infinitely lived agents with total population 1. The preferences of an agent are given by

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\gamma}}{1-\gamma}, \text{ where } 0 < \beta < 1, \ \gamma > 1.$$

An agent enters each period with the capital (wealth) he owns $a \in A$, which depreciates by a constant rate δ (A stands for the set of possible wealth). After that, an agent's span-of-control productivity e is realized in the begining of each period. In my calibration, an agent's productivity $e \in E$ follows a Markov process, where E stands for the set of possible productivity realizations, and the productivity realizations are independent across agents. More details on productivity process is given in the next section. Given two state variables a and e, an agent chooses one of two options: he can either become a worker who supplies one unit of homogenous labor or become a producer. A producer combines labor l and capital k with his span-of-control productivity e to produce

$$y = e^{1-\eta} \left(l^{\alpha} k^{1-\alpha} \right)^{\eta}, \text{ where } \alpha, \eta \in (0,1).$$

Given his income, he ends a period by choosing his consumption and next period wealth. The state of the economy at period t is joint distribution $M_t(a,e) \in \mathcal{M}$, where $\mathcal{M}$ stands for a space of probability distribution.

In the following, I focus on steady states. I assume that a law of large numbers holds so that idiosyncratic uncertainty must disappear on the aggregate. Perfectly competitive labor rental market and price taking capital rental market are the only markets in this economy.

1.2.2 Equilibrium

Denote by r and δ, the net rate of return from wealth and the depreciation rate. The rental rate of capital is the sum of the net rate of return and the depreciation, $r+\delta$. Denote by w the wage rate. Then a producer's profit maximization problem is given by

$$\begin{aligned} \pi(a,e;w,r) &= \max_{l\geq 0,k\geq 0} \left\{ e^{1-\eta}\left(l^{\alpha}k^{1-\alpha}\right)^{\eta} - wl - (r+\delta)k \right\}, \\ \text{s.t.} \quad & k \leq \lambda a \end{aligned} \tag{1.1}$$

where $1 \leq \lambda < \infty$. Let $l : A\times E \to \mathbb{R}$ and $k : A\times E \to \mathbb{R}$ be the optimal labor and capital demand functions respectively. Due to the collateral constraint, a producer's capital rental is restricted by its wealth multiplied by the parameter λ. In particular, $\lambda = 1$ implies no capital rental markets, so that a producer should finance his investment with his own wealth. If $\lambda = 1$, then $r = -\delta$ and therefore a producer employs all his capital. On the other extreme, $\lambda = \infty$ corresponds to no frictions in capital rental markets.

We assume that an agent cannot borrow intertemporally for consumption smoothing nor can they write contracts that depend on his productivity. Then, an agent's wealth should be greater than 0, e.g. $A = [0,\infty)$, and his budget constraint is given by (a " $'$ " denotes next period's value)

$$c + a' = (1+r)a + \max\{w, \pi(a,e;w,r)\}.$$

To define an agent's problem in a recursive form and a recursive competitive equilibrium, I set down some notations. Denote respectively by $\mathcal{B}(A\times E)$, the Borel σ-algebra of the product space $A\times E$. We define an operator $\mathcal{T} : C(A\times E) \to C(A\times E)$ for any function $v \in C(A\times E)$ ($C(A\times E)$ is the set of bounded, continuous functions on $A\times E$)

$$\begin{aligned} \mathcal{T}v(a,e;w,r) = \max_{a'\in\Gamma(a,e;M)} & u\left((1+r)a + \max\{w, \pi(a,e;w,r)\} - a'\right) \\ & + \beta\int_{e'} v\left(a',e';w,r\right) p(e,de'), \end{aligned} \tag{1.2}$$

where $\Gamma(a,e;w,r) = \left[0,\, (1+r)a + \max_{i\in\{0,1\}}\{iw + (1-i)\pi(a,e;w,r)\}\right]$. Let $g : A\times E \to \mathbb{R}$ be the optimal policy function for wealth in the next period.

Finally, the transition function $Q:(A\times E)\times\mathcal{B}(A\times E)\rightarrow[0,1]$ is given by

$$Q\left((a,e),(\mathcal{A},\mathcal{E})\right)=\begin{cases}p\left(e,\mathcal{E}\right) & \text{if } g(a,e)\in\mathcal{A}\\ 0 & \text{otherwise,}\end{cases} \tag{1.3}$$

for all $a\in A$, $e\in E$, $\mathcal{A}\times\mathcal{E}\in\mathcal{B}(A\times E)$.

Definition 1.2.1. *A stationary recursive competitive equlibrium (RCE) consists of a value function,* $v:A\times E\rightarrow\mathbb{R}$*, policy functions,* $g:A\times E\rightarrow\mathbb{R}$*,* $l:A\times E\rightarrow\mathbb{R}$*, and* $k:A\times E\rightarrow\mathbb{R}$*, constant labor and capital rental rates,* w *and* r*, and a probability measure* $M\in\mathcal{M}$ *such that*

1. *Given* w *and* r*,* v *is a fixed point of* $\mathcal{T}$ *in the problem* (2.2)*,* g *is the corresponding policy function, and* l *and* k *are profit maximizing labor and capital demand.*
2. *Labor and capital rental markets clear*

$$\int_{\{(a,e):i(a,e)=0\}} l(a,e)M(da,de)=\int_{\{(a,e):i(a,e)=1\}} M(da,de),$$
$$\int_{\{(a,e):i(a,e)=0\}} k(a,e)M(da,de)=\int aM(da,de).$$

3. *The aggregate law of motion* $\mathcal{P}$ *generates the invariant probability measure* M

$$M\left(\mathcal{A},\mathcal{E}\right)=\mathcal{P}\left(M\left(\mathcal{A},\mathcal{E}\right)\right),$$

for all $\mathcal{A}\times\mathcal{E}\in\mathcal{B}(A\times E)$.

The aggregate feasibility constraint should hold by Walras' law.

1.2.3 Solving for an Approximate Equilibrium

Because we do not have a closed form for steady states in this model, I compute approximate steady states. I follow what is by now a fairly standard approach to compute steady states: I discretize the state space and employ Aiyagari (1994)'s nested fixed point method. In particular, in the most inner loop, I search for value function and stationary density of wealth, and, in the outside loop, I search for market clearing wage and rental rate by iterating each of them until convergence.

I use the value function iteration method to solve the individual optimization problem. While our utility function and the density of wealth are continuous, a computer can only operate on finite sets. Therefore, the approximation of the functions and integrations should be done by a grid with discrete points.

To solve the optimization problem in each iteration, I use the Golden section search algorithm, which does not require smoothness of the objective function (p.623 of Heer and Mauβner (2005)). An agent's wealth choice is not restricted to lie on a grid point and the value of the value function between gridpoints is determined by linear interpolation. To get a stationary distribution, rather than applying the standard simulation method as in Aiyagari (1994), I discretize the density function and iterate it until convergence (Algorithm 7.2.3 of Heer and Mauβner (2005))[2].

In pinning down equilibrium wage and rental rate, I apply three alternative ways to an economy with different cases of λ: $\lambda = \infty$, $\lambda > 1$, and $\lambda = 1$. They are similar in that I follow Aiyagari (1994)'s nested fixed point method and pin down both or one of prices. The differences are as follows. First, in an economy with perfect capital market ($\lambda = \infty$), because production, entry, and exit do not depend on the wealth distribution, therefore, without solving an agent's dynamic problem and stationary distribution of wealth, we can pin down equilibrium wage w and the threshhold productivity between a worker and a producer e^*, both of which simultaneously satisfy the labor market clearing condition and the threshhold condition (an agent with $e < e^*$ chooses to be a worker and an agent with $e > e^*$ chooses to be a producer). To guarantee such w and e^*, I use a sufficiently large number of points for the productivity grid and guess and verify each possible e^*. More details are given in the following. Denote by $E = \{e_1, e_2, \ldots, e_n\}$, where $e_1 = 0 < e_2 < \cdots < e_n$, the discretized support of productivity space. I start with initial guess for e^* such that $e_1 = 0 < e^* < e_2$. Then from the labor market clearing condition, the wage rate is given by the following function of the rental rate and productivity threshhold for an producer e^*

$$w = \alpha \left(\eta \left(\frac{1-\alpha}{r+\delta} \right)^{\eta(1-\alpha)} \left(\frac{\sum_{e>e^*} e\mu(e)}{\mu(e^*)} \right)^{1-\eta} \right)^{\frac{1}{1-\eta(1-\alpha)}}.$$

Given w and r, we construct profit which only depends on productivity in perfect capital rental market, $\pi(e_1)$ and $\pi(e_2)$. After that, we check if $\pi(e_1) < w < \pi(e_2)$. If the inequality

[2] The tolerance levels for value function iteration and the density function iteration are 10^{-6} and 10^{-8} respectively.

does not hold, e.g. $\pi(e_1) < \pi(e_2) \leq w$, then it implies that w is too high due to small supply of labor. Therefore we have to increase the threshhold e^* and consider e^* such that $e_2 < e^* < e_3$. By the same way, we iterate over e^* until we find e^* such that $\pi(e_i) < w < \pi(e_{i+1})$ for $1 < i < n$. If we might not find such a e^*, e.g.

$$\pi(e_i) < \pi(e_{i+1}) < w \text{ and } w < \pi(e_{i+1}) < \pi(e_{i+2}) \text{ for } 1 < i < n,$$

then it implies that the distance between points in the productivity grid is too large and therefore I need to increase the number of points in the grid. After determining w and e^*, we solve an agent's dynamic problem and solve r which satisfies the capital rental market clearing condition. For the cases with $\lambda \in (1, \infty)$, I confirm the capital rental market clearing condition in the outside loop and the labor market clearing condition in the inside loop. Finally, when there is no capital rental market ($\lambda = 1$), the rate of return from wealth is simply depreciation rate $-\delta$. Therefore, I fix $r = -\delta$ and solve for wage rate to clear labor market.

Any previous studies including BS do not prove the existence of equilibria even for the case with perfect capital rental market. To prove the existence, we need to construct the demand surplus functions in each market and apply the fixed point argument. To construct the demand surplus functions, we need to prove the existence of a stationary distribution, which in turn requires the compactness of state space (Theorem 12.12 of Stokey, Lucas, and Prescott (1989)). Huggett (1993) proves the compactness of state space for wealth in an incomplete markets model with two-state Markov process on endowment shock. Even with slightly more general productivity process, e.g. three-state Markov process, however, the existence proof in an incomplete markets model seems to be hard. The main difficulty is to prove that the policy for the next period wealth is increasing in labor productivity. Miao (2002) proves it in the model of Aiyagari (1994) but with additional stronger assumptions on utility function and productivity process.

1.3 Calibration

BS do not examine their model's prediction about plant-level dynamics. To compare their prediction to the result from my alternative calibration, I replicate their calibration. Since the U.S. is a financially developed country reletive to the rest of the world, BS consider

Table 1.1. Replication of Buera and Shin (2013)

Discretization of a		
number of grid points	1200	
wealth states		

$$A = \{0, 0.022, 0.044, \ldots, 892.186, 896.085, 900.0\}$$

Discretization of e		
number of grid points	100	
productivity states		

$$E = \{1.187, 1.193, 1.199, \ldots, 7.735, 10.776, 116.897\}$$

Parameters calibrated in the model		
span of control	η	0.777
discount rate	β	0.905
probability of retaining the previous productivity	χ	0.889
tail index of Pareto distribution	υ	2.08

Targets and results	Target	Model
top 10% employment	0.67	0.67
fraction of producers' income	0.30	0.30
exit rate	0.10	0.10
annual interest rate	0.045	0.045

the model without a collateral constraint to represent the U.S. and calibrate it to match the U.S. data. Table 1.1 summarizes the choice of parameters in my replication of BS. The period in the model is one year. Following BS, I choose the same parameters for risk aversion (γ), the labor share in production (α), and the depreciation rate (δ), all of which are standard in the literature. The only two parameters are involved with productivity process in BS (probability of retaining the past productivity (χ) and tail index of Pareto distribution (υ)) and they are calibrated to match plant-level exit rate and the largest 10% of plant-level employment. The remaining parameters are parameters for span of control (η) and subjective discount rate (β), which are calibrated to match the model to the fraction of entrepreneurs' income and annual interest rate.

Like BS, I calibrate the model economy with no frictions in capital rental market ($\lambda = \infty$) to represent the U.S. economoy. Table 3.2 summarizes the parameters, the moments I used for the calibration, and the resulting values for the initial calibration of the benchmark economy. To match the additional U.S. plant-level dynamics, I deviate from BS in only one dimension: productivity process. In particular, depending on the current productivity e, which could be 0, smaller, or greater than the medium of discretized productivity space E, the next-period productivity e' follows the different productivity process in the following way

$$e' = \begin{cases} \left.\begin{array}{ll} 0 & \text{with } \psi \\ \text{new draw from Pareto}(\omega) & \text{with } 1-\psi \end{array}\right) & \text{if } e = 0 \\ \left.\begin{array}{ll} 0 & \text{with } \phi_1 \\ \exp\left(\rho \log(e) + \varepsilon\right),\ \varepsilon \sim N(0,\sigma^2) & \text{with } 1-\phi_1 \end{array}\right) & \text{if } e > 0 \text{ and } e < \text{median}(E) \\ \left.\begin{array}{ll} 0 & \text{with } \phi_2 \\ \exp\left(\rho \log(e) + \varepsilon\right),\ \varepsilon \sim N(0,\sigma^2) & \text{with } 1-\phi_2 \end{array}\right) & \text{if } e > 0 \text{ and } e > \text{median}(E) \end{cases}$$

I choose the same values for parameters for risk aversion (γ), the labor share in production (α), and the depreciation rate (δ) and calibrate span of control (η) and subjective discount rate (β) to match the same targets as in BS. The remaining parameters are six parameters for productivity process, e.g. tail index of Pareto distribution for current 0 productivity (ω), AR(1) persistance (ρ), AR(1) volatility (σ), probability for an agent with $e > 0$ and $e <$median(E) of $e' = 0$ (ϕ_1), probability for an agent with $e > 0$ and $e >$median(E) of $e' = 0$ (ϕ_2), and probability for an agent with $e = 0$ of $e' = 0$ (ψ). I choose $\omega = 4.15$, which is the same value as tail index of Pareto distribution in BS. My results are not sensitive to

Table 1.2. Calibration with alternative productivity process

Parameters taken from other literature		
risk aversion	γ	1.5
labor share	α	0.67
depreciation rate	δ	0.06
tail index for current 0 productivity	ω	4.15
Parameters calibrated in the model		
span of control	η	0.777
discount rate	β	0.925
AR(1) persistance	ρ	0.965
AR(1) volatility	σ	0.3
$Prob_L(e' = 0 \mid e > 0)$	ϕ_1	0.028
$Prob_H(e' = 0 \mid e > 0)$	ϕ_2	0.007
$Prob_0(e' = 0 \mid e = 0)$	ψ	0.996
Targets and results		
	Data	Model
annual interest rate	0.045	0.045
fraction of producers' income	0.30	0.30
entry rate	0.062	0.063
exit rate	0.055	0.063
AR(1) coefficient for log labor	0.97	0.995
job creation by startups	0.015	0.014
job creation by continuers	0.074	0.120
(total job creation)	(0.090)	(0.134)
job destruction by shutdowns	0.024	0.021
job destruction by continuers	0.076	0.113
(total job destruction)	(0.100)	(0.134)
top 10% employment share	0.67	0.42

the choice of this parameter. I calibrate the other five parameters to simultaneously match the exit (entry) rate, the autocorrelation parameter for AR(1) process for employment, job creation by startups, job creation by continuers, job destruction by shutdowns, and job destruction by continuers (all from Lee and Mukoyama (2012)), and the employment share of the largest 10% of plants (from BS). I use Tauchen's method to discretize the grid and construct transition matrix for productivity.

To construct the discretized space for wealth, I use log and exponential functions, which are widely used in the calibration of a standard incomplete markets model. First, we decide the lower and upper bounds of the grid for wealth. I set the lower bound at 0. To choose a sufficiently large number as the upper bound of the grid point for wealth, I verify with trial and error that once an agent starts with weath in our grid, its future wealth is bounded by the upper bound. We need to choose finer spacing at the lower end of the grid and coaser spacing at the higher end to capture the curvature of wealth distribution. To do so, given the lower and upper bounds, I construct the equidistant grid for log of wealth intead of the grid for wealth directly. In particular, the distance between two points in the grid for log of wealth is

$$\frac{\log(\max(A)+5)-\log(\min(A)+5)}{n(A)-1},$$

where $\max(A)$ and $\min(A)$ are the upper and the lower bounds respectively and $n(A)$ is the number of points in the grid for wealth. We add an arbitrary number 5 because we cannot define $\log(0)$ as a real number. If the grid is dense enough, the choice of this number would not make any difference in our results. Finally, we construct the grid for wealth by taking exponential and subtract 5. Table 1.3 summarizes the grid and transition matrix for productivity as well as the grid for capital.

1.4 Results

The goal of this section is to compare the steady state properties in my alternative calibration to the steady state properties in BS, when varying the parameter of financial frictions (λ=1, 1.25, 1.5, 2, 3, 4, 5, 6, 7, 8, ∞).

In BS, the only parameter to control the plant-level worker flows is the probability of retaining the previous productivity (χ). To make clear whether BS's calibration can meet

Table 1.3. Descretization of Capital and Productivity

Discretization of a

number of grid points 1200

wealth states

$$A = \{0, 0.022, 0.044, \ldots, 892.186, 896.085, 900.0\}$$

Discretization of e

number of grid points 100

productivity states

$$E = \{0, 0.032, 0.035, \ldots, 26.890, 28.841, 30.934\}$$

transition matrix

$$\pi_{ee'} = \begin{pmatrix} 0.9963 & 0 & 0.0009 & \cdots & 0 & 0 & 0 \\ 0.028 & 0.3775 & 0.0891 & \cdots & 0 & 0 & 0 \\ 0.028 & 0.2968 & 0.0837 & \cdots & 0 & 0 & 0 \\ 0.028 & 0.2249 & 0.0747 & \cdots & 0 & 0 & 0 \\ 0.028 & 0.1639 & 0.0634 & \cdots & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ 0.0084 & 0 & 0 & \cdots & 0.0651 & 0.0522 & 0.1171 \\ 0.0084 & 0 & 0 & \cdots & 0.0766 & 0.0647 & 0.1672 \\ 0.0084 & 0 & 0 & \cdots & 0.0856 & 0.0762 & 0.2295 \\ 0.0084 & 0 & 0 & \cdots & 0.0910 & 0.0854 & 0.3028 \\ 0.0084 & 0 & 0 & \cdots & 0.0919 & 0.0909 & 0.3851 \end{pmatrix}$$

the evidence in plant-level worker flows, I tried the different values for the parameter, while I keep the model to match the other targets, e.g. top 10% employment share, fraction of producers' income, and annual interest rate.

Since in BS, tail index parameter can completely control the size distribution of plant, BS's calibration can match the employment share of the largest 10% plants (table 1.1). However, as shown in Table 3.2, there is a differentce between top 10% employment predicted by model and the data in my calibration with alternative productivity process, because the size distribution is not easily controlled in my alternative calibration.

On the other hand, Table 1.4 shows that the results in my calibration with alternative productivity process match the data better than in the replication of BS. I also tried 6% and 14% as my targets for entry and exit rate. But regardless of the value of the parameter, there is a significant difference in plant-level job creation and destruction between the replication of BS and the corresponding data. In an equilibrium of BS, if an agent lost the current productivity, he is more likely to be a worker because the equilibrium number of workers is greater than that of producers, so that job creation by startups and job destruction by continuers are greater than job creation and destruction by continuers.

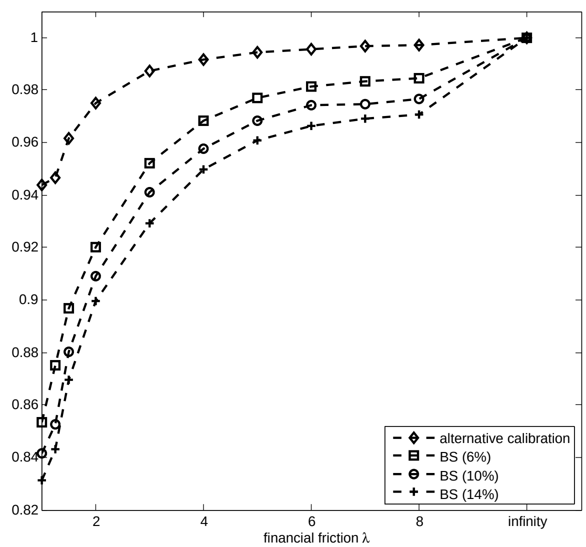

Figure 1.1. TFP Losses from Financial Frictions

Figure 1.1 compare TFP in my alternative calibration and BS. We normalize TFP in perfect capital market at 1 and TFP in an economy with a finite collateral constraint is the value relative to TFP in perfect capital market. The figure shows that in both my alternative calibration and BS, TFP decreases as an economy faces the more severe financial frictions. The quantitative effects are different, so that TFP losses from financial frictions are greater in BS than in my alternative calibration. For instance, for the tightest collateral constraint (a producer only employ capital he owns), TFP is only about 6% lower than in

Table 1.4. Comparing Perfect Capital Market

	Data	Benchmark	BS (10%)	BS (6%)	BS (14%)
entry rate	0.062	0.063	0.101	0.060	0.140
exit rate	0.055	0.063	0.101	0.060	0.140
AR(1) coefficient for log labor	0.97	0.995	0.997	0.998	0.995
job creation by startups	0.015	0.014	0.101	0.060	0.140
job creation by continuers	0.074	0.120	0.007	0.004	0.009
(total job creation)	(0.090)	(0.134)	(0.107)	(0.064)	(0.149)
job destruction by shutdowns	0.024	0.021	0.101	0.060	0.140
job destruction by continuers	0.076	0.113	0.007	0.004	0.009
(total job destruction)	(0.100)	(0.134)	(0.107)	(0.064)	(0.149)

the benchmark model, while it is 16% lower in BS.

Financial frictions can distort both the allocation of factors across incumbent producers and entry and exit of producers. To analyze the effect of financial frictions separately, I decompose TFP effect of financial friction into three components. First, taking as given the aggregate labor and capital and joint distribution of wealth and productivity, I equalize marginal product of capital across producers. This shows the effect of financial friction on allocation across incumbent producers. Second, taking as given the aggregate labor and capital, I allow the most productive agents to become producers, while I equalize marginal product of capital across these producers at the same time. This shows the sum of the

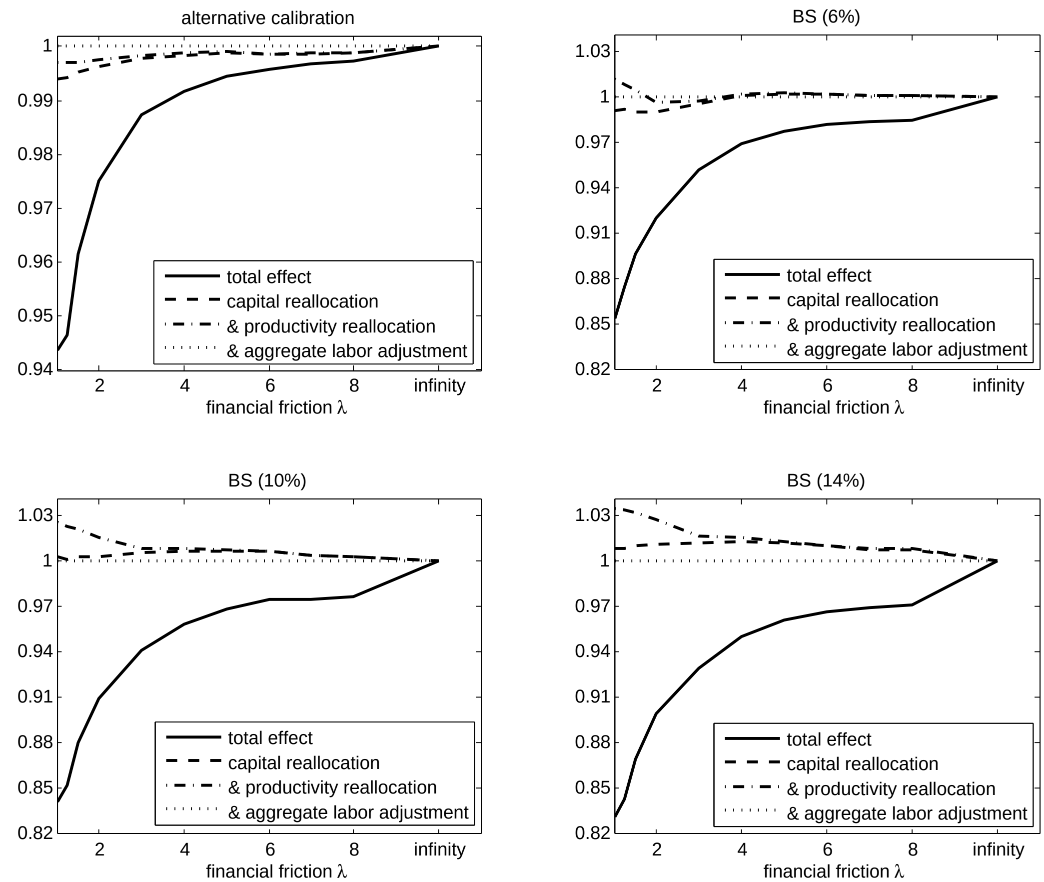

Figure 1.2. TFP Decomposition

effects of financial friction on allocation across incumbent producers and allocation of entrepreneurship across agents. Finally, I adjust the measure of workers and producers, so that they equal to those in perfect capital market. Figure 1.2 shows that in both BS and my alternative calibration most of TFP losses from financial frictions is due to misallocation across incumbent producers.

Since the most of distortions are due to misallocation of factors across incumbent producers (Figure 1.2), we expect TFP losses to be the most related to standard deviation of marginal product of capital. Figure 1.3 shows the standard deviation in BS and my alternative calibration. Note that in an equilibrium without a collateral constraint, producers should equalize their marginal product of capital to the rental rate of capital and therefore there is no dispersion in marginal product of capital. As an economy faces more distortions, the dispersion in marginal product will increase. Figure 1.3 shows that across every degree of financial frictions, financial frictions generates the more severe distortions in BS.

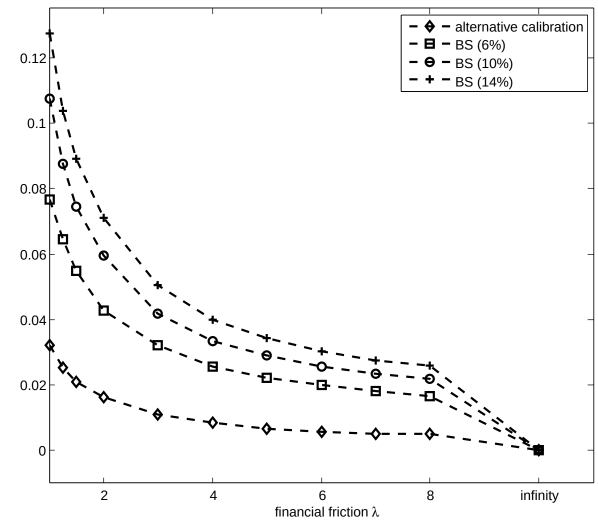

Figure 1.3. Standard Deviation of Marginal Product of Capital

1.5 Final Remarks

This paper shows that when we match the model to the plant-level worker flows, the quantitative effect of financial frictions on TFP can be significantly different from BS. There are two possible extensions of my analysis. First, TFP decomposition in Buera, Kaboski, and Shin (2011) shows that TFP effects of financial frictions are mainly due to entry and exit of producers in a manufacturing sector where producers face fixed or sunk cost. How the quantitative effect would be different with fixed (sunk) cost and compare the results would be one interesting extension. The second extension is to study transitional dynamics. The main focus of BS is transional dynamics. Since the long-run effects are different as shown here, transitional dynamics would be different from BS.

Chapter 2

Entry-Exit and the Losses from a Financial Friction

2.1 Introduction

Recent papers by Buera and Shin (2013) (B&S), Buera, Kaboski, and Shin (2011) (BKS), and Midrigan and Xu (2010) (M&X) study the effect of financial market frictions on total factor productivity (TFP). Despite the similarities in their environments, B&S and BKS report that financial frictions could reduce TFP by almost 40%, while M&X report a reduction in the 5-7% range.[1] Among other differences in their models is a difference regarding openness to international financial markets (capital account openness): B&S and BKS study a closed economy, while M&X assumes openness to a given world capital rental rate. The goal of this paper is to isolate the role of capital account openness on the TFP effects of financial frictions.

To do that, I formulate a single model that is similar to those in the above papers. Individual households either supply labor (are workers) or are entrepreneurs using a span-of-control-type production function. Households are homogeneous as workers, while the span-of-control productivity of a household (productivity as an entrepreneur) follows a two-state Markov process, the outcomes of which are independent across households. Households can only save in the form of capital and entrepreneurs are subject to a col-

[1]Developing a different environment, Moll (2012) claims that financial frictions matter either in the long run or in the short run: when idiosyncratic productivity shock is persistent, even if financial frictions have the small TFP effect, the speed of transitions are slow.

lateral constraint which limits the amount of capital they can employ to a multiple of their own capital. Using this structure, I compare two steady states of a calibrated model numerically: one in which the capital rental rate must clear a domestic capital rental market (closed economy), and one in which that rate is given by financially developed economies (small open economy).

I calibrate the closed economy model without a collateral constraint to represent the U.S. economy. I take parameters for risk aversion, the labor share in the production function, the depreciation rate, and the span of control from previous literature, while I match the model's rate of return, the fraction of entrepreneurs, and the exit rate of entrepreneurs to the corresponding U.S. data statistics to pin down the discount rate and the transition matrix for entrepreneurial productivities. I choose the same parameters for the small open economy model without a collateral constraint and call the resulting common steady state the outcome for the benchmark economy. Taking as given the parameters in the benchmark economy, I vary the collateral constraint and compare steady state properties between the two alternative capital rental market specifications.

The main finding is that TFP in a small open economy is affected less by financial frictions than in a closed economy. For the tightest collateral constraint (an entrepreneur can only employ the capital he owns), TFP in a small open economy is only about 1% lower than in the benchmark economy, while it is 15% lower in a closed economy. The difference in TFP is accompanied by differences in both allocation of entrepreneurship among households with different productivity (entry-exit margin or extensive margin) and allocation of factors among incumbent entrepreneurs (intensive margin). In particular, in a small open economy, there is specialization in that all households with high productivity are entrepreneurs and all households with low productivity are workers. In this sense, our results in a small open economy resemble the results in M&X: TFP losses in a small open economy reflect factor misallocation among incumbent entrepreneurs, not distortions along entry-exit margin. In contrast, in a closed economy, there are distortions on both intensive and entry-exity margin: 15% of those with low productivity and 85% of those with high productivity are entrepreneurs in a closed economy and the dispersion in the marginal product of capital among producers in a closed economy is greater than in a small open economy.

Finally, I use macro data and conduct reduced form estimation to check how capital account openness changes the TFP effect of financial frictions. As a measure of openness, I use Quinn (1997)'s indicator for a government policy stance toward capital account liberalization (*de jure* indicator). As a measure of the absence of financial frictions, I use the sum of private credit owed to bank and other financial intermediaries, private bond market capitalization, and stock market capitalization as a ratio of GDP - from Beck, Demirguc-Kunt, and Levine (2000) (external finance ratio). I regress log of TFP on log of external finance ratio, log of openness, an interaction term of log of external finance ratio and log of openness, and other country-level controls. Then the coefficient of the interaction term divided by the coefficient of log of openness measures how openness affects the elasticity of TFP with respect to the external finance ratio. The estimate is -0.196: that is, a 1% rise in openness is associated with 0.196% decline in the effect of financial frictions on TFP. To further investigate from which group of countries our empirical results come, I split the sample into two sub-samples of low income countries and the rest of the other countries by using World Bank income group categorization and run the same regression on both sub-samples separately. The results from sub-samples show that the estimate of the interaction between openness and the TFP effect of financial frictions in low income countries is greater than the estimate in full sample (in absolute terms), while the same estimate in the rest of the other countries is not significant. Therefore, we conclude that our empirical result that a small open economy is affected less by financial frictions mainly comes from a group of low income countries.

2.2 Model and Equilibrium

This section introduces the model, defines an equilibrium, and describes how to solve the equilibrium.

2.2.1 Model

Time is discrete and denoted by t. There is one (produced) good per date. The economy consists of a continuum of infinitely lived households with total population 1. The preferences of a household are given by

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\gamma}}{1-\gamma}, \text{ where } 0 < \beta < 1,\ \gamma > 1.$$

At each period, a household either becomes a worker who supplies one unit of labor or becomes an entrepreneur. If a household chooses to be an entrepreneur, it combines labor l and capital k with its entrepreneurial productivity e to produce

$$y = e^{1-\eta}\left(l^{\alpha}k^{1-\alpha}\right)^{\eta}, \text{ where } \alpha, \eta \in (0,1).$$

A household's entrepreneurial productivity $e \in E$ follows two-state Markov process, where $E = \{e_l, e_h\}$ stands for the set of possible productivity realizations with $e_l < e_h$. The productivity realizations are independent across households.

A household enters each period with its productivity e and the capital (wealth) it owns $a \in A$ (A stands for the set of possible wealth) and chooses whether to become a worker or an entrepreneur. Given its income, it ends a period by choosing its consumption and its wealth in the next period. The state of the economy at period t is joint distribution in the population $M_t(a,e)$.

2.2.2 Equilibrium

I focus entirely on steady states and, therefore, only defines steady states. We assume that a law of large numbers holds so that idiosyncratic uncertainty must disappear on the aggregate. Labor and capital rental markets are the only markets in this economy and they are competitive. Denote by r and δ, the net rate of return from wealth and the depreciation rate. The rental rate of capital is the sum of the net rate of return and the depreciation, $r+\delta$. Denote by w the wage rate. Then the entrepreneurial household's profit maximization problem is given by

$$\begin{aligned} \pi(a,e;w,r) \quad &= \quad \max_{l\geq 0, k\geq 0} \left\{ e^{1-\eta}\left(l^{\alpha}k^{1-\alpha}\right)^{\eta} - wl - (r+\delta)k \right\}, \\ \text{s.t.} \quad & \quad k \leq \lambda a \end{aligned} \tag{2.1}$$

where $1 \leq \lambda < \infty$. Let $l : A \times E \to \mathbb{R}$ and $k : A \times E \to \mathbb{R}$ be the optimal labor and capital demand functions respectively. Due to the collateral constraint, the household's capital rental is restricted by its wealth multiplied by the parameter λ. In particular, $\lambda = 1$ implies no capital rental markets, so that a household should finance its entrepreneurial project with its own wealth. On the other extreme, $\lambda = \infty$ corresponds to no frictions in capital rental markets.

We assume that a household cannot borrow intertemporally for consumption smoothing nor can they write contracts that depend on its productivity. Then, a household's wealth should be greater than 0, e.g. $A = [0, \infty)$, and its budget constraint is given by (a "$\,'\,$" denotes next period's value)

$$c + a' = (1+r)a + \max_{i \in \{0,1\}} \{iw + (1-i)\pi(a,e;w,r)\},$$

where denote by $i : A \times E \to \{0,1\}$, an indicator function that takes a value 1 if a household works for wage and 0 otherwise.[2]

To define the household's problem in a recursive form and a recursive competitive equilibrium, I set down some notations. Denote respectively by $\mathcal{B}(A \times E)$, the Borel σ-algebra of the product space $A \times E$. We define an operator $\mathcal{T} : C(A \times E) \to C(A \times E)$ for any function $v \in C(A \times E)$ ($C(A \times E)$ is the set of bounded, continuous functions on $A \times E$)

$$\mathcal{T}v(a,e;w,r) = \max_{a' \in \Gamma(a,e;M)} u\left((1+r)a + \max_{i \in \{0,1\}} \{iw + (1-i)\pi(a,e;w,r)\} - a'\right) + \beta \int_{e'} v\left(a',e';w,r\right) p(e,de'), \tag{2.2}$$

where $\Gamma(a,e;w,r) = \left[0,\, (1+r)a + \max_{i \in \{0,1\}} \{iw + (1-i)\pi(a,e;w,r)\}\right]$. Let $g : A \times E \to \mathbb{R}$ be the optimal policy function for wealth in the next period.

Finally, the transition function $Q : (A \times E) \times \mathcal{B}(A \times E) \to [0,1]$ is given by

$$Q((a,e),(\mathcal{A},\mathcal{E})) = \begin{cases} p(e,\mathcal{E}) & \text{if } g(a,e) \in \mathcal{A} \\ 0 & \text{otherwise,} \end{cases} \tag{2.3}$$

for all $a \in A$, $e \in E$, $\mathcal{A} \times \mathcal{E} \in \mathcal{B}(A \times E)$.

Definition 2.2.1. *(closed economy) A stationary recursive competitive equlibrium (RCE) consists of a value function, $v : A \times E \to \mathbb{R}$, policy functions, $g : A \times E \to \mathbb{R}$, $i : A \times E \to \{0,1\}$, $l : A \times E \to \mathbb{R}$, and $k : A \times E \to \mathbb{R}$, constant labor and capital rental rates, w and r, and a probability measure $M \in \mathcal{M}$ such that*

1. *Given w and r, v is a fixed point of $\mathcal{T}$ in the problem* (2.2)*, g is the corresponding policy function, and i, l and k are occupation choice, profit maximizing labor and*

[2] If $\lambda = 1$, then $r = -\delta$ and there is no cost of capital rental in the profit function (2.1). Therefore, any entrepreneur employs all his capital.

capital demand.

2. *Labor and capital rental markets clear*

$$\int_{\{(a,e):i(a,e)=0\}} l(a,e)M(da,de) = \int_{\{(a,e):i(a,e)=1\}} M(da,de),$$
$$\int_{\{(a,e):i(a,e)=0\}} k(a,e)M(da,de) = \int aM(da,de).$$

3. *The aggregate law of motion $\mathcal{P}$ generates the invariant probability measure M*

$$M(\mathcal{A},\mathcal{E}) = \mathcal{P}(M(\mathcal{A},\mathcal{E})),$$

for all $\mathcal{A} \times \mathcal{E} \in \mathcal{B}(A \times E)$.

It is understood that the aggregate feasibility constraint should hold by Walras' law. A stationary RCE in a small open economy is defined in a similar way except for that there is no capital rental market clearing condition.

Definition 2.2.2. *(small open economy) A stationary recursive competitive equlibrium (RCE) consists of a value function, $v : A \times E \to \mathbb{R}$, policy functions, $g : A \times E \to \mathbb{R}$, $i : A \times E \to \{0,1\}$, $l : A \times E \to \mathbb{R}$, and $k : A \times E \to \mathbb{R}$, constant wage rate w and a probability measure $M \in \mathcal{M}$ such that*

1. *Given wage rate w, v is a fixed point of $\mathcal{T}$ in the problem* (2.2)*, g and f are the corresponding policy functions, and i, l and k are occupation choice, profit maximizing labor and capital demand.*
2. *Labor market clears*

$$\int_{\{(a,e):i(a,e)=0\}} l(a,e)M(da,de) = \int_{\{(a,e):i(a,e)=1\}} M(da,de).$$

3. *The aggregate law of motion $\mathcal{P}$ generates the invariant probability measure M*

$$M(\mathcal{A},\mathcal{E}) = \mathcal{P}(M(\mathcal{A},\mathcal{E})),$$

for all $\mathcal{A} \times \mathcal{E} \in \mathcal{B}(A \times E)$.

2.2.3 Solving for an Approximate Equilibrium

Because we do not have a closed form for steady states in this model, I compute approximate steady states for various specifications of the model. I follow what is by now a fairly standard approach to compute steady states: I discretize the state space and employ Aiyagari (1994)'s nested fixed point method. In particular, in the most inner loop, I search for value function and stationary density of wealth, and, in the outside loop, I search for market clearing wage and rental rate by iterating each of them until convergence.

I use the value function iteration method to solve for an individual household problem. While our utility function and the density of wealth are continuous, a computer can only handle the discrete data. Therefore, the approximation of the functions and integrations should be done by a grid with discrete points. As the space for wealth, I choose finer spacing at the lower end of the grid and coaser spacing at the higher end to capture the curvature of wealth density. To choose a sufficiently large number as the upper bound of the grid point for wealth, I verify with trial and error that once a household starts with weath in our grid, its future wealth is bounded by the maximum value of the grid.

To solve the optimization problem in each iteration, I use Golden section search algorithm, which does not require the smoothness of the objective function (p.623 of Heer and Mauβner (2005)). The household's wealth choices are not restricted to lie on a grid point and the value of the value function between gridpoints are determined by linear interpolation. To get a stationary distribution, rather than applying the standard simulation method as in Aiyagari (1994) and B&S, I discretize the density function and iterate it until convergence (Algorithm 7.2.3 of Heer and Mauβner (2005)).[3]

In pinning down equilibrium wage and rental rate, I apply three alternative ways to an economy with different cases of λ: $\lambda = \infty$, $\lambda > 1$, and $\lambda = 1$. They are similar in that I follow Aiyagari (1994)'s nested fixed point method and pin down both or one of prices. The differences are as follows. First, for the case of the benchmark economy ($\lambda = \infty$), I impose specialization (all households with high productivity are entrepreneurs and all households with low productivity are workers) and find a steady state consistent with specialization. Under specialization, the wage rate can be written as the following

[3]The tolerance levels for value function iteration and the density function iteration are 10^{-6} and 10^{-8} respectively.

function of the rental rate

$$w = \alpha \left(\left(\eta \left(\frac{1-\alpha}{r+\delta} \right)^{\eta(1-\alpha)} \right) \left(\frac{\mu_h}{\mu_l} e_h \right)^{1-\eta} \right)^{\frac{1}{1-\eta(1-\alpha)}}.$$

Here, μ_h and μ_l denote the steady state masses of households with high productivity and with low productivity respectively. Therefore, in this case, we need only one outside loop. For the cases with $\lambda \in (0, \infty)$, I confirm the capital rental market clearing condition in the outside loop and labor market clearing condition in the inside loop. Finally, when there is no capital rental market ($\lambda = 1$), the rate of return from wealth is simply depreciation rate $-\delta$. Therefore, I fix $r = -\delta$ and solve for wage rate to clear labor market.

Although I numerically check the existence of equilibria, their existence in this model is not analytically guaranteed. One difficulty is to prove the existence of a stationary probability measure, which in turn requires the compactness of state space (Theorem 12.12 of Stokey, Lucas, and Prescott (1989)). Huggett (1993) proves the compactness of state space for wealth in an incomplete markets model with two-state Markov productivity process on endowment shock.[4] Because of a collateral constraint and occupation choice, a household's value function in our model is not differentiable. Therefore, in our model the compactness proof cannot be obtained in the way Hugget did.

2.3 Calibration

I calibrate the closed economy version of model with no frictions in capital rental market, $\lambda = \infty$. I call this the *benchmark economy*. Table 3.2 summarizes the parameters, the moments I used for the calibration, and the resulting values for the initial calibration of the benchmark economy. The period in the model is one year. Risk aversion (γ), the labor share in production (α), the depreciation rate (δ), and the span of control (η) are chosen from the existing literature about the U.S. economy. Recent literature uses value for η that varies from 0.7153 (Blaum (2012)) to 0.90 (Khan and Thomas (2008)). I use $\eta = 0.81$ from Cooper and Haltiwanger (2006) who estimate the curvature of investment in profit

[4]Even with slightly more general productivity process, e.g. three-state Markov process, the existence proof in an incomplete markets model seems to be hard. The main difficulty is to prove that the policy for wealth in the next period is increasing in labor productivity. Miao (2002) proves it in the model of Aiyagari (1994) but with additional stronger assumptions on utility function and productivity process.

Table 2.1. Parameter values for the benchmark equilibrium

risk aversion	γ	1.5	Attanasio, Banks, Meghir, and Weber (1999)
labor share	α	0.67	Gollin (2002)
depreciation rate	δ	0.06	Stokey and Rebelo (1995)
span of control	η	0.81	Cooper and Haltiwanger (2006)
discount rate	β	0.95	calibrated

Discretization of e

number of grid points 2

productivity states:

$$E = \{e_l, 1\} \text{ with } e_l = 0.1, 0.05, \text{ or } 0.2$$

transition matrix:

$$\pi_{ee'} = \begin{pmatrix} 0.97 & 0.03 \\ 0.20 & 0.80 \end{pmatrix}$$

Discretization of a

number of grid points 1000

wealth states:

$$A = \{0, \ldots, 80\}$$

Targets and results

	Target	Model
rate of return	4%	4%
fraction of entrepreneurs	12%	12%
exit rate of entrepreneurs	20%	20%

function by using the U.S. manufacturing plant-level data.[5]

The remaining parameters are the discount rate β and the parameters associated with

[5] Using FOC for labor demand, the entrepreneurial profit is given by

$$(1-\alpha\eta)e^{\frac{1-\eta}{1-\alpha\eta}}\left(\frac{\alpha\eta}{w}\right)^{\frac{(1-\alpha)\eta}{1-\alpha\eta}}k^{\frac{(1-\alpha)\eta}{1-\alpha\eta}} - (r+\delta)k.$$

the entrepreneurial productivity process. They are determined by requiring that the resulting steady states match the following features of the U.S. economy: the fraction of entrepreneurs in the population, the exit rate of entrepreneurs, and the interest rate. As a support for the productivity process, I use $E = \{e_l, 1.0\}$ with $e_l = 0.1$, 0.05, or 0.2. We match the fraction of entrepreneurs and the exit rate for the benchmark economy to the corresponding U.S. data statistics, 12% and 20%, respectively (Quadrini (2000))[6]. The target net rate of return from capital r for the benchmark economy is 4%.

Table 2.2. Comparing benchmark with U.S. data

	benchmark model ($\lambda = \infty$)	data (U.S. 1990-1994)
capital to GDP ratio	2.67	2.16
external finance ratio	2.11	2.15

Next, in the table 2.2 we evaluate the calibration results for the benchmark economy ($\lambda = \infty$) by comparing two steady state statistics to the corresponding data statistics: capital to GDP ratio and external finance ratio.The particular reason I choose two statistics is that external finance ratio is widely used as a proxy for financial development and financial frictions could affect capital accumulation.[7] Note that neither of them is the target for our calibration. The predicted capital to GDP ratio and external finance to GDP ratio are respectively 19% greater and 2% smaller than their data statistics. Because there are a number of frictions in a real economy, we may view our calibration results as the equilibrium outcomes in the absence of these other frictions.

For the small open economy, I impose the same parameters and the world rental rate is determined by an economy with $\lambda = \infty$. Then, when there is no collateral constraint, the steady state properties in a small open economy is the same to the steady state properties in a closed economy.

The estimate for $\frac{(1-\alpha)\eta}{1-\alpha\eta}$ in Cooper and Haltiwanger (2006) is 0.59. Given our labor share $\alpha = 0.67$, the span of control parameter is 0.81.

[6]Quadrini (2000) defines entrepreneurs as households that own a business or have a financial interest in some business enterprise. The percent is similar to active business owners in Table 1 of Cagetti and Nardi (2008) who also report that the statistics are similar for 1989, 1992, and 1995 waves of the Survey of Consumer Finances.

[7]The previous studies also look at one or both of these statistics to evaluate their calibration results, e.g. B&S, BKS, and M&X.

2.4 Results

The goal of this section is to compare the steady state properties in a closed economy to the steady state properties in a small open economy, when varying the degree of financial frictions (λ=1, 1.25, 1.5, 2, 3, 4, 5, 6, 7, ∞). In most of our analysis, I focus on the results from economies with support of productivities $E = \{0.1, 1\}$. In Figure 2.5, I compare the results between the alternative supports of productivities.

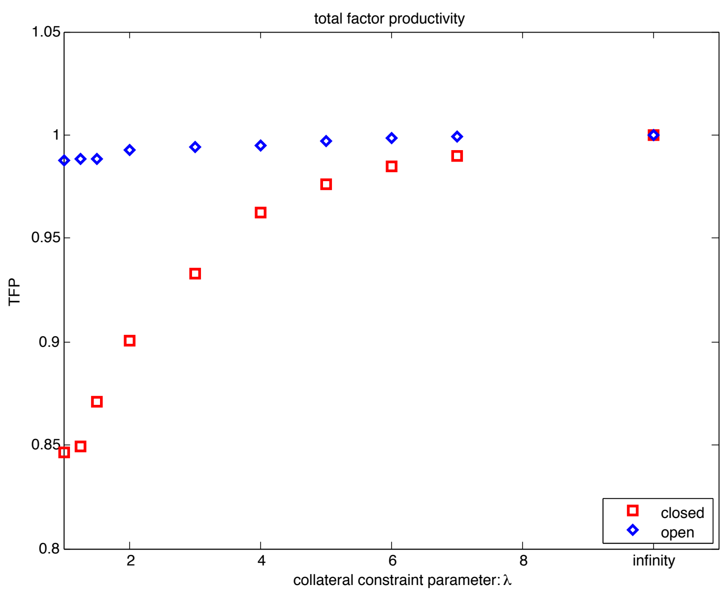

Figure 2.1. TFP Losses from financial frictions

Figure 2.1 shows our main numerical results: TFP in both a small open economy and a closed economy for each λ. We normalize TFP in the benchmark economy at 1 and TFP in an economy with a finite collateral constraint is the value relative to TFP in the benchmark economy. The figure shows that TFP loses in a closed economy are larger than TFP losses in a small open economy for each finite λ. For instance, for the tightest collateral constraint (an entrepreneur only employ capital he owns), TFP in a small open economy is only about 1% lower than in the benchmark economy, while it is 15% lower in a closed economy.

To further analyze the difference in TFP between the two capital rental market specifications, I show in Figure 2.2 how the mass of entrepreneurs with each productivity level varies with λ. I normalize the overall mass of households with each productivity level at 1. The figure shows that the difference in TFP between the two rental market specifica-

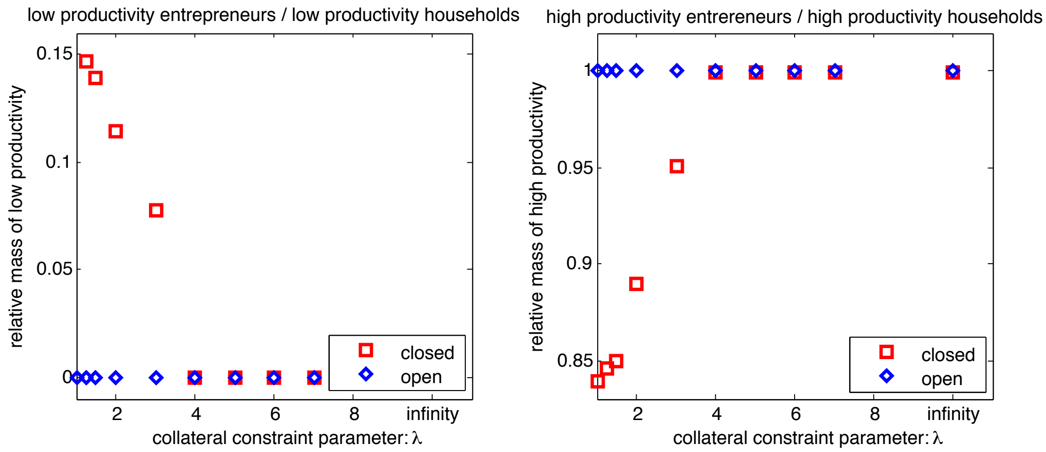

Figure 2.2. Mass of Entrepreneurs for each Productivities

tions (Figure 2.1) is accompanied by the allocation of entrepreneurship among households (entry-exit margin or extensive margin). While entrepreneurs in a closed economy consist of households with both low and high productivity levels when a collateral constraint is tight, in a small open economy there is specialization in that all households with high productivity are entrepreneurs and all households with low productivity are workers. The results in a small open economy resemble the results in M&X, who take as given a small open economy and study the model with and without entry-exit: financial frictions do not tend to prevent productive households from becoming entrepreneurs in a small open economy.

For financial frictions $\lambda \geq 4$, all households with high productivity are entrepreneurs and all households with low productivity are workers: that is, misallocation along the entry-exit margin disappears even in a closed economy (Figure 2.2). However, TFP in a closed economy is still lower than TFP in a small open economy: for the case of $\lambda = 4$, the difference is 3% (Figure 2.1). To see the difference in the factor allocation among incumbent entrepreneus (intensive margin), we compare the density of marginal product of capital between the two rental market specifications.[8] Each graph in Figure 2.3 shows the density of marginal product of capital for either $\lambda = 1$ (no capital rental market) or $\lambda = 4$ and either a small open economy or a closed economy. The figure shows that for both levels of financial frictions, marginal product of capital in a closed economy is more

[8]Because a collateral constraint is involved only with capital demand and there is a single wage rate in our model, there is no gap in marginal product of labor among entrepreneurs. However, the allocation of labor among producers is not efficient in that it differs from the allocation of labor in the benchmark economy.

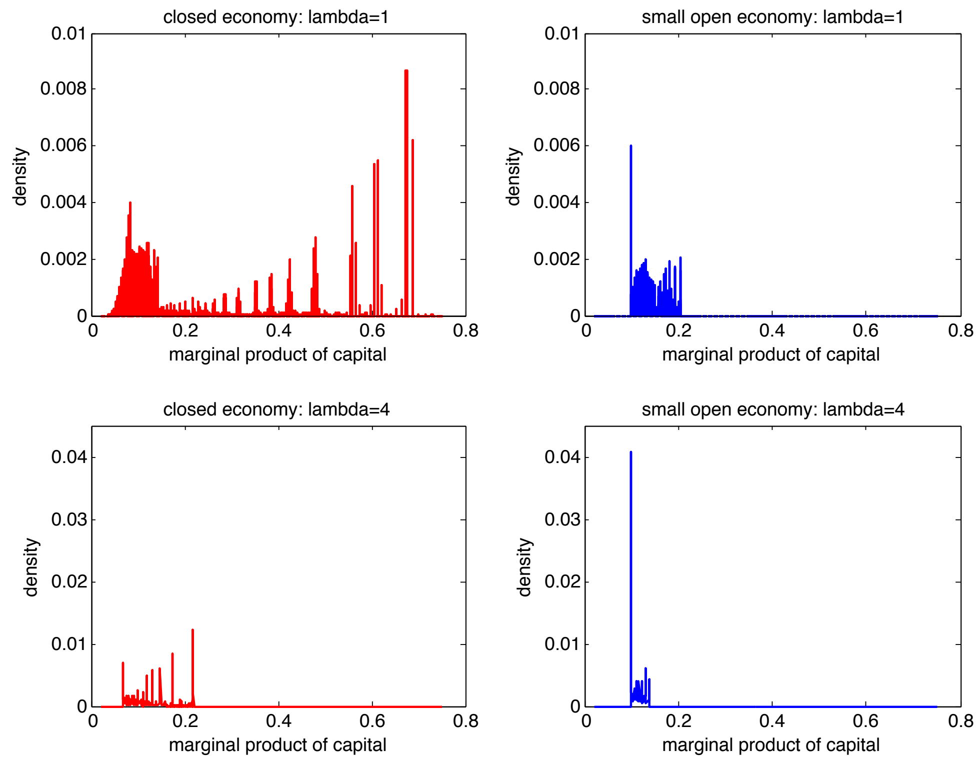

Figure 2.3. Density of Marginal Product of Capital

dispersed. The association between TFP and the dispersion in marginal product of capital resembles the results by Hsieh and Klenow (2009) in that a large dispersion in marginal product of capital is accompanied by low TFP. The difference is that they use abstract tax-type distortions, while the dispersion in this paper is generated from a collateral constraint. To summarize, in a closed economy there is more severe distortions on factor allocation among incumbent entrepreneurs (intensive margin) as well as the allocation of entrepreneurship among households (entry-exit margin) than in a small open economy. In contrast, TFP losses in our small open economy reflect misallocation of factors among households with high productivity (intensive margin), not distortions along entry-exit margin

The first graph in Figure 2.4 shows that households in a small open economy accumulate more wealth on average than in a closed economy and are less likely to be collateral-constrained. The difference in average wealth between the two rental market specifications is accompanied by the difference in the rental rate of capital. The second graph in Figure 2.4 shows the rental rate in the two rental market specifications: the rental rate in a small

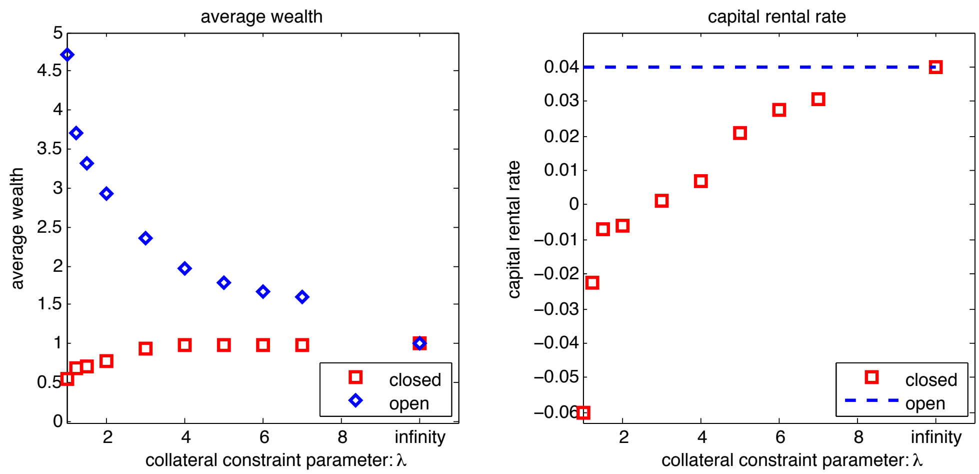

Figure 2.4. Average Wealth and Rental Rate of Capital

open economy is fixed at the world rate of return 4%, while the rental rate in a closed economy declines with the tightness of a collateral constraint and is lower than the rental rate in a small open economy, which is determined from financially developed economies.[9]

In addition, the first graph in Figure 2.4 also shows that average wealth decreases with λ in a small open economy. The results imply that a small open economy with a tight collateral constraint accumulates more wealth than the rest of the world (benchmark economy). Therefore, their capital flows out of their domestic capital rental market and their consumption is strictly greater than their net production (domestic output net of depreciation).

Figure 2.5 compares TFP between the alternative supports of productivities: we maintain high productivity level at 1 and only change low productivity level 0.1 to either 0.05 or 0.2. The results in the other cases are similar to Figure 2.1: TFP in a small open economy is affected less by financial frictions. Quantitatively, the effect of financial frictions on TFP in a closed economy varies with low productivity level e_l. For the tightest collateral constraint, TFP in a closed economy is 91% of benchmark economy when low productivity $e_l = 0.2$, while it is 80% when $e_l = 0.05$. In contrast, because the resulting steady state in a small economy is an equilibrium with specialization, TFP in a small open economy does not vary with our choice of low productivity e_l.

[9]There is one possible channel through which the rental rate in a closed economy declines with the tightness of a collateral constraint: the collateral constraint suppresses the demand of capital and the rental rate in a closed economy should decrease to clear the capital rental market.

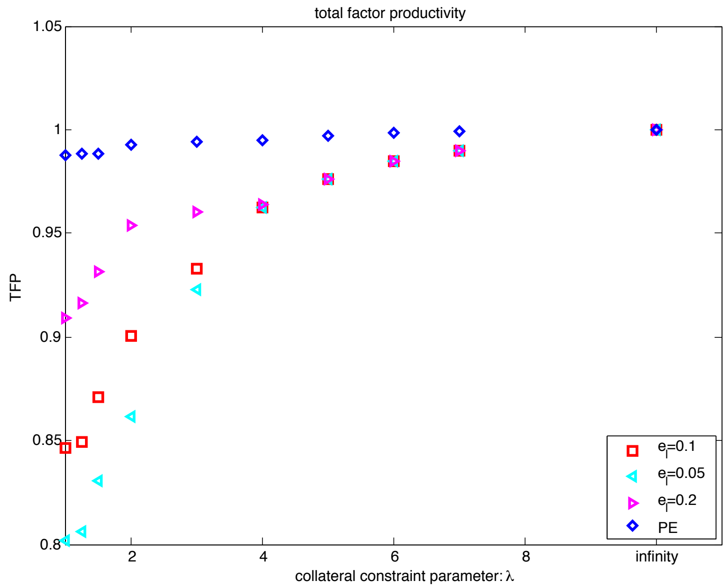

Figure 2.5. Comparison of TFP with Alternative e_l

The accurate quantification of TFP losses from financial frictions requires the data about productivity of individuals who choose not to be producers. However, such data are not available for both the U.S. and developing countries.[10] However, while our quantitative results depend on the support of productivities, considering the other support for productivities does not seem to change our qualitative results: TFP in a small open economy is affected less by its financial frictions than in a closed economy. In the next section, we are going to test such qualitative prediction of the model.

2.5 Evidence

The goal of this section is to estimate the interaction between capital account openness and the effect of financial frictions on TFP. The empirical test in this section is more general than our numerical analysis: while we only consider the absence or presence of capital account control in our numerical analysis, the indicator of capital account openness here captures the severity and magnitude of openness. This allows us to estimate the elasticity of TFP effect of financial frictions with respect to openness. In the following I will describe data, the regression specifications, and results.

[10] For instance, B&S, BKS, and M&X assume functional form of productivity process and use evidence of incumbent producers to construct the parameters of the process.

2.5.1 Data

The data necessary for our empirical analysis are capital, GDP per worker, external finance to GDP ratio (external finance ratio or capitalization ratio), the measure of capital account openness, and the other country-level controls. All data span from 1990 to 1994 except for the openness measure.

Capital is constructed by using data from Penn World Table 7.1 (PWT71). Because PWT71 only provides investment series, I construct capital by calculating the growth rate of investment series between 1970 and the first availiable year of investment (1950) and then apply perpetual inventory method (p.685 of Caselli (2005)). I drop the countries whose first available investment data is later than 1970. GDP per worker is rgdpwok in PWT71. Given capital and GDP per worker, TFP is constructed from Cobb-Douglas function of physical capital and worker.

Following the tradition in the literature, I use the external finance to GDP ratio as a proxy for the absence of financial frictions (financial development). Our external finance to GDP ratio (total capitalization ratio) is constructed as the sum of (i) private credit owed to bank and other financial intermediaries, (ii) private bond market capitalization, and (iii) stock market capitalization as a ratio of GDP - from Beck, Demirguc-Kunt, and Levine (2000). Following BKS, I multiply the stock market capitalization by the book value-market value ratio, 0.33. Because stock market capitalization does not reflect the amount of funds actually obtained by issuers (Rajan and Zingales (1998)), I check that our results are robust to redefining the capitalization ratio as either the ratio of (i) to GDP or the ratio of (i)+(ii) to GDP.

I take the measure of capital account openness (CAP100), from Quinn (1997). He construct the indicator on a government's policy stance toward capital account liberalization (*de jure* indicator), using IMF's annual publication, Annual Report on Exchange Arrangements and Exchange Restrictions.[11] Quinn's indicator is provided as 5-year average values and is 0-100 scale. Therefore, the indicator offers not only of the existence or absence of restrictions but the severity or magnitude of the restrictions. Following Quinn and Toyoda (2008), I use 5-year lags on the openness measure (the average from 1985 to 1989).[12] Us-

[11] Quinn and Toyoda (2008) and Quinn, Schindler, and Toyoda (2011) compare his indicator to the other *de jure* and *de facto* indicators.

[12] A government is more likely to liberalize its capital account when it expects brightest future. Quinn and Toyoda (2008) claim that a focus on a 5-year lags in openness measure should attenuate such endogeneity bias.

ing the average of the openness measure from 1990 to 1994 does not change our results significantly and the results are available upon request.

The other country-level controls consist of GDP as a proxy for the scale of an economy, import plus export as a ratio of GDP (openk from PWT71) as a proxy for an economy's access to larger markets, and institutional quality proxied by government antidiversion policies (GADP from Hall and Jones (1999)).

2.5.2 Evidence from Interaction Effects

This section establishes the main empirical results of this paper.[13] I check in which direction and how much openness to international financial market changes TFP effect of financial frictions. How openness affects the elasticity of TFP with respect to external finance ratio, ξ, is given as follows

$$\xi = \frac{\partial \log\left(\frac{\partial \log(TFP)}{\partial \log(ExFinance)}\right)}{\partial \log(CapOpen)} = \underbrace{\partial\left(\frac{\partial \log(TFP)}{\partial \log(ExFinance)}\right)\frac{CapOpen}{\partial CapOpen}}_{\text{(A)}} \times \underbrace{\left(\frac{\partial \log(TFP)}{\partial \log(ExFinance)}\right)^{-1}}_{\text{(B)}} \tag{2.4}$$

where $CapOpen$ and $ExFinance$ respectively denote capital account openness measure and external finance ratio.

To derive the estimate in (2.4), we estimate the following regression with an interaction term

$$\begin{aligned}\log(TFP_{it}) = c + \beta_1^{TFP}\log(CapOpen_{it}) * \log(ExFinance_{it}) \\ + \beta_2^{TFP}\log(ExFinance_{it}) + \beta_3^{TFP}\log(CapOpen_{it}) \\ + \beta_4^{TFP}X_{it} + \varepsilon_{it}\end{aligned} \tag{2.5}$$

[13] To take a first glance at the interaction between openness and TFP effect of financial frictions, I also conduct split-sample estimation. In particular, I split the sample into two groups: relatively open economies and closed economies and regress log of TFP on log of external finance ratio. The slope of the open economies' group is flatter than that of the closed economies' group: a open economy's TFP is affected less by financial frictions. Therefore the results comply with the results which we will see in this section. The split sample results are available upon request.

Table 2.3. Estimation Results: Full Sample

	financial development measured as		
	total	bank	bank + bond
	(1)	(2)	(3)
log(ExFin)	0.342**	0.355**	0.380***
	(0.146)	(0.149)	(0.144)
log(CapOpen)	0.165***	0.147**	0.143**
	(0.062)	(0.066)	(0.064)
log(ExFin) *log(CapOpen)	-0.067*	-0.068*	-0.072*
	(0.038)	(0.039)	(0.037)
controls	Y	Y	Y
observations	399	399	399
R2	0.647	0.648	0.650

Note: Heteroskedasticity robust standard errors are reported in parentheses with ***, **, and * respectively denoting significance at 1%, 5%, and 10%. Controls consist of log of GDP, log of openness to trade, log of institutional quality, and year dummies.

where X_{it} contains country-level controls such as log of GDP, log of openness to trade, and log of a proxy for institutional quality and year dummies. Two estimates in (2.5), $\hat{\beta}_1^{TFP}$ and $\hat{\beta}_2^{TFP}$, respectively provide the estimates of (A) and (B) in equation (2.4). Then the estimate of ξ in equation (2.4), $\hat{\xi}$, is obtained as the ratio between $\hat{\beta}_1^{TFP}$ and $\hat{\beta}_2^{TFP}$, e.g. $\frac{\hat{\beta}_1^{TFP}}{\hat{\beta}_2^{TFP}}$.

Table 2.3 shows our main empirical results. When we use total capitalization ratio (total in column (1)), the estimate of coefficient for ξ is $\hat{\xi} = \frac{\hat{\beta}_1^{TFP}}{\hat{\beta}_2^{TFP}} = \frac{-0.067}{0.342} = -0.196$: that is, a 1% rise in openness is associated with 0.196% decline in the effect of financial development on TFP. Column (2) and (3) show the results from two alternative measures of financial development: the private credit owed to bank and financial intermediaries as a ratio of GDP (bank in column (2)) and the sum of the private credit and bond market capitalization as a ratio of GDP (bank+bond in column (3)). The estimate for ξ is -0.192 ($= \frac{-0.068}{0.355}$) or -0.189 ($= \frac{-0.072}{0.380}$) depeding on the measure of financial development.

To further investigate from which group of countries our results come, I split the sample into two subgroups of low income countries and the rest of the other countries by using World Bank income group categorization and run the regression (2.5) on both sub-samples separately. Table 2.4 shows the results. The results from split-samples show that the esti-

Table 2.4. Estimation Results: low income country and the rest of world

	low income			rest of world		
			bank			bank
	total	bank	+bond	total	bank	+bond
	(1)	(2)	(3)	(4)	(5)	(6)
log(ExFin)	1.351***	1.125***	1.128***	0.195*	0.191*	0.210*
	(0.390)	(0.421)	(0.418)	(0.110)	(0.100)	(0.108)
log(CapOpen)	-0.273	-0.209	-0.210	0.037	0.037	0.035
	(0.194)	(0.226)	(0.225)	(0.051)	(0.051)	(0.052)
log(ExFin)	-0.364***	-0.301***	-0.302***	-0.042	-0.034	-0.039
*log(CapOpen)	(0.106)	(0.115)	(0.114)	(0.029)	(0.026)	(0.029)
controls	Y	Y	Y	Y	Y	Y
observations	143	143	143	256	256	256
R2	0.413	0.402	0.402	0.662	0.665	0.666

Note: Heteroskedasticity robust standard errors are reported in parentheses with ***, **, and * respectively denoting significance at 1%, 5%, and 10%. Controls consist of log of GDP, log of openness to trade, log of institutional quality, and year dummies.

mate of the interaction between openness and the TFP effect of financial frictions in low income countries is greater than the estimate in full sample in absolute terms ($\hat{\xi} = -0.269$, -0.268, and -0.268 from column (1), (2) and (3)), while the same estimate in the rest of the other countries is not significant (column (4), (5), and (6)). To summarize the results from table 2.3 and 2.4, there is evidence that TFP in an open economy is affected less by financial frictions and this empirical result mainly comes from a group of low income countries.

2.6 Final Remarks

There are at least three limitations in this paper, which also could be possible future works. First, like the recent studies on financial integration (e.g. Mendoza, Quadrini, and Rios-Rull (2009) and Angeletos and Panousi (2011)) in our model we only consider the presence or absence of a government control on capital account. Therefore, even though data on magnitude or severity of the restrictions on capital account are available, we can only check whether the model's predictions are consistent with data qualitatively. It would be interesting to formulate a model with severity of the restrictions on capital account and empirically assess the model's quantitative prediction. Second, the sectors differ in their dependence on the external financing. The recent papers by BKS and Blaum (2012) explicitly study this sector level difference. But, to the best of my knowledge, the interaction between capital account openness and TFP effect of financial frictions in the model with the sector level difference has not been studied. Finally, we could conduct normative analysis. Unlike some of existing literature (Aoki, Benigno, and Kiyotaki (2009)), our results seem to suggest that opening up to international financial markets is good for an economy even when the economy is financially underdeveloped. Studying which factor leads to the gain (or loss) from capital account liberalization in terms of both steady states and transitions would be another interesting direction.

Chapter 3

The Losses from Tax-type Distortions in a Model with Innovation

3.1 Introduction

The goal of this paper is to quantify the aggregate productivity losses from the frictions through the lens of an industry dynamics model with endogenous productivity process. Hsieh and Klenow (2009), henceforth HK, propose that China and India are subject to the large extent of resource misallocation across plants and there would be substantial gains if resources are hypothetically reallocated to match their allocative efficiencies to the U.S. level. However they analyze the losses (or hypothetical gains) in a model in which the frictions affect only the resource allocation across plants and they do not take into account plant-level dynamics such as entry and process innovation. In this paper I ask whether the allocative frictions affect the aggregate productivity through not only the resource allocation across plants but also a plant-level process innovation by bringing the plant-level dynamics into the model. My answer based on the results is that there is no significant difference between the aggregate productivity losses in this model and those in HK's static model. The intuition is as follows. Imagine that we hypothetically remove or reduce the allocative frictions for a majority of plants.When a plant tends to face the less extent of allocative frictions, it will expect larger future profits and have larger value than when it would face the more extent of the frictions. As a result a plant will raise investment in process innovation until its marginal value of innovation is equal to its marginal cost of innovation. I refer to these effects of improving the allocative efficiency to encourage more process innovation and to raise the aggregate productivity as productivity upgrading effects. On the other hand there is an infinite measure of potential entrants and they will enter into the market since value of entry now becomes larger than entry cost. The more plants enter, the competition will become the tougher and plants, even productivive plants, will make the less profits and will have the less value. Since being more producive by making costly investment will become less attractive than before more plants enter, a plant will have incentives to reduce the process innovation investment. I refer to those second competiting effects of improving the allocative efficiency to discourage process innovation as entry effects. Our result implies that after I hypothetically improve the allocative efficiency in Korea, two conflicting effects, productivity upgrading effects and entry effects, tend to offset each other almost completely.

To quantitatively assess the aggregate productivity losses from the allocative frictions in our industry dynamics model, I take a closed economic version of Atkeson and Burstein (2010), henceforth AB, with allocative frictions to data for Korean Manufacturing plants. First I choose parameters in the model to match the moments of the model to the corresponding data implications in Korea. Then to quantify the losses from the frictions (or hypothetical gains from improving the allocative efficiency), I hypothetically move the allocative efficiency in the model of Korean economy into the U.S. level and measure a change in the aggregate productivity.

The model predicts that the aggregate productivity will be 153% higher after improving the allocative efficiency. This value of aggregate losses is almost the same as that from HK's static model and having another channel through which the frictions affect the aggregate productivity in the model (process innovation) does not have any additional, significant implications. Since the proposed losses from the allocative frictions on process innovation reflect productiviy upgrading effects as well as entry effects, the results imply that they offset each other.

One way to see if there are offsetting movements is to single out productivity upgrading effects from the aggregate productivity losses in a model in which entry does not respond to a change in the allocative frictions and to ask if the aggregate process innovation responds to a change in the frictions. More precisely, since productivity upgrading effects amplify the losses from frictions in the absence of entry effects, we should observe that allowing the plant-level process innovation in the model magnifies the aggregate productivity losses when endogenous entry is not allowed in the model. I calibrate a industry dynamics model with endogenous productivity and exogenous entry to Korean economy. After fitting its moments to the data mements in Korea, I again hypothetically move its level of the allocative efficieny into the U.S. level. The model with exogenous entry predicts that process innovation responds to the change in the frictions and the responses are significant ($16 \sim 37\%$ depending on parameters). However the effects on process innovation become insignificant once endogenous entry comes into effect.

3.2 Model

Following AB, I model a sector composed of a continuum of monopolistically competitive production units, a representative household, and a representative producer of a composite good. Aside from parameter differences, the main departure from AB is that a production unit faces plant specific frictions that distort its factor demand and it employs two factors, labor and capital, taking as given its productivity and frictions. The sector faces fixed supplies of labor and capital in each period. The composite good is necessary for operating, innovation, and entry of a production unit. Time is discrete. I mainly focus attention on a steady state equilibrium and omit time subscripts unless it gives any confusion to readers.

3.2.1 Production Units

Variable Profits

Each production unit produces a variety υ, employing $l(\upsilon)$ units of labor and $k(\upsilon)$ units of capital according to Cobb-Douglas production function: $y(\upsilon) = a(\upsilon)l(\upsilon)^{\gamma}k(\upsilon)^{1-\gamma}$ where a labor share $\gamma \in (0,1)$. The aggregate output is aggregated through the isoelastic Spence-Dixit-Stiglitz form with a constan elasticity $\varepsilon > 1$:

$$Y = \left[\int y(\upsilon)^{(\varepsilon-1)/\varepsilon} d\upsilon\right]^{\varepsilon/(\varepsilon-1)} \tag{3.1}$$

From standard argument, the aggregate output price is

$$P = \left[\int p(\upsilon)^{1-\varepsilon} d\upsilon\right]^{1/(1-\varepsilon)} \tag{3.2}$$

and a production unit faces a residual demand curve: $p(\upsilon) = PY^{1/\varepsilon} y(\upsilon)^{-1/\varepsilon}$. I assume that each variety υ is produced by a production unit with a different combination of productivity ω and frictions z and that an unit-level productivity is $a(\omega) = \exp(\omega)^{1/(\varepsilon-1)}$. Here I rescale the productivity with $1/(\varepsilon-1)$ and therefore the equilibrium labor, capital, and variable profit are proportional to $\exp(\omega)$. When a production unit takes as given price of labor and capital, P_L and P_K, and aggregate price and output, P and Y, its variable profit is

$$\Pi(\omega,z) \equiv PY^{1/\varepsilon}\left(\exp(\omega)^{1/(\varepsilon-1)} l(\omega,z)^{\gamma} k(\omega,z)^{1-\gamma}\right)^{1-1/\varepsilon} - P_L l(\omega,z) - P_K k(\omega,z) \quad (3.3)$$

I define the frictionless employment and stock of capital of an establishment, $l^*(\omega)$ and $k^*(\omega)$, as the solution of maximization of (3.3) with respect to labor and capital respectively

$$\begin{aligned} l^*(\omega) &\equiv \Phi\left(\frac{\varepsilon(1-\alpha)-1}{P_L}\right)\exp(\omega) \\ k^*(\omega) &\equiv \Phi\left(\frac{\alpha}{P_K}\right)\exp(\omega), \end{aligned}$$

where $\Phi \equiv X^{1/(1-\alpha)}(P_K/\alpha)^{-\alpha/(1-\alpha)}$,

$$X \equiv \frac{(P_L/P)^{1-\varepsilon(1-\alpha)} PY^{1-\alpha}}{(\varepsilon(1-\alpha))^{\varepsilon(1-\alpha)}(\varepsilon(1-\alpha)-1)^{1-\varepsilon(1-\alpha)}}, \qquad \text{and} \qquad \alpha \equiv \frac{(1-\gamma)(1-1/\varepsilon)}{1-\gamma(1-1/\varepsilon)} < 0 \quad (3.4)$$

Following Caballero and Engel (1999),[1] I define the unit-level frictions z that influence demand of labor and capital by the same proportion

$$z \equiv \log\left(k(\omega,z)\right)/k(\omega)^*) = \log\left(l(\omega,z)/l(\omega)^*\right)$$

I rewrite the profit function (3.3) as

$$\Pi(\omega,z) = \Phi\varepsilon(1-\alpha)\left[\exp\left(\frac{\varepsilon-1}{\varepsilon}z\right) - \frac{\varepsilon-1}{\varepsilon}\exp(z)\right]\exp(\omega) \quad (3.5)$$

[1]In Caballero and Engel (1999) z is due to a lumpy adjustment cost of capital. The objective of my paper is to study the aggregate implications of resource misallocation, not the impact of lumpiness on aggregate investment. Therefore I do not specify the source of frictions and instead I parametrize the distribution of z from the corresponding data moment.

The profit $\Pi(\omega, z)$ increases with productivity level ω for a given z and it reaches a maximum when $z = 0$ for a given ω.

A Composite Good

A competitive producer produces a composite good with Cobb-Douglas production function: $L_C^{\lambda} K_C^{\rho} Y_C^{1-\lambda-\rho}$ where λ, $\rho \in [0,1]$ and $\lambda + \rho \in [0,1]$. A production unit pays a fixed cost, an entry cost, and a cost for process innovation with the composite good.

Dynamics of a Plant

Conditional on survival, a production unit's process innovation investment q governs its productivity ω. On the other hand, I assume that once a production unit draws its frictions z when it entered an economy, it keeps the constant level of the frictions z for the rest of its life. The Bellman equation for the production unit's dynamic programming problem is

$$\begin{aligned} V(\omega, z) &= \max \left[0, \widetilde{V}(\omega, z)\right] \\ \widetilde{V}(\omega, z) &= \max_{q \in [0,1]} \Pi(\omega, z) - \exp(\omega) c(q) - n_f + \frac{1}{R} \left[q V(\omega + s, z) + (1 - q) V(\omega - s, z) \right] \end{aligned}$$

where $\exp(\omega)c(q)$ is a cost function of process innovation decision $q \in [0,1]$ with $c' > 0$ and $c'' > 0$, $n_f > 0$ is a fixed cost, R is a discount rate. s is a step size, so that a production unit draws a new productivity, which could be $\omega + s$ with probability q and $\omega - s$ with probability $1 - q$. For each friction level z, $\widetilde{V}(\omega, z)$ strictly increases with productivity ω.[2] In the presence of fixed cost, if ω is sufficiently small then $\widetilde{V}(\omega, z)$ can be negative for a given z. Therefore there is endogenous exit in the model and there exits a cut-off $x(z)$ in which a production unit either operates if $\omega \geq x(z)$ or exits otherwise.

A couple of implications from the a plant's Bellman equation must be noted. First, there is a positive relationship between a plant-level productivity and its investment in process innovation in a frictionless economy. A more productive plant has a larger marginal value of process innovation than a less productive plant does. Until a plant equalizes its marginal value of innovation to its marginal cost of innovation, it raises its investment in process innovation. Therefore a plant's investment in process innovation q tends to

[2] The Bellman equation has an unique value function $V(\omega, z)$ if $\beta\left(q \exp(s) + (1-q)\exp(-s)\right) < 1$. Numerically solving the model, our result satisfies this condition. As long as $q < 0.4754$, this condition holds. Since the Bellman equation has a unique solution and $\Pi(\omega, z)$ is strictly increasing in ω, $\widetilde{V}(\omega, z)$ is the only solution to the Bellman equation and is strictly increaing in ω.

increase with productivity ω.

Another important implication is that the frictions discourage the process innovation by a plant. Since the plant's factor employment level in a frictious economy is not its first best employment level, a plant makes less profit in such a frictious economy than it might do in the frictionless economy. Because by process innovation a plant sacrifices a part of its current profit to raise its future profit and its future profit becomes smaller in a frictious economy than in the frictionless economy, a plant has less incentive for the costly innovation in a frictious economy than in the frictionless economy. This innovation-incentive problem caused by the existence of the frictions yields a change in the aggregate productivity through the channel of a plant's process innovation. By facing less frictions than before (my counterfactual experiment later), a plant will expect the larger future profit and thereby it will invest more in process innovation, and the larger overall innovation will affect the aggregate productivity. I refer to these effects of improving the allocative efficiency to encourage process innovation and to raise the aggregate productivity as productivity upgrading effects, which are distinguished from the direct effects on the aggregate productivity of the factor allocation.

We can observe the productivity upgrading effects in a plant's Bellman equation. With decision of q, a production unit determines the drift of its binomial productivity process. For sufficiently large production units the first order condition is $c'(q) = V(z)\,[\exp(s) - \exp(-s)]$.[3] As z gets close to 0, the marginal value of process innovation increases.[4] Since a production unit invests in process innovation until the marginal value of innovation is equal to marginal cost of innovation, higher marginal value implies more plant-level innovation investment q. In turn if the measure of production units with $z \approx 0$ will increase then more overall process investment will be made and the aggregate productivity will rise as a result. By this way, productivity upgrading effects come into effect.

[3] The profit function $\Pi(\omega, z)$ and the cost function $\exp(\omega)c(q)$ is homogenous of degree 1 in $\exp(\omega)$. The standard q-theory implies that guessing and verifying the value function $V(\omega, z)$, we prove that it is linear in $\exp(\omega)$, e.g. $V(\omega, z) = \exp(\omega)V(z)$.

[4] The Bellman equation has a unique solution and $\Pi(\omega, z)$ approaches to its maximal value as z gets close to 0. As a result $V(z)$ also achieves its maximum at $z = 0$. In turn the marginal value of process innovation, $V(z)[\exp(s) - \exp(s)]$, reaches its maximum at $z = 0$.

3.2.2 Households

Infinitely-lived, identical households only value consumption of the aggregate output with preferences of form $\sum_{t=0}^{\infty} \beta^t \log(C_t)$. Each household faces an intertemporal budget constraint of the form $P_0 C_0 - P_{L0} L - P_{K0} K + \sum_{t=1}^{\infty} \left(\prod_{j=1}^{t} \frac{1}{R_j}\right)(P_t C_t - P_{Lt} L - P_{Kt} K) \leq \overline{W}$ where $\overline{W}$ is the initial value of production units in the sector.

3.2.3 Steady State Equilibrium

A steady state equilibrium is an equilibrium in which all of the variables are constant and the distribution of establishments are stationary. A steady state equilibrium is a set of aggregate variables $\{P, P_L, P_K, Y, C, Y_r, L_r, K_r, R\}$, prices and quantities for production units $\{p(\omega,z), y(\omega,z), l(\omega,z), k(\omega,z)\}$, value functions, profits, exit, and process innovation of production units $\{V(\omega,z), \Pi(\omega,z), x(z),\ q(\omega,z)\}$, and measure of operating and entering production units $\{M(\omega,z), M_e\}$ that satisfy

1. Conditional on survival, given prices and quantities of aggregate variables, a plant's static decisions are subject to the allocative frictions z. Given these decisions, the plant chooses the process innovation q to maximize its value of the Bellman equation.

2. *Free entry*: If the number of entrants is finite and strictly positive, free entry condition must hold:

$$n_e = \frac{1}{R} \int V(\omega,z) dG \tag{3.6}$$

   where G is an entrant's measure of productivity ω and frictions z.

3. *Composite-good producer optimality*: Taking as given aggregate prices, cost minimization of the composite-good producers is

$$\rho L_r / \lambda K_r = P_K / P_L \tag{3.7}$$

$$\lambda Y_r / (1-\lambda-\rho) L_r = P_L / P \tag{3.8}$$

$$1 = \lambda^{-\lambda} \rho^{-\rho} (1-\lambda-\rho)^{-(1-\lambda-\rho)} P_L^{\lambda} P_K^{\rho} P^{1-\lambda-\rho} \tag{3.9}$$

4. *Household optimality*: Taking as given aggregate prices, households maximize their utility.

5. *Market clearing*:

$$\text{Labor:} \quad \int l(\omega,z)dM(\omega,z) + L_r = L \tag{3.10}$$

$$\text{Capital:} \quad \int k(\omega,z)dM(\omega,z) + K_r = K \tag{3.11}$$

$$\text{Composite good:} \quad n_e M_e + \int \left[n_f + a(\omega)c(q(\omega,z))\right] dM(\omega,z) = L_r^{\lambda} K_r^{\rho} Y_r^{1-\lambda-\rho} \tag{3.12}$$

$$\text{Aggregate output:} \quad C + Y_r = Y \tag{3.13}$$

6. *Stationary distribution*: The measure of operating production units evolves according to

$$M(\omega',z) = M_e\left[G(\omega',z) - G(x(z),z)\right] + \int_{\omega=-\infty}^{\omega'-s} q(\omega,z)dM(\omega,z) + \int_{\omega=x(z)}^{\omega'+s} [1-q(\omega,z)]\, dM(\omega,z) \tag{3.14}$$

if $\omega' \geq x(z)$. Otherwise $M(\omega',z) = 0$.

3.3 Quantitative Analysis

Since this model does not permit a closed-form solution for the stationary equilibrium, I resort to a numerical method to compute the approximate equilibrium. A production unit in the model corresponds to a plant in the data. I refer to model moments as functions of ω and z, e.g. $l(\omega,z)$, $k(\omega,z)$, and so forth and data moments as l, k, etc.

3.3.1 Baseline Parametrization

I calibrate the set of parameters $(\varepsilon, \gamma, s, \sigma_\omega, \sigma_z, \rho_{\omega z}, K, R)$ to match the corresponding data moments for Korean Manufacturing plants in 2005.

3.3.1.1 Production Technology, Demand Elasticity, and Plant-level Physical Productivity

Following the approach in Xu (2008) and Midrigan and Xu (2009), I write log production function as:

$$\log y = \frac{1}{\varepsilon - 1}\omega + \frac{\varepsilon}{\varepsilon - 1} s_L (\log l - \log k) + \log k \tag{3.15}$$

where s_L is expenditure share of labor over revenue. Applying this into each establishment's demand curve, $y = Y(p/P)^{-\varepsilon}$, I rewrite log revenue function as

$$\log r - s_L(\log l - \log k) = \left(1 - \frac{1}{\varepsilon}\right) \log k + \frac{1}{\varepsilon} \log Y + \frac{1}{\varepsilon}\omega \tag{3.16}$$

I calculate the left hand side of the equation and regress it on log capital by OLS. The estimated markup is $(1 - 1/\varepsilon)^{-1} = 1.22$. After calculating average expediture share of labor $\bar{s}_L$, I find that the labor share $\gamma = (1 - 1/\varepsilon)^{-1}\overline{s_L}$ is 0.28. From the equation (3.4), the resulting expenditure share of capital α is 0.46. These results must suffer from the potential endogeneity problem. However these estimated parameters are close to the other literature which studies Korean manufacturing economy and hanles the endogeneity problem. In particular, my results are close to the markup of 20.5% and $\alpha = 0.45$ in Midrigan and Xu (2009) and $\alpha = 0.41$ in Gilchrist and Sim (2007). Therefore I conclude that the endogeneity problem would not be substantial and I use my OLS results for the quantitative version of the model. Taking as given a parameter of production function, I infer plant-level physical productivity as

$$TFPQ = \frac{y}{l^{\gamma} k^{1-\gamma}} = (P^{\varepsilon} Y)^{\frac{1}{\varepsilon - 1}} \frac{(py)^{\frac{\varepsilon}{\varepsilon - 1}}}{l^{\gamma} k^{1-\gamma}} \equiv \chi \frac{(py)^{\frac{\varepsilon}{\varepsilon - 1}}}{l^{\gamma} k^{1-\gamma}} \tag{3.17}$$

where I set $\chi = 1$ as in HK since our reallocation gains are not affected by χ. The model's corresponding moment for $TFPQ$ is

$$TFPQ(\omega, z) = \frac{y(\omega, z)}{l(\omega, z)^{\gamma} k(\omega, z)^{1-\gamma}} = \exp\left(\frac{1}{\varepsilon - 1}\omega\right) \tag{3.18}$$

and the standard deviation of $\log(TFPQ(\omega,z))$ across plants is

$$\sigma(\log TFPQ(\omega,z)) = \frac{1}{\varepsilon-1}\sigma(\omega) \tag{3.19}$$

3.3.1.2 Plant-Level Frictions

Following HK, I measure plant-level frictions from data. First I calculate plant-level revenue productivity as

$$TFPR = \frac{r}{l^{\gamma}k^{1-\gamma}} \tag{3.20}$$

I assume that a plant faces the same factor prices as in HK. Then following the approach in HK, Restuccia and Rogerson (2008), and Midrigan and Xu (2009), I postulate that plant-level frictions account for the observed dispersion in revenue productivity. In this spirit the model's corresponding moment for $TFPR$ is

$$TFPR(\omega,z) \equiv \frac{r(\omega,z)}{l(\omega,z)^{\gamma}k(\omega,z)^{1-\gamma}} = \varepsilon(1-\alpha)\left(\frac{P_L}{\varepsilon(1-\alpha)-1}\right)^{\gamma}\left(\frac{P_K}{\alpha}\right)^{1-\gamma}\exp\left(-\frac{1}{\varepsilon}z\right) \tag{3.21}$$

and the standard deviation of $\log(TFPR(\omega,z))$ across plants is

$$\sigma(\log TFPR(\omega,z)) = \frac{1}{\varepsilon}\sigma(z) \tag{3.22}$$

Therefore by estimating the standard deviation of $\log TFPR$ in data, we can estimate the standard deviation of z.

There could be various reasons that plant-level revenue productivity is not equalized. Altough I cannot distinguish the sources of the frictions by HK's approach, I can capture various source of frictions altogether such as time to build in production factors, adjustment cost, financing frictions, government policy, and quality of an economy's institution. The objective of this paper is to quantify the effects from the overall extent of frictions in the industry dynamics model, not to analyze the implications of a specific source of frictions. Therefore my estimates of the frictions by HK's approach use the correct measure of the frictions.

3.3.1.3 Distribution of Entrants

I assume that an entrant draws its productivity ω and frictions z according to joint normal distribution with $\omega \sim N(0,\sigma_z^2)$ and $z \sim N(0,\sigma_z^2)$ with correlation $\rho_{\omega z}$. Using three data moment, $\sigma(\log TFPQ)$, $\sigma(\log TFPR)$, and the correlation $\rho(\log TFPQ, \log TFPR)$, I calibrate three parameters σ_z, σ_ω, and $\rho_{\omega z}$ in two alternative models separately. The first model is the industry dynamics model in which the plant-level productivity and entry are endogenously determined. In this full flavored model the allocative frictions affect the aggregate process innovation through two channels, productivity upgrading and entry. Next, to appreciate only the productivity upgrading effects I shut down the entry effects. More precisely, I estimate a similar model except that entry is constant before and after our hypothetical experiment. Table 3.1 summarizes the calibration results for parameters of entrants' distribution.

Table 3.1. Parameters of entrants' distribution

Endogenous entry	Data	Model	Parameter
$\sigma(\log TFPQ)$	0.9123	0.9126	$\sigma_\omega = 7.2492$
$\sigma(\log TFPR)$	0.9066	0.8873	$\sigma_z = 0.2340$
$\rho(\log TFPQ, \log TFPR)$	0.9806	0.6117	$\rho_{\omega z} = -0.9746$
Exogenous entry	Data	Model	Parameter
$\sigma(\log TFPQ)$	0.9123	0.7652	$\sigma_\omega = 6.1488$
$\sigma(\log TFPR)$	0.9066	0.8978	$\sigma_z = 30.0132$
$\rho(\log TFPQ, \log TFPR)$	0.9806	1.1806	$\rho_{\omega z} = -0.9891$

3.3.1.4 Process Innovation

I follows AB for parameters to shape productivity process. Time periods is equal to two months. I take the cost function of process innovation: $c(q) = H\exp(bq)$ where b is the curvature parameter. I calibrate the cost parameter H for $b = 10$ as a benchmark model and $b = 100$ as an alternative model. To do so I match the model's slope of right tail of employment distribution of plants between 100 and $1,000$ workers with the corresponding data moment of -0.41. The model's slope is -0.44 and -0.31 for the full flavored model and the model with exogenous exit respectively. I choose the step size of upgrading or taking down $s = 0.21$ so that I match the standard deviation of the growth rate of capital of plants in model to 0.53 in Korean data on an annual basis.

3.3.1.5 Other Parameters

Aggregate labor L is normalized to 1. In calibrating the model, I match the median plant (50% of total workers are employed by plants employing less than this plant) in the model to the data moment of 47. Aggregate capital is 55.89, which is capital per a worker in Korean Manufacturing sector reported by Bank of Korea. I choose a discount rate R of 8% as the real corporate bond rate in Korea. The labor, capital, aggregate output share, λ, ρ, $1-\lambda-\rho$, in the composite-good production are respectively $1/3$, $1/3$, and $1/3$ for the benchmark parametrization. I also set $[\lambda,\rho,1-\lambda-\rho]$ at $[0.1,0.1,0.8]$, $[0.1,0.8,0.1]$, or $[0.8,0.1,0.1]$ for alternative cases. I choose entry cost $n_e = 1$. Free entry condition implies that any changes to n_e can be effectively canceled out by rescaling a plant's productivity. I set fixed cost n_f at 0.1 for the benchmark and 1 for sensitivity analysis. Table 3.2 lists baseline parameters and their values.

Table 3.2. Summary of Baseline Parametrization

	Parameter	Value
Demand elasticity	ε	5.61
Labor share in production function	γ	0.28
Curvature in innovation cost	b	10
Step size of upgrading	s	0.21
Entry cost	n_e	1
Fixed cost	n_f	0.1
Aggregate labor	L	1
Aggregate capital	K	55.89
Discount rate	R	0.08
Labor share in composite good	λ	$1/3$
Capital share in composite good	ρ	$1/3$

3.3.2 Losses from the Allocative Frictions

In this section I ask how much Korean economy in 2005 has lost from its allocative frictions. To quantify the aggregate productivity losses from the frictions, I move the quantitative version of the model into its hypothetical version with the U.S. level of the dispersion in plant-level $\log TFPR$[5] and measure a change in the aggregate productivity. I interpret the difference between the aggregate productivity in the equilibrium of the initial version of the model and that of its hypothetical version as what Korean economy has lost from its allocative frictions[6].

First I define the aggregate productivity as:

$$TFP = \frac{\left(\int \exp(\omega)\exp(\frac{\varepsilon-1}{\varepsilon}z)dM(\omega,z)\right)^{\frac{\varepsilon}{\varepsilon-1}}}{\int \exp(\omega)\exp(z)dM(\omega,z)} \tag{3.23}$$

where $Y = \left(\int y(\omega,z)^{\frac{\varepsilon-1}{\varepsilon}} dM(\omega,z)\right)^{\frac{\varepsilon}{\varepsilon-1}} = TFP\left(\int l(\omega,z)dM(\omega,z)\right)^{\gamma}\left(\int k(\omega,z)dM(\omega,z)\right)^{1-\gamma}$. Assume that plant-level productivity $\exp(\omega)$ and frictions $\exp(z)$ are joint-log normally distributed. From the equation (3.23), I follow HK and decompose the overall losses from misallocation, $\log(TFP/TFP^h)$[7]:

$$\log\left(\frac{TFP}{TFP^h}\right) = \underbrace{\frac{1}{\varepsilon-1}\left((\tilde{\mu}_w - \tilde{\mu}_w^h) + \frac{1}{2}(\tilde{\sigma}_\omega^2 - \tilde{\sigma}_\omega^{h2})\right)}_{\text{process innovation}} \underbrace{-\frac{1}{2\varepsilon}\left(\tilde{\sigma}_z^2 - \tilde{\sigma}_z^{h2}\right)}_{\text{allocation}} \tag{3.24}$$

where $\tilde{\mu}_\omega$, $\tilde{\sigma}_\omega^2$, $\tilde{\mu}_z$, and $\tilde{\sigma}_z^2$ are means and variances of ω or z in a steady state of our quantitative version of the model respectively. The superscript h stands for the corresponding statistics in a steady state of the hypothetical economy. The last components in the above equation (3.24), labeled as allocation , are the losses only from resource misallocation across plants. If the allocative frictions do not affect the plant-level productivity, the aggregate productivity difference solely comes from resource allocation and depends on the variance of plant-level frictions z in a steady state. Unless the allocative frictions in Korea would affect the plant-level process innovation, its TFP will be 163.09% higher than the current level if its allocative efficieny was the same as the U.S. level and will be 230.39%

[5] 0.49 is the U.S. level of a standard deviation in $\log TFPR$ in 2005 according to HK. In terms of the allocative frictions z, the U.S. level of a standard deviation of z is $2.75 = \varepsilon \times \sigma(\log TFPR) = 5.61 \times 0.49$ from the equation (3.22).

[6] There could be many factors to determine TFP difference between the U.S. and Korea. The focus of my paper is to study the difference in the allocative friction between two countries and its hypothetical gain from improvement in allocation.

[7] Because we only have the variation in z, the equation (3.24) is the correct decomposition as noted in Hsieh and Klenow's appendix.

higher if I fully remove the dispersion in $\log TFPR$.[8]

I next turn to the decomposition of losses from allocative frictions in alternative models, using the equation (3.24). Table 3.3 lists the results. I hypothetically move our initial equilibrium of the model into the new equilibrium with the U.S. level of dispersion in $\log TFPR$ by changing entrants' standard deviation of z, σ_z. In this way I closely match the losses from allocation in alternative models (-158.64 or -153.39) with the proposed losses in HK's static model (-163.09).

Table 3.3. Proposed losses from misallocation in alternative models

	process innovation	allocation	overall losses
HK's static model	-	-163.08	-163.09
industry dynamics model w/ innovation	-16.72	-158.64	-175.36
industry dynamics model w/ innovation and entry	less than 0.01	-153.39	-153.39

Note: Every number is in terms of percent.

The full flavored model (the 3rd row in Table 3.3) predicts that the most of the aggregate productivity losses from allocative frictions come from the dispersion in frictions (allocation in equation (3.24)) and allowing a plant to improve productivity does not make a significant, additional impact on the aggregate productivity. Once I reduce the dispersion in frictions, every plant is more likely to face the less frictions. Since the plants with the less frictions will have larger expected profits, the measure of plants with larger value will increase and therefore the plants will have more incentives to engage in process innovation. However, the larger value of plants makes entry more attractive and more severe

[8] If I fit the allocative efficiency in Korea to that of the U.S.,

$$\frac{\Delta TFP}{TFP} \approx \log\left(\frac{TFP}{TFP^h}\right) = -\frac{\varepsilon}{2}\left(\mathrm{var}(\log TFPR) - \mathrm{var}(\log TFPR)_h\right) = -\frac{5.61}{2}\left(0.9066^2 - 0.49^2\right) = -163.09\%$$

If I fully remove the dispersion in $\log TFPR$,

$$\frac{\Delta TFP}{TFP} \approx \log\left(\frac{TFP}{TFP^h}\right) = -\frac{\varepsilon}{2}\left(\mathrm{var}(\log TFPR) - \mathrm{var}(\log TFPR)_h\right) = -\frac{5.61}{2}\left(0.9066^2 - 0^2\right) = -230.39\%$$

competition from entry will hurt and reduce every plant's profits. As the value of every plant declines, every plant has less incentives to invest in process innovation. The results show that these two competing forces will offset each other almost completely.

The results in the model of exogenous entry (the 2nd row in Table 3.3) shows the isolation of the sole effects of productivity upgrading from the overall losses. The model predicts that if entry does not respond to a change in the dispersion of frictions then the aggregate productivity will rise by 175.36% with a significant, extra effects of 16.72% from process innovation. Without the offsetting effects from entry, the reduction in frictions for plants will generate more process innovation by those plants. Therefore the amplification through a channel of process innovation takes a significant effect which the static model does not capture, although these effects on process innovation become insignificant once I consider endogenous entry in the model.

3.3.3 Sensitivity Analysis

In this subsection I ask if innovation cost curvature b, fixed cost n_f, and parameters for a production function of a composite good λ and ρ would affect our quantitative results. Table 3.4 reports the effects of a change in the allocative effiency from the level of Korea to the U.S. level on process innovation for different parameter values.

Table 3.4. Sensitivity analysis for different parameter values

	Model with endogenous entry	Model with exogenous entry
benchmark	less than 0.01	-16.72
$b = 100$	less than 0.01	-16.04
$(\lambda, \rho) = (0.1, 0.1)$	less than 0.01	-16.72
$(\lambda, \rho) = (0.8, 0.1)$	less than 0.01	-16.72
$(\lambda, \rho) = (0.1, 0.8)$	less than 0.01	-16.72
$n_f = 1$	less than 0.01	-37.27

Note: Every number is in terms of percent.

From the table, I find the following results. In the absence of endogenous entry, the losses from process innovation increase due to productivity upgrading effects. Although the losses from productivity upgrading effects vary depeding on parameters, once endogenous entry is allowed in the model the losses from productivity upgrading effects are almost completely offset by the entry effects regardless of our choice of the value of parameters in the sensitivity analysis. Therefore, as in the benchmark model the change in the allocative efficiency does not yield any significant change in process innovation in our full flavored model.

The losses from process innovation vary from 16.72% to 37.27% when endogenous entry is not allowed in the model. The larger b implies the higher cost of process innovation than in the benchmark. Facing the higher cost, a plant responds less to a change in the allocative frictions than in the benchmark. Therefore a change in process innovation (-16.04%) is smaller than that of the benchmark (-16.72%). Neither λ nor ρ affects a plant-level value function and its optimal decision rule. Since a plant-level decision affects the distribution of primitives, z and ω, and in turn this distribution determines the aggregate productivity losses in equation (3.24), different values of λ and ρ do not change our benchmark result significantly. Finally, under a larger fixed cost n_f, the change in allocative efficiency takes a bigger effect than under a smaller n_f of the benchmark. This result implies that under a larger n_f zero-profit cutoff for plants increases more than under a smaller n_f of the benchmark; as a result more plants exit, the surviving plants are more producitive and invest more in process innovation. Therefore the larger n_f is, the aggregate productivity will increase the more dramatically after improving the allocative efficiency.

3.4 Concluding Remarks

I assess the aggregate productivity losses from the allocative frictions in Korean manufacturing industry through the lens of industry dynamics model with process innovation. My main result is that there is no significant difference between the aggregate productivity losses predicted in the model here and those in HK's model. The specific findings are the following. The existence of the frictions discourages a plant-level process innovation. Therefore having endogenous process innovation in the industry dynamics model implies a change in the aggregate productivity through both the factor allocation channel and the productivity upgrading channel. The quantitative results show that both effects are significant when endogenous entry is not allowed. However if endogenous entry is allowed, the competition by new entrants tends to almost completely offset productivity upgrading effects. There are two possible extensions in the current analysis. The first extension is to allow the frictions to change according to productivity. Another extension is to allow accumulation of capital.

Appendix A

Data

I use Korean Annual Manufacturing Survey data in 2005 collected by the Korean Statistical Office. The survey covers all manufacturing plants with five or more workers. The survey reports information about each plant's total revenue, number of employees, total wage bill, payment for materials, energy use, the book value of capital stock, purchase, sales, and depreciation for land, buildings, machinery, and equipment. Using a perpetual inventory method as in Caballero, Engel, and Haltiwanger (1995) and focusing on building, machinery, and equipment, I construct plant-level capital:

$$I_{2005} = Purchase_{2005} - Sales_{2005} \tag{A.1}$$

$$K_{2006} = K_{2005} - Depreciation_{2005} + I_{2005} \tag{A.2}$$

I delete observations with negative value of revenue, capital stock, sales, purchase, and depreciation, which are an outcome of measurement error. I also delete observations with zero value of revenue and capital stock. To avoid the extreme observations and rounding errors, I also exclude the observations with the highest or lowest 1 percentile in the average product of capital and labor. My final sample consists of 109,780 observations. Table A.1 illustrate summary statistics.

Table A.1. Summary Statistics

Variance	mean	std.	1%	99%
Revenue	4484.26	66,345.77	80	51,497.5
Physical capital	1224.49	37,746.46	0	12,429.1
Physical investment	288.72	17,198.06	-321.7	3052.7
Number of workers	22.62	162.24	5	198
Wage bill	596.26	8,594.06	23	5,757.4
Number of observations	109,780			

units of variables: millions of won

Appendix B

Numerical Method

I proceed in three steps. First, taking as given initial guesses for the cost parameter for process innovation H and a constant in profit Φ, I solve for plant-level optimal decision rules. Next, find Φ to satisfy the free entry condition (FE) and compute stationary distribution as well as aggregate variables. Finally, check whether the slope of right tail of size distribution is equal to data moment; if not, adjust H and Φ and go back to the first step.

Step 1: Starting initial guesses for the innovation-cost parameter H and the constant on plant-level profit Φ, I solve the Bellman equation by value function iteration on a grid. I use a grid with 4,897 points for productivity, ω, and 21 points for allocation frictions, z. The lower and upper bound for frictions are -4 and 4 respectively, so that they bind with very small probabilities in a stationary distribution. I take the grid for productivity from Atkeson and Burstein (2010) in which the lower and upper bound are -2,448 and 2,448.

Step 2: In computing the optimal decision rules and calculate the value of entry, check whether FE holds for a given Φ, the constant on plant-level profit. If FE does not hold, adjust Φ and go back to the first step. If FE holds, I iterate the equation (3.14) and find stationary distribution. I compute the aggregate variables as follows. Using the equation (3.7), (3.8), and (3.12), first I solve for capital and labor use in the composite-good production, K_r and L_r, and price ratio, P_K/P_L:

$$K_r = \frac{\rho \Upsilon K}{\Phi \alpha A + \rho \Upsilon} \tag{B.1}$$

$$L_r = \frac{\lambda \Upsilon L}{\Phi(\varepsilon(1-\alpha)-1)A + \lambda \Upsilon} \tag{B.2}$$

$$\frac{P_K}{P_L} = \frac{\rho L_r}{\lambda K_r} \tag{B.3}$$

where $\Upsilon = n_e + \int \left[n_f + \exp(\omega) c(q(\omega, z)) \right] d\widetilde{M}(\omega, z)$ and $A = \int \exp(\omega + z) d\widetilde{M}(\omega, z)$. Taking as given K_r, L_r, and P_K/P_L, I solve for the other aggregate variables. Applying the equation on the constant in plant-level profit Φ into labor market clearing in equation (3.11), I rewrite aggregate output Y:

$$Y = \frac{K - K_r}{AM_e} \left[\frac{(P_K/P_L)(P_L/P)^{\varepsilon(1-\alpha)}}{\alpha \left(\varepsilon(1-\alpha)\right)^{-\varepsilon(1-\alpha)} \left(\varepsilon(1-\alpha)-1\right)^{\varepsilon(1-\alpha)-1}} \right]^{1/(1-\alpha)} \tag{B.4}$$

The plant-level price consistent with its labor and capital employment is:

$$p(\omega, z) = \frac{\varepsilon}{\varepsilon - 1} \left(\frac{P_L}{\gamma} \right)^{\gamma} \left(\frac{P_K}{1-\gamma} \right)^{1-\gamma} \exp\left(\frac{z - (\omega + z)\varepsilon}{\varepsilon(\varepsilon - 1)} \right) \tag{B.5}$$

Substituting $p(\omega, z)$ in the equation (B.5) into the equation (3.2), From the equation (3.2), I rewrite wage relative to aggregate price P_L/P:

$$\frac{P_L}{P} = \frac{\varepsilon - 1}{\varepsilon} (\gamma)^{\gamma} (1-\gamma)^{1-\gamma} \left(\frac{P_K}{P_L} \right)^{\gamma} (BM_e)^{1/(\varepsilon-1)} \tag{B.6}$$

where $M(\omega, z) = M_e \widetilde{M}(\omega, z)$ and $B = \int \exp\left(\omega + \frac{1-\varepsilon}{\varepsilon} z\right) d\widetilde{M}(\omega, z)$. Expressing the user cost for capital P_K in the equation (3.9) and substituting it into the equation for Φ, I rewrite Φ as:

$$\Phi = \frac{\alpha^{\alpha/(1-\alpha)} \lambda^{\lambda} \rho^{\rho} (1-\lambda-\rho)^{1-\lambda-\rho} \left(\frac{P_L}{P_K} \right)^{1/(1-\alpha)+\rho-1} \left(\frac{P}{P_L} \right)^{\varepsilon+\lambda+\rho-1}}{\left(\left(\varepsilon(1-\alpha)\right)^{\varepsilon(1-\alpha)} \left(\varepsilon(1-\alpha)-1\right)^{1-\varepsilon(1-\alpha)} \right)^{1/(1-\alpha)}} Y \tag{B.7}$$

I solve the system of equations (B.4), (B.6), and (B.7) for Y, P_L/P, and M_e.

Step 3 After solving for the aggregate variables, I obtain the employment based size distribution of plant and check whether the slope of its right tail of the model matches that of data. As the cost parameter H increases, the absolute value of the slope will increase, since the larger H implies a larger cost for process innovation and a plant chooses less investment if it is subject to a larger cost. If they do not match, adjust H and Φ and go back to the first step.

Bibliography

AIYAGARI, S. R. (1994): "Uninsured Idiosyncratic Risk and Aggregate Saving," *Quarterly Journal of Economics*, 109(3), 659–684.

ANGELETOS, G.-M., AND V. PANOUSI (2011): "Financial Integration, Entrepreneurial Risk, and Global Dynamics," *Journal of Economic Theory*, 146, 863–896.

AOKI, K., G. BENIGNO, AND N. KIYOTAKI (2009): "Adjusting to Capitla Account Liberalization," *Working Paper*, LSE and Princeton University.

ATKESON, A., AND A. T. BURSTEIN (2010): "Innovation, Firm Dynamics, and International Trade," *Journal of Political Economy*, 118(3), 433–484.

ATTANASIO, O. P., J. BANKS, C. MEGHIR, AND G. WEBER (1999): "Humps and Bumps in Lifetime Consumption," *Journal of Business and Economic Statistics*, 17, 22–35.

BANERJEE, A. V., AND E. DUFLO (2005): "Growth Theory through the Lens of Development Economics," in *Handbook of Economic Growth*, ed. by P. Aghion, and S. Durlauf, vol. 1A, pp. 473–552. Elsevier, Amsterdam.

BECK, T., A. DEMIRGUC-KUNT, AND R. LEVINE (2000): "A New Database on the Structure and Development of the Financial Sector," *World Bank Economic Review*, 14: 597605.

BLAUM, J. (2012): "Wealth Inequality and the Losses from Financial Frictions," *Working Paper*, Brown University.

BUERA, F. J., J. P. KABOSKI, AND Y. SHIN (2011): "Finance and Development: A Tale of Two Sectors," *American Economic Review*, 101(5), 1268–2002.

BUERA, F. J., AND Y. SHIN (2013): "Financial Frictions and the Persistence of History: A Quantitative Exploration," *Journal of Political Economy*, 121(2), 221–272.

CABALLERO, R. J., AND E. M. ENGEL (1999): "Explaining Investment Dynamics in U.S. Manufacturing: A Generalized (S,s) Approach," *Econometrica*, 67(4), 783–826.

CABALLERO, R. J., E. M. ENGEL, AND J. C. HALTIWANGER (1995): "Accounting for Plant-Level Misallocation," *Brookings Papers on Economic Activity*, 26(2), 1–54.

CAGETTI, M., AND M. D. NARDI (2008): "Entrepreneurship, Frictions, and Wealth," *Journal of Political Economy*, 114(5), 835–870.

CASELLI, F. (2005): "Accounting for Cross-Country Income Differences," in *Handbook of Economic Growth*, ed. by P. Aghion, and S. Durlauf, vol. 1A, pp. 473–552. Elsevier, Amsterdam.

COOPER, R., AND J. C. HALTIWANGER (2006): "On the Nature of Capital Adjustment Costs," *Review of Economic Studies*, 73(3), 611–633.

DAVIS, S. J., AND J. HALTIWANGER (1990): "Gross Job Creation and Destruction: Microeconomic Evidence and Macroeconomic Implications," *NBER Macroeconomics Annual*, 5, 123–186.

EVANS, D. S., AND B. JOVANOVIC (1989): "An Estimated Model of Entrepreneurial Choice under Liquidity Constraints," *Journal of Political Economy*, 97(4), 808–827.

GILCHRIST, S., AND J. W. SIM (2007): "Investment during the Korean Financial Crisis: a Structural Econometric Approach," *Working Paper*.

GOLLIN, D. (2002): "Getting Income Shares Right," *Journal of Political Economy*, 110, 458–474.

HALL, R. E., AND C. I. JONES (1999): "Why Do Some Countries Produce So Much More Output per Worker than Others?," *The Quarterly Journal of Economics*, 1, 83–116.

HEER, B., AND A. MAUβNER (2005): *Dynamic General Equilibrium Modelling, Computational Methods and Applications*. Springer.

HOLTZ-EAKIN, D., D. JOULFAIAN, AND H. S. ROSEN (1994): "Sticking It Out: Entrepreneurial Survival and Liquidity Constraints," *Journal of Political Economy*, 102(1), 53–75.

HSIEH, C.-T., AND P. J. KLENOW (2009): "Misallocation and Manufacturing TFP in China and India," *The Quarterly Journal of Economics*, 124(4), 1403–1448.

HUGGETT, M. (1993): "The Risk-free Rate in Heterogenous-Agent Incomplete-Insurance Economies," *Journal of Economic Dynamics and Control*, 17, 953–969.

JEONG, H., AND R. TOWNSEND (2007): "Sources of TFP Growth: Occupational Choice and Financial Deepening," *Economic Theory*, 32, 179–221.

KHAN, A., AND J. K. THOMAS (2008): "Idiosyncratic Shocks and the Role of Nonconvexities in Plant and Aggregate Investment Dynamics," *Econometrica*, 76(2), 395–436.

LEE, Y., AND T. MUKOYAMA (2012): "Entry, Exit, and Plant-level Dynamics over the Business Cycle," *Working Paper*, Sogang University, Federal Reserve Board.

MENDOZA, E. G., V. QUADRINI, AND J.-V. RIOS-RULL (2009): "Financial Integration, Financial Development, and Global Imbalances," *Journal of Political Economy*, 117(3), 371–416.

MIAO, J. (2002): "Stationary Equilibria of Economies with a Continuum of Heterogeneous Consumers," *Working Paper*, Boston University.

MIDRIGAN, V., AND D. Y. XU (2009): "Accounting for Plant-Level Misallocation," *Working Paper*.

——— (2010): "Finance and Misallocation: Evidence from Plant-Level Data," *Working Paper*.

——— (forthcoming): "Finance and Misallocation: Evidence from Plant-Level Data," *American Economic Review*.

MOLL, B. (2012): "Productivity Losses from Financing Frictions: Can Self-Financing Undo Capital Misallocation?," *Working Paper*, Princeton University.

MOLL, B., R. M. TOWNSEND, AND A. KARAIVANOV (2013): "Financial Obstacles and Inter-Regional Flow of Funds: Limited Commitment and Moral Hazard," *Working Paper*, Princeton University, MIT, and University of Chicago.

PAULSON, A. L., R. M. TOWNSEND, AND A. KARAIVANOV (2006): "Distinguished Limited Liability from Moral Hazard in a Model of Entrepreneurship," *Journal of Political Economy*, 114(1), 100–144.

QUADRINI, V. (2000): "Entrepreneurship, Saving, and Social Mobility," *Review of Economic Dynamics*, 3, 1–40.

QUINN, D. P. (1997): "The Correlates of Changes in International Financial Regulation," *American Journal of Political Science*, 91(3), 531–551.

QUINN, D. P., M. SCHINDLER, AND A. M. TOYODA (2011): "Assessing Measures of Financial Openness and Integration," *IMF Economic Review*, 59(3), 488–522.

QUINN, D. P., AND A. M. TOYODA (2008): "Does Capital Account Liberalization Lead to Growth?," *Review of Financial Studies*, 21(3), 1403–1449.

RAJAN, R., AND L. ZINGALES (1998): "Financial Dependence and Growth," *The American Economic Review*, 88(3), 559–586.

RESTUCCIA, D., AND R. ROGERSON (2008): "Policy Distortions and Aggregate Productivity with Heterogenous Plants," *Review of Eonomic Dynamics*, 11(4), 707–720.

STOKEY, N., R. LUCAS, AND E. PRESCOTT (1989): *Recursive Methods in Economic Dynamics*. Harvard University Press.

STOKEY, N. L., AND S. REBELO (1995): "Growth Effects of Flat-Rate Taxes," *Journal of Political Economy*, 103, 519–550.

XU, D. Y. (2008): "A Structural Empirical Model of R&D, Firm Heterogeneity, and Industry Evolution," *Working Paper*.

Minsoo Han

Education

- Ph.D. Economics, Pennsylvania State University, August 2013
- M.A. Economics, Korea University, July 2006
- B.A. Economics, Korea University, February 2001

Ph.D. Thesis

- Three Essays on Misallocation and Productivity
  Committee Chair: Neil Wallace

Working Papers

- Plant-Level Worker Flows and the Losses from Financial Frictions
- Capital Account Openness and the Losses from Financial Frictions
- The Losses from Tax-type Distortions in a Model with Innovation