What Is Driving Asset Sales: Productivity Shocks and Asset Reallocation

Liu Yang[1]
University of Maryland

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(Comments Welcome)

Abstract

This paper shows that a dynamic neoclassic model with productivity shocks can generate some of the documented evidence supporting the misvaluation theory. Change of productivity over time drives asset reallocation as firms rationally expand or downsize. With fixed transaction cost, higher aggregate productivity increases the gain from transfer and makes sales more likely to occur. On the aggregate level, industries, whose idiosyncratic shocks have lower persistence and higher dispersion, are more likely to have changes in productivity across firms and therefore experience larger amount of asset purchases and sales. Model is calibrated using plant-level data from Longitudinal Research Database (LRD) and the empirical evidence supports model's implication on how shock attributes may affect cross sectional asset sales.

[EMPIRICAL RESULTS IN TABLE 5 TO 10 WILL BE AVAILABLE ONCE THEY ARE CLEARED FROM THE CENSUS BUREAU FOR DISTRIBUTION]

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1 Introduction

One of the puzzles in finance is why asset reallocation is not only industry-clustered, but also time-variant. For example, Mitchell and Mulherin (1996) show that seven industries account for more than half of the total takeover activities in the 1993 - 1994 period. Harford (2005) find that the average number of bids any industry sees in a 24-month non-wave period is 7.8, compared to 34.3 during the wave period from 1981 to 2000. What makes assets in one industry more likely to flow than others? Why some time periods are associated with higher asset reallocation?

Recent studies such as Shleifer and Vishny (2003), Dong, Hirshleifer, Richardson and Teoh (2004) and Rhodes-Kropf and Viswanathan (2004) reveal that merger waves are correlated with market valuation wave and suggest that higher asset reallocation may be a result from managerial timing of market overvaluation. In their empirical paper, Rhodes-Kropf, Robinson and Viswanathan (2004) point out several facts as evidence for misvaluation driven mergers such that mergers cluster in time when aggregate valuation is high and acquirers have higher valuation at the time, but lower long term value.

In this paper, I develop a dynamic structural model of asset sales based on productivity shocks and show that much of the documented empirical evidence supporting market-driven theories can be generated by rational investment strategy under productivity shocks.

Similar to Maksimovic and Phillips (2002)[2], I consider a model where firms choose optimal sizes based on their productivity level. As it changes over time, firms with positive shock will have incentive to expand while those with negative shock will have to cut their capacities. Since shocks are mean-reverting, firms are more likely to acquire at the time when it has higher productivity, compared to its over time mean. In the presence of fixed cost, aggregate productivity affects the probability that transactions occur. This is because as the gain from transferring assets from less to more productive firms increases in the level of aggregate productivity, it is more likely to overcome the fixed cost when aggregate productivity is high. In this model, firms make rational investment strategies on both new investment and existing assets and the price for existing assets are set in the equilibrium to reflect the true opportunity cost of capital at the time. Simulated data reveal that asset sales are clustered in time when aggregate valuation is high and firms with higher market to book value buy others with lower market to book value. Furthermore, since firms are more likely to buy whenever productivity increases; given the same level of positive shock, those with lower long run valuation productivity have higher increase and are more likely to expand through acquisition.

Furthermore, the attributes of productivity shocks also explain the cross-sectional difference in asset reallocation observed empirically. Since purchases and sales of assets result from changes in productivity due to shocks, industries with idiosyncratic shocks that are less persistent and have

[2] In their model, firms choose optimal sizes in two industries given their productivity shocks.

noisier error terms (henceforth referred to as shock dispersion), are more likely to have higher asset reallocation as productivities are more likely to shuffle across firms. This is different from the Q-theory in Jovanovic and Rousseau (2002), which predicts higher asset reallocation when productivity is widely dispersed. In this model, dispersion in productivity itself does not guarantee asset reallocation. In fact, an industry can maintain a wide distribution in productivity while no reallocation is necessary if productivities are fixed over time.

The empirical analysis using the plant-level data from Longitudinal Research Database (LRD) supports the model implication. Examining the persistence and volatility of idiosyncratic productivity shocks across 112 manufacturing industries at the three-digit SIC level in the period between 1974 and 2000, I find that on average, industries with lower shock persistence and higher shock volatility have higher asset sales. Together, shock persistence and volatility explain about XX percent of the industry fixed effects of asset sales after controlling for other industry characteristics, such as capital expenditure, profitability and asset turnover.

The model is solved in a recursive equilibrium framework through simulation where firms maximize their value by choosing the optimal investment strategy. Asset prices are endogenous from market clearing based on industry structure and aggregate productivity. The equilibrium aspect of this model is in the same spirit as Shleifer and Vishny (1992), who show that in recession, the lack of buyers may lead to a deep discount on resale value of the asset. The opposite can also hold, as this paper illustrates. That is, in expansions, when orders for new investments cannot all be filled in the short-run, the increase of demand will lead to a premium in the price of existing assets. Compared to most of the models in the existing literature on asset sales, who use fixed asset prices[3], the equilibrium price approach here provides a more realistic setting and helps to study firms' investment decision in the business cycle.

The rest of the paper is organized as follows. Section 2 describes the related literature. Section 3 presents an example of two firms and three periods to fix the basic intuition. Section 4 describes the model and simulation methodology. Section 5 discusses model implications using simulated moments; Section 6 tests model conjectures and Section 7 concludes.

2 Related Literature

This research relates to the existing literature on merger waves and asset sales.

The hypothesis that broad economic shocks are sources of merger activities can be traced to Gort (1969). It argues that economic disturbances produce mergers within the industry as "they alter

[3]For example, Jovanovic and Rousseau (2001) and Eisfeld and Rampini (2005). An exception is Maksimovic and Phillips (2001), who assume that input price will increase as demand increases.

randomly the ordering of expectations of individuals, with the result that some non-owners move to the right of current owners on the value scale". Jovanovic and Rousseau (2002) show that firms with higher productivity will acquire those with lower productivity, and more acquisitions will occur when the distribution widens. Since their model builds on constant return to scale, it does not track firm's behavior over time; whereas here, using decreasing return to scale, I model both size and industry structure explicitly to account for the dynamics of firm's investment strategy.

Various papers have documented the evidence that asset reallocation are indeed caused by economic shocks. For example, Mitchell and Mulherin (1996) find a strong industry clustering effect in asset sales and relate it to the changes within industry. Andrade, Mitchell and Stafford (2001) attribute the unexpected industry shocks as the causes for takeover waves in both 80's and 90's. Maksimovic and Phillips (2001) find that positive demand shock creates incentives for asset transfers between less and more productive plants. Andrade and Stafford (2004) show that mergers help to clean out the excess capacity when industry is experiencing negative demand shock.

On the other hand, market valuation theory offers alternative view on asset sales. Shleifer and Vishny (2003) model mergers as rational managers taking advantage of irrational stock market when synergy from mergers is over-valued. Rhodes-Kropf and Viswanathan (2004) propose a story where errors in valuing potential takeover synergies are correlated with overall valuation error and attribute the over-estimated synergy in high valuation as causes for merger waves. In a later empirical study, Rhodes-Kropf, Robinson and Viswanathan (2004) document several empirical evidence to support the misvaluation theory - they find that mergers cluster in industries where time-series sector valuation error is high; acquirers have higher firm-specific valuation error; and buyers are have lower long-run market-to-book than seller. This paper shows that some of the documented evidence merger occurrence and firm characteristics can be replicated using a dynamic neoclassic model with productivity shocks without any misvaluation. Since I do not model financing decisions such as raising equity, my model cannot explain the choice of payment.

Several papers have highlighted the role of liquidity in asset sales. Lang, Poulson and Stulz (1995) argue that management sells assets when it provides the cheapest way to raise capital. Schlingemann, Stulz and Walking (2002) examine sales of divisions and find that the probability for a segment to be divested is higher when its asset is in an industry with a liquid market. Shleifer and Vishny (1992) demonstrate that when industry experiences a negative aggregate shock, resale value of the asset has to take a discount as the potential buyer may also face cash constraint as well. Here,liquidity is modeled through both fundamental and market friction in this model. I show that shock attributes such as persistence and dispersion affect frequency of participation as well as the transaction amount in asset sales while higher level of fixed cost makes sales more pro-cyclical.

In addition, this paper joins the small, but growing literature in corporate finance that matches the simulated panel based on numerical solution from structural models, with the empirical findings to recover firms' decisions. Gomes and Livdan (2004) investigate firms decision to diversify in a dynamic framework given uncertainty in growth opportunities in both industries. Hennessy and Whited (2004) illustrate a dynamic model with endogenous choice of leverage, distribution and investment, which enables them to explain a number of anomalies on capital structures. In another paper, Hennessy and Whited (2005) focus on the well-documented investment cash flow sensitivity and explore the factors that are related to costs of external financing. To study how asset reallocation differ in the business cycle, Eisfeldt and Rampini (2005) use a calibrated dynamic model with adjustment costs and argue that costs for reallocation needs to be substantially counter-cyclical to be consistent with the observed empirical findings.

3 Basic Intuition: An Example

To illustrate the basic idea on how asset transfer may occur as a rational response to the productivity shocks and how shock attributes affect the total reallocation over time, in this section, I start with an simple example, where the economy is consisted of two firms ($i \in \{1,2\}$), who live for three periods ($t \in \{0,1,2\}$).

3.1 Set Up

Time Line

- At $t = 0$, both firms are endowed with the same initial capital stock $k_1^0 = k_2^0 = k$. After observing the aggregate $\left(z_a^0\right)$ and idiosyncratic productivity shocks $\left(z_1^0, z_2^0\right)$, they make decisions on new investment $\left(I_1^0, I_2^0\right)$ and asset transfer $\left(x_1^0, x_2^0\right)$.

  There is a timing difference between investing in new assets and buying existing assets. Assets bought from the other firm can be used for production in the current period, whereas new investment will not be available until the next period. The difference in timing of availability reflects the time-to-build attributes in capital investment such that new investments in machinery and structure usually takes several building periods [4].

  The adjusted capacity then reflects both the initial endowment and asset bought (sold) such that $\widetilde{k}_i^{\,0} = \left(k_i^0 + x_i^0\right)$.

- At $t = 1$, the carried over capacity k_i^1 is a sum of un-depreciated capital and new investment placed from previous period:

$$k_i^1 = (1-\delta)\,\widetilde{k}_i^{\,0} + I_i^0 \qquad i \in \{1,2\}$$

[4] The time-to-build attributes in capital investment are illustrated in Kydland and Prescott (1982) and Chrsitiano and Todd (1996).

where δ is depreciation rate. A new set of shocks are revealed $\left(z_a^1, \left\{z_1^1, z_2^1\right\}\right)$ and firms make decisions on asset sales $\left\{x_1^1, x_2^1\right\}$ only.

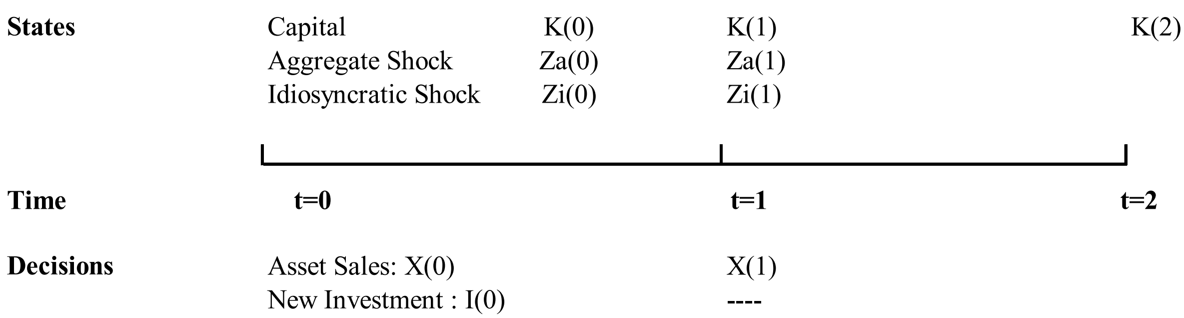
- At $t = 2$, the undepreciated assets k_i^2, are liquidated at a unit price and firm collects the proceeds from the liquidation and

$$V_i^2 = (1 - \delta)\, \widetilde{k_i}^1 \qquad i \in \{1, 2\}$$

where $\widetilde{k_i}^1 = \left(k_i^1 + x_i^1\right)$

A detailed time line is shown in the Figure 1 below:

Figure 1: Time Line (2-Firm Example)



Production Technology Firm produces output using capital stock k_i, via an increasing and concave production function, π:

$$\pi\left(k_i, A_i\right) = A_i k_i^{\alpha}$$

where $\alpha < 1$ and A_i reflects stochastic total factor productivity, which consists of a common factor across firms, z_a and an idiosyncratic factor z_i that is firm-specific:

$$\ln(A_i) = z_a + z_i$$

There are two states of the world, prosperity $(z_a > 0)$ and depression $(z_a < 0)$. z_a follows Markov process with transition probability $\begin{pmatrix} \pi_a & 1 - \pi_a \\ 1 - \pi_a & \pi_a \end{pmatrix}$ such that $\Pr\left(z_a^t = z_a^{t-1}\right) = \pi_a$

For simplicity, I assume that idiosyncratic shocks also have two states and it is completely symmetrical such that at any period, $z_1 = -z_2$. I denote firm 1's idiosyncratic shock as z and assume that it has a transition probability π_i such that $\Pr\left(z^t = z^{t-1}\right) = \pi_i$.[5] z_a and z are independent from each other at any period.

Investment Decisions Firms make decisions on new investment (I) and asset transfers (x) . Price for new investment, P_I is normalized to be one, and price for existing assets, P_x is endogenous and comes from market clearing such that

$$x_1 (P_x) + x_2 (P_x) = 0$$

There is a fixed cost, f_x, for participating in asset transfers to account for the additional transaction costs encountered such as searching for partners, negotiating deals and legal fees.

$$\begin{aligned} f_x &> 0 \quad if\ x \neq 0 \\ &= 0 \quad if\ x = 0 \end{aligned}$$

Therefore, cost of new investment is

$$C(I) = I$$

and cost (benefit) of asset sale is[6]:

$$C(x) = P_x \cdot x + f_x$$

New investment is non-negative and has an upper bound proportional to current capital stock, $0 \leq I_i \leq \overline{I} \times k_i$. The maximum constraint restriction reflects the limited supply of new investment in the short run.[7]

3.2 Implications

I show the equilibrium asset sales in the three cases. In Case 1, both aggregate and idiosyncratic shocks are permanent; in Case 2 idiosyncratic shock switches between firms while the aggregate shock stays constant; and in Case 3, only aggregate shock changes.

Proposition 1 *The share of total assets for the more-productive firm is* $r \frac{\exp\left(\frac{z}{1-\alpha}\right)}{\exp\left(\frac{z}{1-\alpha}\right)+\exp\left(\frac{-z}{1-\alpha}\right)}$ *and it is increasing in shock magnitude such that* $\frac{\partial r}{\partial z} > 0$.

Proof. See Appendix. ■

[5] It is set up such that Firm 1's idiosyncratic productivity z, follows a Markov process with transition probability π_i; after z is realized, Firm 2's productivity will be set to $-z$.

[6] For seller of assets, the net benefit equals to the proceeds minus the fixed cost.

[7] The supply constraint for new capacity in the short run is widely documented in the economics literature such as in Jovanovic (1998). An alternative way to model the limited supply of new investment is to have new investment available in a series of allotments that taken place in several periods.

Case 1 $z_a^0 = z_a^1 > 0 \qquad z^0 = z^1 > 0$

In this case, there is no change in aggregate state or idiosyncratic productivities. Firm 1 has a high productivity in both periods and we have the share of Firm 1 as $r^0 = r^1 = r > \frac{1}{2}$. Assume for now that the participation constraint due to fixed cost f_x, is not binding. I will discuss the participation constraint in more details in Case 3.

$$x_0^1 = \left(r - \frac{1}{2}\right)\left(k_1^0 + k_2^0\right) - k_1^0 > 0$$
$$x_1^1 = 0$$
$$X_{total} = \left|x_1^{t=0}\right|$$

Firm 1 will buy capacity from Firm 2 at $t = 0$, given that the participation constraint is satisfied and do nothing at $t = 1$. The total reallocation in both periods is, $X = \left|x_0^1\right|$. It is increasing in r and hence, increasing in z, the shock magnitude, i.e., $\frac{\partial X}{\partial z} > 0$.The higher the difference in productivity, the more assets will transfer.

Case 2 $z_a^0 = z_a^1 > 0 \qquad z^0 > 0$ *and* $z^1 < 0$

In this case, aggregate state stays the same and Firm 1' s productivity changes from high to low. We have the share of Firm 1 as $r^0 = r$ and $r^1 = 1 - r$. Again, assume that participation constraint is not binding.

$$\begin{aligned} x_0^1 &= \left(r^0 - \frac{1}{2}\right)\left(k_1^0 + k_2^0\right) - k_1^0 > 0 \\ x_1^1 &= (1 - 2r)\left[(1-\delta)\left(k_1^0 + k_2^0\right)\right] < 0 \\ X_{total} &= \left|x_1^{t=0}\right| + \left|x_1^{t=1}\right| \end{aligned}$$

As Firm 1 changes from more to less-productive, the transaction will be reversed. The total reallocation in both periods is $X = \left|x_1^0\right| + \left|x_1^1\right|$. It can be shown that if the participation constraint is not binding at $t = 0$, it will not be binding at $t = 1$ either.[8]

Case 3 $z_a^0 < 0 \qquad z_a^1 > 0 \qquad z^0 = z^1 > 0$

[8]This is because the gain from asset sales, D, is increasing in the optimal transfer amount. As the larger firm also has low productivity, the optimal transfer amount is higher than that at = 0 when firms have equal sizes.

In this case, Firm 1 has high productivity in both periods, and aggregate state changes from recession to expansion.

$$\begin{aligned} x_1^{t=0} &= c \quad x_1^{t=1}=0 \quad if \quad -z_a > \overline{z_a} \\ x_1^{t=0} &= 0 \quad x_1^{t=1}=c \quad if \quad -z_a < \overline{z_a} < z_a \\ x_1^{t=0} &= 0 \quad x_1^{t=1}=0 \quad if \quad \overline{z_a} > z_a \end{aligned}$$

where

$$\begin{aligned} c &= \left(r-\frac{1}{2}\right)2k-k \\ \overline{z_a} &= \ln\left(f_x\right)-z-\ln\left(k^{\alpha}\left[\frac{1}{(2r)^{1-\alpha}}+2r^{\alpha}\left(1-\alpha\right)-1\right]\right) \end{aligned}$$

Proposition 2 *The gain of reallocation increases in the amount of asset transferred and is higher in expansion, i.e.,* $\frac{\partial D}{\partial |x|} > 0$ *and* $\frac{\partial D}{\partial z_a} > 0$.

Proof. See Appendix. ■

Proposition 3 *The cutoff aggregate productivity* $\overline{z_a}$ *increases in fixed cost and decreases in shock magnitude* z.

Proof. See Appendix. ■

The cases above provide interesting insights:

Case 1 is a static model of asset sales. When productivity shocks are permanent, the amount of asset sales increases in the magnitude of idiosyncratic shocks. As the difference of productivity enlarges, the optimal share for the more-productive firm increases, and so does the need for reallocation. This is similar to the Q-theory in Jovanovic and Rousseau (2002).

Case 2 shows asset sales in a dynamic framework. When productivities change over time, in addition to the initial asset sales, reallocation will occur whenever there is change in relative productivity over time. The expected asset sales in the second period depend on the transition probability, π_i. Lower persistence increases the change for change and thus increase the expected sales. Figure 1a shows the simulated relationship between shock persistence (π_i), magnitude (z) and asset sales in both periods for the two-firm economy in this example. Asset sales in both periods are higher for larger shock magnitude; and the expected reallocation in the second period is higher when shocks are less persistent.

Lastly, whether or when transaction will occur depends on the aggregate productivity in recession and expansion compared to the fixed costs, as shown in Case 3. This generates interesting prediction on the timing of asset sales in the business cycle. Studies focusing on liquidity, for example, Shleifer and Vishny (1992) and Harford (2005) have suggested that the procyclicality of asset reallocation may be due to the limitation of liquidity in recession. Here, this simple example shows that even without the liquidity concern, when there exists fixed cost, asset sales decision can be delayed until expansion arrives. Figure 1b demonstrates the relationship between fixed cost, aggregate state and asset sales. Transaction is more likely to occur when fixed cost is low and when economy is in expansion.

4 A Dynamic Equilibrium Model of Asset Sales

Although informative, the two-firm three-period example has its limitations. There are only two firms with two levels of idiosyncratic shocks and shocks are symmetric. As a result, only the extreme case of productivity switch is modeled. Moreover, the time frame of three periods is too short to show the evolution of industry. In this section, I describe a dynamic structural model of asset sales with endogenous asset prices for an economy consisted of a large number of competitive firms and infinite time horizon. First, I specify optimization problem for firms, market clearing condition for asset prices, and the law of motion for industry structure. Then, the recursive equilibrium is defined. Finally, using technique developed in Krusell and Smith (1997), I characterize the approximated equilibrium.

4.1 Firm's Optimization Problem

Production Technology Each firm produces output using capital stock k, via an increasing and concave production function, π :

$$\pi\left(k_i, A_i\right) = A_i k_i^{\alpha}$$

where $\alpha < 1$ and A reflects stochastic total factor productivity.

Productivity Shocks Firms experience a common aggregate productivity shock z_a and an idiosyncratic productivity shock z_i that is firm specific:

$$\ln(A_i) = z_a + z_i$$

Both aggregate and idiosyncratic shocks follows $AR(1)$, with zero means and white noise error terms such that

$$\begin{aligned} z_{a,t+1} &= \rho_a z_{a,t} + \varepsilon_{a,t+1} \\ z_{i,t+1} &= \rho_i z_{i,t} + \varepsilon_{i,t+1} \end{aligned}$$

where $\varepsilon_a \sim N(0, \sigma_a)$ and $\varepsilon_i \sim N(0, \sigma)$. z_a and z_i are independent from each other, i.e., $cov(z_{a,t}, z_{i,t}) = 0$, for all i and t.

Investment Decisions After observing productivity shocks, firms make decision on new investment I_i and asset transfer, x_i given prices (P_I, P_x). Positive x_i is a purchase and negative x_i represents a sale in existing asset. Price for new investment is normalized to be one, $P_I \equiv 1$.

Firms cannot sell more than what they have, i.e., $k_i + x_i \geq 0$. In the case where equality holds, it represents a complete ownership transfer. New investment is non-negative and has an upper bound proportional to current capital stock, $0 \leq I_i \leq \overline{I} \times k_i$.

Adjustment cost occurs in both new investment and asset transfer (both sales and acquisitions). It takes quadratic form such that:

$$\Gamma^j(k_i, j_i) = \frac{\gamma_j}{2}\left(\frac{j_i}{k_i}\right)^2 k_i \qquad where\ j \in \{I, x\}$$

Numerous papers in the economics literature have found quadratic specification of adjustment cost to be a good approximation for inventory cost and machinery setup(disassemble) costs, which fits the observed investment activities.[9] The coefficient of adjustment costs (γ_j) describes how costly it is to integrate the newly added assets into existing capacity. In both cases, purchases and sales, changes have to be made as to accommodate the increase or decrease of capacity. Since new investments are built-to-suit while acquired assets may require additional 'disassemble' cost, I assume that $\gamma_x > \gamma_I > 0$. [10]

There exists a fixed cost, f_x, for engaging in asset transfers to account for transaction costs encountered in asset sales and acquisitions, such as searching for partners, negotiating deals and legal fees. The existence of fixed costs complies with the empirical findings that firms who participate in the transaction usually sell and buy significant amount of assets, compared to their existing sizes.

$$\begin{aligned} f_x &> 0 \qquad if\ x \neq 0 \\ &= 0 \qquad if\ x = 0 \end{aligned}$$

Therefore, cost of new investment is

$$C(k, I) = I + \Gamma(k, I)$$

[9] For a model detailed discussion on adjustment cost, see Cooper and Haltiwanger (2003).

[10] Later in the paper, this assumption is relaxed to have the same adjustment cost for both asset sales and new investment.

and cost (benefit) of asset sale is[11]

$$C(x) = P_x \cdot x + \Gamma(k, x) + f(x)$$

As in the example, there is a timing difference between new investment and buying existing assets from other firms. Existing asset will be transferred immediately for production usage while new investment takes one period to be realized. After asset transfer, total capacity available for current production equals to $(k_i + x_i)$ and capacity carried over to the next period, k_i', is a sum of un-depreciated current capital and new investment placed, $k_i' = (1-\delta)(k_i + x_i) + I_i$, where δ is depreciation rate.

Industry Structure Industry structure is summarized as the joint distribution of beginning capacity and idiosyncratic shock, $F = F(k_i, z_i)$

β is discount rate. Time is discrete and horizon is infinite.

Value Function Firm's optimization problem can be expressed as follows:

$$\begin{aligned} & V(k_i, z_i; z_a, F, P_x) \qquad\qquad (2A) \\ = & \max_{\substack{0 \leq I_i \leq \overline{I} \times k_i \\ x_i \geq -k_i}} \pi(k_i + x_i, A_i) - \left[I_i + P_x x_i + \sum_{j \in \{I,,x\}} \Gamma^j(k_i, j_i) + f_x \right] + \beta EV(k_i', z_i'; z_a', F', P_x' | z_i; z_a, F, P_x) \end{aligned}$$

It maximizes the total firm value, which consists of current profit, measured as profit (the first term) minus investment cost (the second term), and the discounted expected value (the third term).

4.2 Market Clearing

Using $(2A)$, given any price level P_x, firm's asset transfer decision can be traced, following the decision rule, $x_i = x(k_i, z_i; z_a, F, P_x)$

Let D_x denote the net aggregate demand for existing capacity. Given industry structure $F(k_i, z_i)$, and aggregate productivity z_a, it can be written as:

$$D_x(P_x | F, z_a) = \int_{k_i \in K} \int_{z_i \in Z_I} x(k_i, z_i; z_a, F, P_x) F(k_i, z_i) \; dk_i \; dz_i$$

[11] For firms who sell assets, $x < 0$ and the net gain from transaction equals proceeds minus the adjustment cost and fixed cost.

Market clearing implies that under the equilibrium price P_x, net aggregate demand equals to zero, i.e.,

$$D_x (P_x | F, z_a) = 0 \tag{3}$$

Or alternatively, we can write, $P_x = P_x (F, z_a)$.

4.3 Law of Motion

To complete the value function in $(2A)$, we still need to define a mapping H as law of motion, which describes the evolution of future industry structure from the current structure. Since firms' decisions also depend on aggregate shock, the law of motion should contain the aggregate state as well. Hence we have, $F' = H (F, z_a)$.

The future equilibrium price is also well defined under H such that

$$P_x' = P_x (F', z_a') = P_x (H (F, z_a), z_a')$$

Under market clearing condition and the law of motion for industry structure, the value function can then be written as

$$V(k_i, z_i; z_a, F)$$
$$= \max_{\substack{0 \leq I_i \leq \overline{I} \times k_i \\ x_i \geq -k_i}} \pi (k_i + x_i, A_i) - \left[I_i + P_x (F, z_a) x_i + \sum_{j \in \{I,,x\}} \Gamma^j (k_i, j_i) + f_x \right] + \beta EV (k_i', z_i'; z_a', F' | z_i; z_a, F) \tag{2B}$$

4.4 Recursive Equilibrium

Definition 1 *A recursive competitive equilibrium is a set of decision functions $\{x, I\}$, a price function P_x, and a law of motion H such that:*

(i) $V(k_i, z_i; z_a, F)$ *solves firm's optimization problem in (2B) given H and P_x*

(ii) $P_x (F, z_a)$ *satisfies market clearing condition in (3) such that $D_x (P_x (F, z_a)) = 0$*

(iii) H *is generated by the decision rules implied by V*

4.5 Approximate Equilibrium

4.5.1 Methodology

The definition of recursive competitive equilibrium implies that given the law of motion H and price function P_x, individual decision rules can be generated from value function; price is set such that asset market will clear given the decision rules implied from value function; aggregating individual decisions under the equilibrium price will trace out the evolution of industry structure implied by H.

Unfortunately, industry structure F, defined as the joint distribution of (k_i, z_i) is a high dimension object and numerical solution to dynamic programming problems become increasingly difficult as the size of state space increases.

To solve this problem, I follow methods in Krusell and Smith(1997) and Krusell and Smith(1998), which approximate the law of motion for aggregate state in an economy with heterogeneous agents. The method can be briefly summarized as follows.

Suppose that firms perceive future structure depend only on the first I moments of current structure, $m \equiv (m_1, m_2..., m_I)$ (besides the aggregate shock, z_a) and the law of motion for m is given by a function H_I, such that, the matrix of I moments in the next period, m', can be expressed as a function of I current moments: $m' = H_I(m, z_a)$. Given the law of motion H_I, firms decide on optimal decision rules on new investment and asset transfer, $I_I(.)$ and $x_I(.)$. Given such decision rules and an initial distribution of capacity and idiosyncratic shocks, it is possible to derive the implied aggregate behavior - a time series of the joint distributions, by simulating a large panel of firms. One can then compare the simulated evolution of moment $\widehat{H_I}$ with the perceived law of motion H_I, on which firms base their decisions and iterate until they converge.

4.5.2 Estimating Approximate Equilibrium

Suppose there are only two states of the world, expansion $\left(z_a = z_a^H > 0\right)$ and recession $\left(z_a = z_a^L < 0\right)$.

Similar to Krusell and Smith (1998), I start by using only the first moment of $F(k_i, z_i)$. Since idiosyncratic shock z_i has a zero mean, I use mean capacity, $\overline{k}$ to proxy for industry structure $F(k_i, z_i)$.

I assume a simple log-linear law of motion for $\overline{k}'$ such that

$$\begin{aligned} \log \overline{k}' &= a_0 + a_1 \log \overline{k} \qquad if\ z_a = z_a^L \\ \log \overline{k}' &= b_0 + b_1 \log \overline{k} \qquad if\ z_a = z_a^H \end{aligned} \tag{4}$$

Let price function $P_x(F, z_a)$ be approximated as follows:

$$\begin{aligned} P_x &= c_0 + c_1 \log \overline{k} \qquad if\ \ z_a = z_a^L \\ P_x &= d_0 + d_1 \log \overline{k} \qquad if\ \ z_a = z_a^H \end{aligned} \tag{5}$$

The optimization problem becomes:

$$V(k_i, z_i; z_a, \overline{k})$$
$$= \max_{\substack{0 \leq I_i \leq \overline{I} \times k_i \\ x_i \geq -k_i}} \pi (k_i + x_i, A_i) - \left[I_i + P_x \left(\overline{k}, z_a \right) x_i + \sum_{j \in \{I,,x\}} \Gamma^j (k_i, j_i) + f_x \right] + \beta EV \left(k_i', z_i'; z_a', \overline{k}' | z_i; z_a, \overline{k} \right) \tag{2C}$$

The approximate equilibrium is an approximate law of motion $\widehat{H}$ identified by $\left(\widehat{a_0}, \widehat{a_1}, \widehat{b_0}, \widehat{b_1}\right)$ and an approximate pricing function $\widehat{P_x}$ identified by $\left(\widehat{c_0}, \widehat{c_1}, \widehat{d_0}, \widehat{d_1}\right)$ such that when taken as given by all firms, it tracks movement of $\overline{k}$ and asset price P_x in a simulated economy with negligible error. That is, the error between the forecasted evolution $\overline{k}' \left(\widehat{H}\right)$ and the realized evolution $\sum_{i=1}^{N} k_i'/N$, and the error between the expected price $\widehat{P_x}$ and realized price P_x are very small.

Appendix C offers a detailed description on how the computational strategy is implemented.

Proposition 4 *There exists a unique continuous function V: $K \times Z_I \times Z_A \times \overline{K} \rightarrow R_+$ that solves (2B) and there exists stationary policy functions $I(k_i, z_i; z_a, \overline{K})$ and $x(k_i, z_i; z_a, \overline{K})$*

Proof. See Appendix ■

5 Model Implications

5.1 Benchmark Simulations

Parameters I solve firm's optimization problem numerically on a grid of points in the state space. The parameter values are reported in Table 1.

Using techniques developed in Tauchen (1986), I transform AR(1) process that describes the evolution of both shocks into a discrete-state Markov chain, letting z_i have 10 points and z_a have 2 points with support in $\left[-3\sigma^j/\sqrt{1-(\rho^j)^2}, 3\sigma^j/\sqrt{1-(\rho^j)^2}\right]$.

Cooper and Haltiwanger (2003) estimate that the serial correlations for aggregate and idiosyncratic productivity shocks are $(0.76, 0.89)$ and the innovations to shocks have standard deviations of $(0.05, 0.30)$, using plant-level data from LRD. Hennessy and Whited (2004) use a standard deviation of 0.118 and a serial correlation of 0.740 for total productivity shocks. Eisfeldt and Rampini (2005) use $(0.75, 0.75)$ as serial correlation for both shocks and standard deviations of $(0.015, 0.057)$. For benchmark model, I set $\rho \equiv (\rho_a, \rho_i) = (0.75, 0.75)$ and $\sigma \equiv (\sigma_i, \sigma_a) = (0.10, 0.30)$.

The production technology parameter α is set to be 0.5, compared to 0.592 in Cooper and Haltiwanger (2003), 0.333 in Eisfeldt and Rampini (2005) and 0.623 in Hennessy and Whited (2004). For adjustment costs, I use $(\gamma_x, \gamma_I) = (0.20, 0.10)$ for the benchmark model. For $\gamma_x = 0.2$, the average adjustment cost for a 50% expansion is about 5%.

The state space for capital stock, k_i, is set on a discrete grid of 25 points and I use 8-point and 20-point grids to represent state space for mean capacity and price respectively. The common discount rate is set to be $\beta = 0.9$ and depreciation rate is chosen to be $\delta = 0.1$.

I simulate 5,000 firms in 1,000 time periods, where the first 50 periods are discarded.

Predictions for Mean Capacity and Investment Price The equilibrium law of motion for mean capacity $\left(\overline{k}\right)$ and acquisition price (P_x) in the benchmark model is estimated as follows:

$$\begin{aligned}
\log \overline{k}' &= 0.5953 + 0.6849 \times \log \overline{k} \qquad if\ z_a = z_a^L \\
\log \overline{k}' &= 0.6969 + 0.6757 \times \log \overline{k} \qquad if\ z_a = z_a^H \\
P_x &= 1.6489 - 0.2826 \times \log \overline{k} \qquad if\ \ z_a = z_a^L \\
P_x &= 1.7084 - 0.2731 \times \log \overline{k} \qquad if\ \ z_a = z_a^H
\end{aligned}$$

R-squares for the capital regressions are over 99% while R-squares for price regressions are over 95%. Using the simulated sample , Figure 2a plots next period's mean capacity $\left(\overline{k}'\right)$ against this period's mean capacity $\left(\overline{k}\right)$ and Figure 2b plots current asset price (P_x) as a function of current mean capacity $\left(\overline{k}\right)$.

Optimal Decision Rule of Asset Sales Figure 3 shows value functions based on firm sizes (k_i) and idiosyncratic productivity shocks (z_i) in both good $\left(z_a = z_a^H\right)$ and bad $\left(z_a = z_a^L\right)$ times. Not surprisingly, value increases in both k_i and z_i and it is higher in good times.

Figure 4A describes firm's decisions on asset sales (x_i/k_i) given current capacity and idiosyncratic shocks. The solid lines represent decisions in bad times and the dotted lines show decisions in good times. Four sub-panels represent firms in different size quartile. For all plots, idiosyncratic productivity shocks are plotted on the X-axis and the ratio of asset transfer over the beginning capacity is plotted on the Y-axis. The vertical lines in each sub-panel show the expected range of idiosyncratic shocks given the end capacity in the last period [12]

Clearly, when idiosyncratic shocks fall within the range, it is optimal to maintain current capacity. Selling off assets is optimal when firms receive lower than expected shocks and buying is optimal when

[12] The lines for each sub-panel are constructed such that the probability of idiosyncratic shocks fall into the range is about 90%.

shocks turn out to be better than expected. The optimal decision rule on asset sales derived in the full model is similar to that in the two-firm example such that change of the productivity over time gives firm incentive to buy or sell existing assets. Firms with increasing productivity tend to buy and firms with decreasing productivity tend to sell.

Research that studies asset sales transactions have found that significant difference exists between buyer and seller. For example, both Lang, Poulsen and Stulz (1994) and Schlingemann, Stulz and Walking (2002) find that firms that sell assets or divest segments perform poorly before the sale. Findings here suggest a new dimension - current size, as a factor in decisions for asset sales. Given the same idiosyncratic shock, smaller firms are more likely to buy assets and larger firms are more likely to sell assets. The intuition is as follows. Since current size is a function of realized productivities from the past, larger firms expect to have higher productivity shocks than smaller firms. As a result, given the same shock level, it is more likely that shocks are below expectation for larger than for smaller firms. Similar empirical findings have been documented in Maksimovic and Phillips (2001). They show that for single segment firms, when controlling for productivity, larger firms are more likely to engage in partial firm sales. [13]

Simulated Moments Using the decision rules derived above, I simulate a large panel of firms. The simulated sample allows me to compute interesting quantities such as investment ratio, asset sales ratio and Tobin's q both on the firm- and industry-level. Related variables are defined as below:

	Firm-level	Industry-level
Investment	$\frac{i}{k} = I_i/k_i$	$\frac{I}{K} = \sum_{i=1}^{N} I_i / \sum_{i=1}^{N} k_i$
Asset Sales	$\frac{x}{k} = x_i/k_i$	$\frac{X}{K} = \sum_{i=1}^{N} q_i \times 1\left(q_i > 0\right) / \sum_{i=1}^{N} k_i$
Tobin's q	$\frac{v}{k} = v_i/k_i$	$\frac{V}{K} = \sum_{i=1}^{N} \left(\frac{v_i}{k_i}\right) /N$

Table 2 describes moments using simulated data. First, both asset sales and new investments are higher in expansions. On average, about 4.9 percent of the total existing assets change ownership in good times, compared to 3.6 percent in bad times. New investments in good times accounts for 11.8 percent of total existing assets, compared to 8.1 percent in bad times. This is consistent with empirical findings that investments and asset sales are both pro-cyclical. For example, Maksimovic and Phillips (2001) document that over the period 1974 to 1992, an average of 3.89 percent of large manufacturing plants change ownership and in expansion years, the number is about 6.19 percent.

[13] In Maksimovic and Phillips (2001), for multiple-segment firms, who produce in multiple industries, the probability of asset sale is decreasing in size. Since I do not consider the case of diversification and divestiture in this paper, I focus only on within industry transfers for firms that only produce in that sector.

Second, new investment is sensitive to the change of aggregate states. It achieves the highest level when aggregate state moves from bad to good, averaging 13.86 percent, compared to 11.22 percent if good economy is a continuation from previous period. The reverse is also true – new investment hits the lowest level at 6.24 percent when aggregate state moves from good to bad, compared to 8.71 percent when previous period also had a bad aggregate shock. On the other hand, asset sales mainly depend on current shock and do not seem to be affected as much by previous state. Similar findings have also documented by Andrade and Stafford (2004), who find that non-merger investments positively respond to sales growth while merger investments do not.

Third, firms make significant capacity changes through asset purchases and sales. On average, acquirers buy about 40 percent while sellers sell about 25 percent of their existing assets. Furthermore, 6.6 percent and 5.3 percent of total number of firms buy or sell at least half of their assets in good and bad times, respectively. The magnitude from the simulated data is consistent with Gertner, Power and Scharstein (2002)'s finding that the spin-off unit accounts for 24 percent of the total asset in the parent company prior to the transaction.

Finally, consistent with the findings from research that studies asset sales transactions; significant difference exists between buyer and seller. Overall, buyers have average size while sellers are much bigger. Moreover, buyers have higher valuation, 22% higher compared to the average firms, measured using value to book ratio, while sellers are valued about 29% below the average. In this model, although it is the change of productivity over time that drives asset purchases and sales, the general pattern in valuation between buyers and sellers are consistent with the widely documented empirical findings that firms with higher valuation buy those with lower valuation.

Re-examine Evidence of Misvaluation Theory In their paper, Rhodes-Kropf, Robinson and Viswanathan (2004) find that current valuation has a significant positive effect while long run value to book has a significant negative effect on being an acquirer. The simulated panel shows the same pattern. Table 2 Panel E reports results from a Probit model estimation using simulated data. Firms are more likely to buy existing assets when the current market to book ratio (q) is high, but the long run average valuation is low. The intuition is as follows. Since firms are more likely to buy whenever productivity increases; given the same level of positive shock, those with lower long run average productivity have higher increase and therefore are more likely to expand through acquisition. In this model, firms make rational decisions and market value reflects the true growth opportunity; yet, it generates the same pattern in asset sales documented as evidence for misvaluation. This suggests that the observed phenomenon may not be due to misvaluation, but change of productivity.

5.2 Comparative Statics

The dynamic structural model developed above describes an industry with aggregate and idiosyncratic productivity shocks that have time-invariant persistence and volatility. In this section, I simulate industries with different shock attributes and evaluate how they affect asset sales.

Table 3 reports sensitivities of simulated moments with respect to model parameters. For each related parameter, I simulate model twice: once with a value of parameter of interest twenty-five percent above and once with a value twenty-five percent below the baseline value.[14] The moments are reported in Panel A and elasticities are reported in Panel B. For each parameter, elasticity is calculated as the change of moments divided by change in underlying parameters and then multiplied by the ratio of baseline structural parameter over the baseline moment.

First, fixed cost (f_x) has a negative effect on asset sales. Higher fixed cost increases the minimum gain requirement for both participants and results in fewer sales. On average, firms trade less frequently but for larger amount. The overall asset reallocation is less. The fixed cost here may have several interpretations. For example, it can be related to the model in Rhoskropf et. al. (2004), as a searching cost to describe how difficult it is to find a trading partner. Or, it can also be viewed as a technology parameter to account for the general transaction cost in asset sales, such as financing, communication costs and legal fees.

Second, attributes of aggregate shock (ρ_a, σ_a) have moderate effect on new investments, but very little impact on asset sales. Higher persistence (ρ_a) makes current state more likely to linger and higher volatility (σ_a) enlarges the difference between good and bad states, both of which lead to more state-dependent investments[15]. Meanwhile, although both persistence and volatility have some positive effects on asset sales in good times, there is almost no effect in bad times. One possible explanation could be that in good times, not only do asset sales occur to reflect the change in relative productivity from random disturbances (as in bad times), they also respond to the unfilled needs of more productive firms to expand given that new investments are limited in the short run.

Third, the parameters for idiosyncratic shock (ρ_i, σ_i) have very strong effects on asset sales. Lower persistence increases the chances for change in productivities, and leads to more asset sales - a 25 percent decrease in ρ_i would result in 25 percent (23.3 percent) increase in the amount of assets sales and 19 percent (16 percent) increase in participation frequency in good (bad) times. Industries with noisier shocks also have larger and more active asset sales market - a 25 percent increase in σ_i leads to 60 percent (69 percent) increase in the amount of assets sales and 36 percent (48 percent) increase in participation frequency in good (bad) times.[16] The results documented here comply with Gort (1969)

[14] Similar method is used in Henessy and Whited (2005).

[15] This might partly due to the assumption that investment is limited to a certain threshold in the short run. In fact, when constraint on investment is relaxed later in the paper, we do see an increase of investment sensitivity.

[16] For illustration, these numbers are calculated as 25%× elasticity. For example, the elasticity of ρ_i on $\frac{Q}{K}$ when $z_a = H$ is -1.006 and therefore for a 25% increase in ρ_i, the predicted decrease in $\frac{Q}{K}$ would equal to $25\% \times -1.006 = -25\%$

and suggest that asset sales are indeed results of economic disturbances.

Table 4 reports the robustness checks when several assumptions are relaxed. The moments from baseline model are reported in the first column as a reference. In the second column, I double the cap of new investments available at a certain point of time from 20 percent to 40 percent. In the third column, instead of having higher adjustment costs for asset sales, same adjustment costs parameters are used for both asset sales and new investment. Most of the moments do not change for more than 10% from baseline values suggesting that these assumptions are not critical for the main results in the model.

5.3 Asset Sales in Business Cycle

The rich setting of this structural model makes it possible to study asset sales in the business cycle. Here, I start with a random initial distribution in both firm sizes and productivities $\left(\{k_i, z_i\}_{i=1}^{N}\right)$ and set the aggregate shocks as follows so that the simulated industry moves from recession to expansion and then back to recession:

$$z_{a,t} = \left\{ \begin{array}{cc} z_a^L & if\ t \in [1,20] \\ z_a^H & if\ t \in [21,40] \\ z_a^L & if\ t \in [41,60] \end{array} \right\} \quad (6)$$

I simulate 5000 firms using parameters as specified in the benchmark model.

Regardless of the initial distribution, by the end of period 20, the mean capacity converges to 6.60 with standard deviation of 3.16; 3.7 percent of the existing assets change ownership and new investment accounts for 10 percent of total existing assets, all of which suggest that the model is stable.

At the strike of the positive shock ($t = 21$), the existing capacity is very low, after a series of negative shocks. To respond to the productivity increase and the general demand for capacity, investment shoots up, reaching 15 percent in the first year and 13 percent in the second year. Average capacity rises sharply, although at a decreasing rate. Price of existing assets also jumps up from 1.12 to 1.19 at the transition, reflecting the increasing opportunity cost inefficient firms face. As firms expand, new investments slow down and as the marginal value of capital decreases, price starts to fall. It takes about 10 periods for both mean capacity and price to stabilize and converge to their long-run equilibrium.

When the negative productivity shock hits ($t = 41$), the economy has very high capacity, as a result of 20 periods of expansion. At the onset, the general demand to cut down sizes drives the price of existing assets down from 1.15 to 1.07. The low price level makes existing assets an attractive alternative to investing in new assets for firms that demand additional capacity. Indeed, investments are very low at the transition period - only 5 percent given the 10 percent depreciation rate. As firms keep cutting down capacities, price slowly climbs up. Again, it takes about 10 periods for both capacity and price stabilize to its long-run equilibrium.

Figure 5 describes the evolution of mean capital $\left(\overline{k}\right)$ and asset prices (P_x) on the time path.

6 Empirical Tests on Model Implications

6.1 Data and Construction of Variables

I use the data from Longitudinal Research Database (LRD), maintained by the Center for Economic Studies at the Bureau of the Census. The LRD is a large micro database containing plant-level information for approximately 50,000 manufacturing plants in the SIC codes 2000 - 3999. [17]. There are several advantages of using LRD for my study, relative to Compustat. First, it offers detailed information such as output and input on the plant level so that I can estimate productivity on the plant level. Second, it has separate identifiers for plant and firm, hence I can track down plants even as they change owners. This is key for my study, as it allows me to identify assets that have changed ownership from year to year in each industry.

My sample contains the period from 1974 to 2000. As in Maksimovic and Phillips (2001), I aggregate plants into firm level business segments at the three-digit SIC level and exclude segments that are less than $1 million in real value of shipments in 1982 dollars.

Productivity Measures I use total factor productivity (TFP) at the three-digit SIC level as productivity measure. The calculation follows Schoar (2002). TFP is obtained at the plant level from estimating a log-linear Cobb-Douglas production function for each industry year. Specifically, I estimate the following equation:

$$\ln(Y_{ijt}) = a_{jt} + b_{jt} \ln\left(K_{ijt}\right) + c_{jt} \ln\left(L_{ijt}\right) + d_{jt} \ln\left(M_{ijt}\right) + \varepsilon_{ijt}$$

where Y_{ijt} is the total value of shipments of plant i in industry j at time t, K_{ijt}, L_{ijt} and M_{ift} represent the value of capital stock, the equivalent total production man-hours and value of inputs of plants i in industry j at time t, respectively.[18]

[17] See Maksimovic and Phillips (2001) for a detailed description on the LRD.

[18] Value for capital stock (K) are generated by recursive perpetual inventory formula. Labor inputs (L) are adjusted to reflect both production and non-production man hours. Inputs (M) are expenses for parts and intermediate goods, fuel, and energy purchased.

Industry is defined at the three-digit SIC level. As pointed out by Schoar (2002), since coefficients on capital, labor and material inputs may vary by industry and year, this specification allows for different factor intensities in different industry-year. The TFP measure for each plant is the estimated residual from these regressions, which measures plant's relative productivity in that industry-year.

Estimation of Shock Persistence and Volatility Since TFP is the residual part of plant's productivity, it estimates the relative rank of a plant in its industry in a specific year. To estimate the shock persistence and volatility for an industry, I fit an $AR(1)$ process:

$$TFP_{ij,t} = \rho_j TFP_{ij,t-1} + \varepsilon_{ijt} \tag{7}$$

where $TFP_{ij,t}$ is the idiosyncratic productivity of plant i in industry j at time t.

I use the autoregressive coefficient ρ_j as a measure for shock persistence, and the standard deviation of the error terms as the measure for shock volatility such that $\sigma_j = std\left(\{\varepsilon_{ijt}\}_{i=1,t=1}^{n\quad T}\right)$ where n is the total number of plants in industry j and T is the total number of years in the sample.

To have a staple time series of productivities, I delete industries with less than 50 plants in any given year and with less than 5 years of observation in the time series for the $AR(1)$ estimation. My final sample consists of estimates for persistence and volatility for 112 industries at the three-digit SIC levels.

Rate of Asset Sales Similar to Maksimovic and Phillips (2001), the rate of asset sales in an industry for a given year is defined as the ratio of total number of plants that change ownership over total number of existing plants. [19] The descriptive statistics are shown in Panel B in Table 5. On average, xxx percent of large manufacturing plants change ownership in the period from 1974 to 2000, and the number is much higher in expansion years, approaching xxx percent. [20]

6.2 Calibration

I calibrate cost parameters in the structural model to fit the average level of asset sales and investments during both expansion and recession years. Other parameters are pre-chosen based on the existing literature. For example, using LRD data, Cooper and Haltiwanger (2003) estimate the technology parameter at 0.592 and the persistence and standard deviation of error terms for aggregate shock

[19] For robustness, I also use the ratio of total amount of assets that change ownership over total assets as a measure for asset sales rate. The results are qualitatively the same.

[20] Maksimovic and Phillips (2001) document similar facts using LRD data from 1974 - 1992. They find an average asset sales rate of 3.89 percent and a rate of 6.89 percent for expansion years.

to be 0.889 and 0.08, respectively. I use the discount rate of 0.935 and depreciation rate of 0.12, from Gomes (2001). The persistence and standard deviation of error term for idiosyncratic shock are estimated using LRD data as the average of industry persistence and dispersion.

The estimated parameters are reported in Table 5.

6.3 Tests and Results

The main idea of this model is that asset sales result from productivity changes over time driven by productivity shocks; therefore, industries with higher probability of productivity change will have more asset sales. Using model's implication on the relationship between shock attributes and asset sales, I form conjectures below:

Conjecture 1 *Industries with lower persistence in idiosyncratic shocks have higher asset sales.*

Conjecture 2 *Industry with higher volatility in idiosyncratic shocks have higher asset sales.*

I test these conjectures in two ways. First, I compare the asset sales across industries and test whether shock persistence and volatility explain the cross-sectional difference. Then, to control for other potential factors that may have changed over time, after estimating an industry fixed effect model on asset sales using the panel data, I examine the relationship between the estimated industry fixed effect and related shock attributes.

I divide industries in my sample into 3 groups with equal number of observations based on shock persistence ρ and volatility σ. Table 6 shows the summary statistics of each $\rho-$ and $\sigma-$ group. The High-ρ group has an average persistence of XXX and the Low-ρ group has an average persistence of XXX. The volatility in High- and Low-σ groups are XXX and XXX, respectively.

Table 7 reports results from univariate tests, comparing asset sales between High- and Low-ρ industries as well as between High- and Low-σ industries. On average, High-ρ group has an asset sales rate of XXX percent, compared to XXX percent in Low-ρ group; and High-σ group has an asset sales rate of XXX percent, compared to XXX percent in Low-σ group. Both parametric and non-parametric tests reject the null hypotheses that no significant difference exists in asset sales ratio across different ρ and σ groups. Instead, all tests support the conjectures that industries in Low-ρ and High-σ groups have higher asset sales.

Table 8 reports results in a regression setting, where I also control for other industry characteristics such as capital expenditure, asset turnover rate, profitability and industry demand. Column (1) to (3) show that both persistence and volatility appear to be significant factors in explaining asset sales, individually or jointly. In addition, industries with lower asset turnover rate and higher profit margin tend to have higher asset sales.

To control for the variation of asset sales over time that may potentially be caused by other factors, I estimate a panel regression with industry fixed effects:

$$s_{jt} = \alpha_j + \beta \cdot X_{jt} + \varepsilon_{jt}$$

where s_{jt} is the rate of asset sales of industry j from time t to $t+1$ and X_{jt} includes control variables of industry j at time t, which consist of various industry characteristics that have been studied in the literature in asset sales or merger decisions, such as capital expenditure, asset turnover rate, profitability, sales growth, size distribution and percentage of diversified firms.

Table 9 Panel A report the results. Within the industry, asset sales are higher when new investments are low and asset utilization rate is low. Compared to recession years, rate of reallocation is significantly higher in expansion years. Dispersion in asset sizes, measured by Herfindahl index has a positive effect - higher dispersion, or lower Herfindahl index, is associated with higher asset sales. Profitability, on the other hand, is not a significant factor. Neither is the percentage of diversified firms in the industry. F test examining the group effects rejects the hull hypothesis that no significant difference exists across industries.

Then, I regress the estimated industry fixed effects $\widehat{\alpha_j}$ on shock persistence and volatility:

$$\widehat{\alpha_j} = \beta_0 + \beta_1 \cdot \rho_j + \beta_2 \cdot \sigma_j + \varepsilon_j$$

Panel B describes the results. Overall, results are consistent with model implications. Together, both factors explain about XXX percent of the total variation in industry fixed effects.

Table 9 reports results of an OLS regression where I regress the percentage of asset sales on shock persistence and volatility, controlling for other industry characteristics. The specification is as follows:

$$s_{jt} = \beta_0 + \beta_1 \rho_j + \beta_2 \sigma_j + \beta_3 \cdot X_{jt} + \varepsilon_{jt}$$

where s_{jt} is the percentage of asset sales of industry j from time t to $t+1$; (ρ_j, σ_j) are estimated persistence and volatility of idiosyncratic shocks of industry j and X_{jt} includes control variables of industry j at time t.

Again, consistent with model implication, I find that the result are consistent with model predictions. Furthermore, other industry characteristics such as capital expenditure, asset turnover, profit margin and sales growth also affect the rate of asset sales. [I will describe results in greater detail once results are cleared from Census Bureau.]

7 Conclusion

In this paper, I develop a dynamic structural model of asset sales, where firms make rational investment decisions on both new investments and existing assets, under productivity shocks. Price of existing assets is endogenized, to reflect the true value of growth opportunity given aggregate states and industry structures. The model is solved numerically through simulation. It shows that in a dynamic setting, change of productivity over time drives asset reallocation. Firms with increasing productivity are buyers and others with decreasing productivity are sellers on the market for existing assets. In the presence of fixed transaction cost, higher aggregate productivity relaxes the participation constraint and makes sales more likely to occur. Using a simulated panel, I show that some of the documented evidence supporting misvaluation theory can be generated by dynamic neoclassic model with productivity shocks. For example, asset reallocation coincide with higher overall market valuation; buyers have high and sellers have low market to book ratio; and acquirers have higher valuation at the time, but lower long run valuation.

Shock attributes also explain the cross-sectional differences in asset sales. Since purchases and sales of assets result from changes in productivity due to shocks, industries with idiosyncratic shocks that are less persistent and have noisier error terms, are more likely to have higher asset reallocation as productivities are more likely to shuffle across firms.

I calibrate the cost parameters in the structural model based on average asset sales and investment rate in both expansion and recession using the plant-level data from Longitudinal Research Database (LRD). Data also supports model implications that industries with lower shock persistence and higher shock dispersion, on average, have higher asset sales, after controlling for other industry characteristics. Shock attributes, such as persistence and volatility, explain XXX percent of the variation in industry fixed effects.

A Derivation for Two-Firm Example

I solve the model from backwards.

- At t=1

Value function for firm i can be expressed as follows

$$V\left(k_i^1, z_a^1, z_i^1\right) = \max_{x_i^1 \geq -k_i^1} \pi\left(k_i^1 + x_i^1, A_i^1\right) - P_x^1 x_i^1 - f_x + \beta\left(1-\delta\right)\left(k_i^1 + x_i^1\right)$$

Together with the market clearing condition

$$x_1^1\left(P_x^1\right) + x_2^1\left(P_x^1\right) = 0$$

We can solve for $\left(P_x^1, \left\{x_i^1\right\}_{i=1}^2\right)$ such that

$$\begin{aligned} x_1^{1*} &= -x_2^{1*} && && \text{(A1)} \\ &= \frac{\exp\left(\frac{z^1}{1-\alpha}\right)}{\exp\left(\frac{z^1}{1-\alpha}\right) + \exp\left(\frac{-z^1}{1-\alpha}\right)}\left(k_1^1 + k_2^1\right) - k_1^1 && if && f_x \leq D^1 \\ &= 0 && if && f_x > D^1 \end{aligned}$$

and

$$P_x^{1*} = \alpha \exp\left(z_a^1\right)\left(\frac{\exp\left(\frac{z^1}{1-\alpha}\right) + \exp\left(\frac{-z^1}{1-\alpha}\right)}{\left(k_1^1 + k_2^1\right)}\right)^{1-\alpha} + \beta\left(1-\delta\right) \qquad if \qquad x_1^1 \neq 0 \qquad \text{(A2)}$$

where $D^1 = \min\left\{\left[\pi\left(k_i^1 + x_i^{1*}, A_i^1\right) - \pi\left(k_i^1, A_i^1\right)\right] - \left[P_x^{1*} - \beta\left(1-\delta\right)\right] x_1^{1*}\right\}_{i=1}^2$ is the minimum gain from transaction across two firms.

- At t=0

Using value function derived from above, firm's optimization problem can be expressed as:

$$V\left(k_i^0, z_a^0, z_i^0\right) = \max_{\substack{x_i^0 \geq -k_i^0 \\ 0 \leq I_i^0 \leq \overline{I}}} \pi\left(k_i^0 + x_i^0, A_i^0\right) - P_x^0 x_i^0 - f_x + \beta E V^1\left(k_i^1, z_a^1, z_i^1\right)$$

where $\quad k_i^1 = \left(1-\delta\right)\left(k_i^0 + I_i^0\right)$

Again, with market clearing condition

$$x_1^0\left(P_x^0\right)+x_2^0\left(P_x^0\right)=0$$

we can solve for equilibrium price and optimal asset transfer

$$\begin{aligned} x_1^{0*} &= -x_2^{0*} \qquad\qquad (A3)\\ &= \frac{\exp\left(\frac{z^0}{1-\alpha}\right)}{\exp\left(\frac{z^0}{1-\alpha}\right)+\exp\left(\frac{-z^0}{1-\alpha}\right)}\left(k_1^0+k_2^0\right)-k_1^0 \qquad if \qquad f_x\leq D^0\\ &= 0 \qquad if \qquad f_x>D^0 \end{aligned}$$

and

$$P_x^{0*}=\alpha\exp\left(z_a^0\right)\left(\frac{\exp\left(\frac{z^0}{1-\alpha}\right)+\exp\left(\frac{-z^0}{1-\alpha}\right)}{\left(k_1^0+k_2^0\right)}\right)^{1-\alpha}+(1-\delta)\,\beta EP_x^{1*} \qquad if \qquad x_1^0\neq 0 \qquad (A4)$$

where $D^0=\min\left\{\left[\pi\left(k_i^0+x_i^{0*},A_i^0\right)-\pi\left(k_i^0,A_i^0\right)\right]-\left[P_x^{0*}-\beta\left(1-\delta\right)\right]x_1^{0*}\right\}_{i=1}^2$.

The expected future price for existing asset depends on current aggregate productivity and whether the constraints on investment are binding

$$\begin{aligned} \beta EP_x^{1*} &= 1-\mu_1 \qquad if \qquad I_i^{0*}=0\\ &= 1 \qquad if \qquad 0\leq I_i^{0*}\leq\overline{I}\\ &= 1+\mu_2 \qquad if \qquad I_i^{0*}=\overline{I} \end{aligned}$$

where μ_1 and μ_2 are Lagrangian multipliers for the restrictions that $I_i^{0*}\geq 0$ and $I_i^{0*}\leq\overline{I}$, respectively.

B Proofs

B.1 Proposition 1

Let r denote the optimal share of firm with higher productivity such that $r\equiv\frac{\exp\left(\frac{z}{1-\alpha}\right)}{\exp\left(\frac{z}{1-\alpha}\right)+\exp\left(\frac{-z}{1-\alpha}\right)}$. It is increasing in shock magnitude such that $\frac{\partial r}{\partial z}>0$.

Proof. Let $\exp\left(\frac{z}{1-\alpha}\right)=c$, we have $\frac{\partial c}{\partial z}=\frac{1}{1-\alpha}\exp\left(\frac{z}{1-\alpha}\right)>0$

$$\begin{aligned} r &\equiv \frac{\exp\left(\frac{z}{1-\alpha}\right)}{\exp\left(\frac{z}{1-\alpha}\right)+\exp\left(\frac{-z}{1-\alpha}\right)}=\frac{c}{c+\frac{1}{c}}=\frac{c^2}{c^2+1} \\ &= 1-\frac{1}{c^2+1} \\ \frac{\partial r}{\partial z} &= \frac{2c}{\left(c^2+1\right)^2}>0 \end{aligned}$$

Therefore

$$\frac{\partial r}{\partial z}=\frac{\partial r}{\partial c}\times\frac{\partial c}{\partial z}>0$$

■

B.2 Proposition 2

The gain of reallocation increases in the amount of asset transferred and is higher in expansion, i.e., $\frac{\partial D}{\partial |x|}>0$ and $\frac{\partial D}{\partial z_a}>0$.

Proof. $D^0=\min\left\{\left[\pi\left(k_i^0+x_i^{0*},A_i^0\right)-\pi\left(k_i^0,A_i^0\right)\right]-\left[P_x^{0*}-\beta\left(1-\delta\right)\right]x_1^{0*}\right\}_{i=1}^2$

From $(A3)$ and $(A4)$ and the condition that $k_1^0=k_2^0=2k$

Without loss of generality, assume that $z^0=z>0$, i.e., Firm 1 has the higher idiosyncratic productivity at $t=0$. Therefore

$$\begin{aligned} k+x_1^0 &= 2rk \\ \left(k-x_1^0\right) &= 2\left(1-r\right)k \end{aligned}$$

Since $r\equiv\frac{\exp\left(\frac{z}{1-\alpha}\right)}{\exp\left(\frac{z}{1-\alpha}\right)+\exp\left(\frac{-z}{1-\alpha}\right)}$, we can rewrite $\exp\left(\frac{z}{1-\alpha}\right)+\exp\left(\frac{-z}{1-\alpha}\right)=\frac{\exp\left(\frac{z}{1-\alpha}\right)}{r}$

$$\begin{aligned} D_1^0 &= \exp\left(z_a^0+z\right)\left[(2rk)^\alpha-k^\alpha\right]-\alpha\exp\left(z_a^0+z\right)\left(\frac{1}{2rk}\right)^{1-\alpha}(2rk-k) \\ D_2^0 &= \exp\left(z_a^0-z^0\right)\left[(k)^\alpha-\left(2\left(1-r\right)k\right)^\alpha\right]+\alpha\exp\left(z_a^0+z\right)\left(\frac{1}{2rk}\right)^{1-\alpha}(2rk-k) \end{aligned}$$

First, I prove that $0<D_1^0<D_2^0$. Therefore $D^0=D_1^0$

Then

$$
\begin{aligned}
D^0 &= D_1^0 = \exp\left(z_a^0 + z\right)\left[(2rk)^\alpha - k^\alpha - \alpha\left(\frac{1}{2rk}\right)^{1-\alpha}(2rk-k)\right] \\
&= \exp\left(z_a^0 + z\right)\left[(2rk)^\alpha - k^\alpha - \alpha\,(2rk)^\alpha + \alpha\frac{k^a}{(2r)^{1-\alpha}}\right] \\
&= \exp\left(z_a^0 + z\right)k^\alpha\left[(2r)^\alpha(1-\alpha) - 1 + \frac{\alpha}{(2r)^{1-\alpha}}\right]
\end{aligned}
$$

Therefore

$$
\frac{\partial D^0}{\partial z_a} = \exp\left(z_a^0 + z\right)k\left[(2r)^\alpha(1-\alpha) - 1 + \frac{\alpha}{(2r)^{1-\alpha}}\right] = D^0 > 0
$$

$$
\begin{aligned}
\frac{\partial D^0}{\partial r} &= \exp\left(z_a^0 + z\right)k^\alpha\left[2(1-\alpha)(2r)^{\alpha-1} + 2\alpha\,(2r)^{\alpha-2}\right] > 0 \\
\frac{\partial D^0}{\partial x} &= \frac{\partial D^0}{\partial r}\frac{\partial r}{\partial x} > 0
\end{aligned}
$$

■

B.3 Proposition 3

The cutoff aggregate productivity $\overline{z_a}$ increases in fixed cost and decreases in shock magnitude z.
Proof.

$$
\begin{aligned}
\overline{z_a} &= \ln(f_x) - z - \ln(k^\alpha) - \ln\left[\frac{1}{(2r)^{1-\alpha}} + 2r^\alpha(1-\alpha) - 1\right] \\
\frac{\partial\overline{z_a}}{\partial f_x} &= \frac{1}{f_x} > 0
\end{aligned}
$$

Let $m = \frac{1}{(2r)^{1-\alpha}} + 2r^\alpha(1-\alpha) - 1$

$$
\begin{aligned}
\frac{\partial m}{\partial r} &= (2r)^{\alpha-2}(\alpha-1)\cdot 2 + (1-\alpha)(2r)^{\alpha-1}\cdot 2 \\
&= 2(1-\alpha)(2r)^{\alpha-2}(2r-1) > 0
\end{aligned}
$$

Therefore

$$
\frac{\partial\overline{z_a}}{\partial z} = -1 - \frac{\partial\overline{z_a}}{\partial m}\cdot\frac{\partial m}{\partial r}\cdot\frac{\partial r}{\partial z} < 0
$$

■

B.4 Proposition 4

There exists a unique continuous function V: $K \times Z_I \times Z_A \times \overline{K} \rightarrow R_+$ that solves (2B) and there exists stationary policy functions $I(k_i, z_i; z_a, \overline{k})$ and $x(k_i, z_i; z_a, \overline{k})$

Proof. See Appendix ■

Proof. The maximum allowable capital stock $\overline{k}$ is determined by

$$\begin{aligned} \exp(\overline{z})\pi'(k_{\max}) - \delta &= 0 \\ &\Rightarrow k_{\max} = \left[\frac{\overline{z}\alpha}{\delta}\right]^{\frac{1}{1-\alpha}} \end{aligned}$$

where $\overline{z} = \max(z_a) + \max(z_i)$

Since $k > k_{\max}$ is not economically profit, let

$$K \equiv [0, k_{\max}]$$

By definition, K is compact and non-empty. Therefore,the set for mean of k, $\overline{K}$ is also compact and nonempty.

The production function $\pi(.)$ is continuous and concave such that $\pi' > 0$ and $\pi'' < 0$

$\beta < 1$

Therefore, it satisfies the condition (1) - (3) in Cooper and Russell (2004), and by Theorem 3 in Cooper and Russell (2004), there exists a unique continuous function V: $K \times Z_I \times Z_A \times \overline{K} \rightarrow R_+$ that solves (2B) and there exists stationary policy functions $I(k_i, z_i; z_a, \overline{k})$ and $x(k_i, z_i; z_a, \overline{k})$ ■

C Computation of Approximate Equilibrium

The steps below outline in details my computation strategy for approximate equilibrium:

- Step1

  Guess an initial law of motion H_0 with coefficients $\{a_0, a_1, b_0, b_1\}$ and initial pricing function identified as $\{c_0, c_1, d_0, d_1\}$ Solve problem $(2C)$, for value function $V(k_i, z_i; z_a, \overline{k})$, and decision rules $x(k_i, z_i; z_a, \overline{k})$ and $I(k_i, z_i; z_a, \overline{k})$

- Step 2

  Use value function $V(k, z_i; z_a, \overline{k})$ derived from Step 1 to solve problem $(1D)$ given current price P_x, assuming that future price will evolve based on rules defined in (4) .Derive for value function $\widetilde{V}(k, z_i; z_a, \overline{k}, P_q)$ and decision rules $\widetilde{x}(k_i, z_i; z_a, \overline{k}, P_x)$ and $\widetilde{I}(k_i, z_i; z_a, \overline{k}, P_x)$.

$$\widetilde{V}(k_i, z_i; z_a, \overline{k}, P_x)$$
$$= \max_{\substack{0 \leq I_i \leq \overline{I} \times k_i \\ q_i \geq -k_i}} \pi(k_i + x_i, A_i) - \left[I_i + P_x x_i + \sum_{j \in \{I,,x\}} \Gamma^j (k_i, j_i) + f_x \right] + \beta EV \left(k_i', z_i'; z_a', \overline{k}' | z_i; z_a, \overline{k} \right) \tag{1D}$$

- Step 3

  Fix an initial capacity/idiosyncratic shock distribution for a large number of firms $F^0 = \left\{k_i^0, z_i^0\right\}_{i=1}^N$ and pick an initial aggregate shock level $\left\{z_a^0\right\}$. Find the price level $\left(P_x^0\right)$, at which market clears using decisions rules from Step 2.

  Base on the equilibrium price P_x^0, derive decision rules $x_i^0 = \widetilde{x}(k_i^0, z_i^0; z_a^0, \overline{k}^0, P_x^0)$ and $I_i^0 = \widetilde{I}(k_i^0, z_i^0; z_a^0, \overline{k}^0, P_x^0)$.

  Capacity in the next period $\left\{k_i^1\right\}_{i=1}^N$ can be calculated through $k_i^1 = (1-\delta)\left(k_i^0 + x_i^0\right) + I_i^0$ and aggregate state is identified by $\overline{k}^1 = \sum_{i=1}^N k_i^1 / N$

- Step 4

  Generate idiosyncratic and aggregate shocks for the next period, following AR(1) using $(\rho_a, \sigma_a, \rho_i, \sigma_i)$

  Repeat a large number of times to obtain a time series of price and mean capacity $\left\{P_x^t, \overline{k}^t\right\}_{t=1}^T$

- Step 5

  Use the stable part of the obtained time series to regress $\left\{\log \overline{k}_{t+1}\right\}$ and $\{P_{x,t}\}$ on constants and $\left\{\log \overline{k}_t\right\}$ for each value of z_a to get the realized law of motion $\widehat{H}$ and realized pricing function $\widehat{P_x}$ Compare the *perceived* law of motion H_0 and perceived pricing function P_x^0 with the *realized* law of motion $\widehat{H}$ and realized pricing function $\widehat{P_x}$. If different, use new coefficients $\left(\widehat{a_0}, \widehat{a_1}, \widehat{b_0}, \widehat{b_1}, \widehat{c_0}, \widehat{c_1}, \widehat{d_0}, \widehat{d_1}\right)$ to construct initial guess, return to Step1, and iterate until convergence.[21]

[21] Convergence is achieved if the norm of the difference in coefficients divided by the norm of the initial coefficients is less than 1%, i.e.

$$\frac{\left[(a_0 - \widehat{a_0})^2 + (a_1 - \widehat{a_1})^2 + \left(b_0 - \widehat{b_0}\right)^2 + \left(b_1 - \widehat{b_1}\right)^2\right]^{1/2}}{\left[a_0^2 + a_1^2 + b_0^2 + b_1^2\right]^{1/2}} < 0.01$$
$$\frac{\left[(c_0 - \widehat{c_0})^2 + (c_1 - \widehat{c_1})^2 + \left(d_0 - \widehat{d_0}\right)^2 + \left(d_1 - \widehat{d_1}\right)^2\right]^{1/2}}{\left[c_0^2 + c_1^2 + d_0^2 + d_1^2\right]^{1/2}} < 0.01$$

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Table 1: Parameter Value in Benchmark Simulation

This table reports the parameter value used in benchmark simulation.

Production technology parameter	α	0.50
Discount rate	β	0.90
Depreciation rate	δ	0.10
Aggregate shock persistence	ρ_a	0.75
Idiosyncratic shock persistence	ρ_i	0.75
Aggregate shock W.N. std dev.	σ_a	0.10
Idiosyncratic shock W.N. std dev.	σ_i	0.30
Adjustment cost (investment)	γ_i	0.10
Adjustment cost (acquisition)	γ_x	0.20
Fixed cost for acquisition	f_x	0.20

Table 2: Simulation Results

This table shows simulation results in benchmark model using parameters in Table 1. Standard deviations are reported in parentheses. Panel E presents result of Probit regressions using the simulated panel. The dependent variable is a dummy variable, which take value of 1 if the firm is a buyer on the market for existing assets.

Panel A: Aggregate Investment and Asset Sales

	$z_a = z_a^H$	$z_a = z_a^L$	All
Asset Sales$\left(\frac{X^+}{K}\right)$	4.9%	3.7%	4.3%
	(0.2%)	(0.2%)	(0.7%)
Capital Expenditure$\left(\frac{I}{K}\right)$	11.8%	8.1%	10.0%
	(1.5%)	(1.4%)	(2.4%)

Panel B: Aggregate Investment and Sales (Time Path)

	Asset Sales$\left(\frac{X}{K}\right)$	New Investment$\left(\frac{I}{K}\right)$
$z_a = z_a^H, z_{a,-1} = z_a^H$	4.87%	11.22%
	(0.18%)	(1.02%)
$z_a = z_a^H, z_{a,-1} = z_a^L$	4.98%	13.86%
	(0.16%)	(1.05%)
$z_a = z_a^L, z_{a,-1} = z_a^L$	3.65%	8.71%
	(0.15%)	(0.91%)
$z_a = z_a^L, z_{a,-1} = z_a^H$	3.66%	6.24%
	(0.13%)	(0.86%)

Panel C: Firm Level Asset Sales

	Good Times $\left(z_a = z_a^H\right)$		Bad Times $\left(z_a = z_a^L\right)$	
	$x > 0$	$x < 0$	$x > 0$	$x < 0$
Frequency	0.129	0.131	0.103	0.102
Mean	0.420	−0.270	0.403	−0.258
	(0.292)	(0.181)	(0.283)	(0.182)

Panel D: Size and Productivity of Buyers and Sellers				
	Good Times		Bad Times	
	Buyer	Seller	Buyer	Seller
Size / Mean(size)	1.01	1.35	0.99	1.36
Tobin's q / Mean(Tobin's q)	1.21	0.71	1.22	0.71

Panel E: Firm-Level Merger Intensity Regression			
Dependent Variable: Prob (Buyer)			
	Coef	Z	P(z)
Firm q (q_{it})	0.607	253.1	0.00
Long Run Average q ($\overline{q_i}$)	-0.978	-73.6	0.00
Aggregate State (z_a)	0.130	7.5	0.00
Constant	0.001	0.0	0.99
Pseudo R^2	14%		

Table 3: Sensitivity of Model Moments to Parameters

This table presents model moments when parameters are adjusted with respect to baseline model. The baseline parameters are: $f_x = 0.2$, $\rho_a = 0.75$, $\sigma_a = 0.1$, $\rho_i = 0.75$, $\sigma_i = 0.3$. For each parameter, I simulate the model twice: once with a value of parameter of interest twenty-five percent above and once with a value twenty-five percent below the baseline value. The moments are reported in Panel A and elasticities are reported in Panel B. For each parameter, elasticity is calculated as the change of moments divided by change in underlying parameters and then multiplied by the ratio of baseline structural parameter over baseline moment.

Panel A: Simulated Moments

	Base	f_x		ρ_a		σ_a		ρ_i		σ_i	
		$+\Delta$	$-\Delta$	$+\Delta$	$-\Delta$	$+\Delta$	$-\Delta$	$+\Delta$	$-\Delta$	$+\Delta$	$-\Delta$
$\frac{X}{K}$ $(z_a = H)$	4.9%	3.7%	6.5%	5.1%	4.8%	5.1%	4.9%	2.6%	5.1%	7.9%	2.1%
$\frac{X}{K}$ $(z_a = L)$	3.7%	2.9%	5.3%	3.6%	3.7%	3.5%	3.7%	2.0%	3.7%	6.4%	1.4%
$\frac{I}{K}$ $(z_a = H)$	11.8%	11.7%	12.3%	12.0%	11.4%	12.2%	11.8%	11.8%	11.8%	11.7%	11.8%
$\frac{I}{K}$ $(z_a = L)$	8.1%	8.7%	8.1%	8.1%	8.6%	7.8%	8.1%	8.3%	7.7%	8.4%	8.2%
Freq $(x > 0, H)$	13.1%	12.1%	18.8%	15.4%	12.9%	13.0%	12.9%	10.3%	14.6%	17.0%	8.8%
Freq $(x > 0, L)$	10.0%	7.6%	17.3%	10.5%	9.7%	10.1%	10.3%	7.1%	9.7%	14.0%	5.3%
$E(x \mid x > 0)$	42%	38%	36%	36%	42%	42%	42%	31%	38%	47%	31%
$E(x \mid x < 0)$	−27%	−25%	−20%	−28%	−27%	−27%	−27%	−15%	−26%	−24%	−21%
$E(k/\overline{k} \mid x > 0)$	1.01	1.00	1.09	1.22	1.00	1.02	1.01	1.05	1.01	1.11	0.95
$E(k/\overline{k} \mid x < 0)$	1.34	1.34	1.12	1.51	1.34	1.32	1.35	1.21	1.23	1.19	1.25
$E(v/\overline{v} \mid x > 0)$	1.20	1.24	1.13	1.38	1.21	1.20	1.21	1.26	1.18	1.19	1.22
$E(v/\overline{v} \mid x < 0)$	0.71	0.73	0.83	0.86	0.71	0.72	0.71	0.75	0.78	0.81	0.77

Panel B: Elasticity

	f_x	ρ_a	σ_a	ρ_i	σ_i
$\frac{X}{K}$ $(z_a = H)$	−0.57	−1.01	2.39	0.11	0.09
$\frac{X}{K}$ $(z_a = L)$	−0.65	−0.93	2.73	−0.03	−0.10
$\frac{I}{K}$ $(z_a = H)$	−0.05	−0.01	−0.03	0.10	0.06
$\frac{I}{K}$ $(z_a = L)$	0.07	0.15	0.03	−0.13	−0.07
Freq $(x > 0, z_a = H)$	−0.52	−0.67	1.26	0.43	0.20
Freq $(x > 0, z_a = L)$	−1.00	−0.20	2.25	0.14	0.07
$E(x \mid x > 0)$	0.05	−0.32	0.77	−0.30	−0.10
$E(x \mid x < 0)$	0.18	−0.82	0.22	0.04	0.04
$E(k/\overline{k} \mid x > 0)$	−0.09	0.08	0.31	0.48	0.05
$E(k/\overline{k} \mid x < 0)$	0.17	−0.02	−0.10	0.26	−0.02
$E(v/\overline{v} \mid x > 0)$	0.09	0.13	−0.05	0.28	−0.03
$E(v/\overline{v} \mid x < 0)$	−0.13	−0.10	0.10	0.41	0.01

Table 4: Robustness Check

This table shows the related moments when several assumptions are relaxed. Column 1 shows baseline moments. Column 2 shows moments when the cap for maximum new investments available is set to be equal to 0.4. Column 3 shows moments when the adjustment cost parameter for investments is raised to 0.2. The baseline parameters are: $f_x = 0.2$, $\rho_a = 0.75$, $\sigma_a = 0.1$, $\rho_i = 0.75$, $\sigma_i = 0.3$, $\overline{I} = 0.2$, $\gamma_I = 0.1$, $\gamma_x = 0.2$.

	Baseline (1)	$\overline{I} = 0.4$ (2)	$\gamma_I = 0.2$ (3)
$\frac{X}{K}\,(z_a = H)$	4.9%	4.2%	5.0%
$\frac{X}{K}\,(z_a = L)$	3.7%	3.6%	3.7%
$\frac{I}{K}\,(z_a = H)$	11.8%	12.7%	11.8%
$\frac{I}{K}\,(z_a = L)$	8.1%	7.6%	7.9%
Freq $(x > 0, z_a = H)$	13.1%	12.1%	13.2%
Freq $(x > 0, z_a = L)$	10.0%	8.8%	10.1%
$E(x \mid x > 0)$	42%	37%	42%
$E(x \mid x < 0)$	−27%	−24%	−27%
$E(k/\overline{k} \mid x > 0)$	1.01	1.14	1.03
$E(k/\overline{k} \mid x < 0)$	1.34	1.33	1.34
$E(v/\overline{v} \mid x > 0)$	1.20	1.19	1.20
$E(v/\overline{v} \mid x < 0)$	0.71	0.75	0.72

Table 5: Calibration Results

Panel A: Pre-chosen Parameters		
Production technology parameter	α	0.592[a]
Discount rate	β	0.935[b]
Depreciation rate	δ	0.12[b]
Aggregate shock persistence	ρ_a	0.889[a]
Aggregate shock W.N. std dev.	σ_a	0.08[a]
Idiosyncratic shock persistence	ρ_i	XXX[c]
Idiosyncratic shock W.N. std dev.	σ_i	XXX[c]

[a] Haltiwanger and Cooper (2003); [b] Gomes (2001); [c] estimated from LRD

Panel B: Target Statistics and Calibrated Parameters			
Target Statistics		Calibrated Parameters	
Mean Asset Sales Rate (Expansion)	XXX	Adj. cost (investment)	γ_i
Mean Asset Sales Rate (Recession)	XXX	Adj. cost (acquisition)	γ_x
Mean Investment Rate (Expansion)	XXX	Fixed cost for acquisition	f_x
Mean Investment Rate (Recession)			

Table 6: Summary Statistics for Industry-Level Shock Persistence and Volatility

This table describes the summary statistics for estimated shock persistence (ρ) and volatility (σ) in each group, based on 112 industries on 3-digit SIC level. Groups are formed such that High-group consists observations in the top 33 percentile; Low-group consists of observations in the bottom 33 percentile and Medium-group consists of observations in between.

Summary Statistics on Shock Persistence (ρ)					
Group	Mean	Median	Std. Dev.	Min	Max
Low					
Medium					
High					
Total					

Summary Statistics on Shock Volatility (σ)					
Group	Mean	Median	Std. Dev.	Min	Max
Low					
Medium					
High					
Total					

Table 7: Shock Persistence, Volatility and Asset Sales

This table reports the test results for comparing average assets sales between High- and Low-ρ industries and between High- and Low-σ industries, respectively. Groups are formed such that High-group consists observations in the top 33 percentile; Low-group consists of observations in the bottom 33 percentile and Medium-group consists of observations in between. p-values are reported in parentheses. For each year, asset sales rate is measured as the number of plants that change ownership divided by total number of plants in that year.

Panel A: Shock Persistence and Asset Sales			
	# of Obs	Mean	Std. Dev.
Low - ρ			
High - ρ			
T Test			
Signed Rank Test			
Likelihood Ratio Chi-Square			
Spearman Correlation			
Kendall's Tau			

Panel B: Shock Volatility and Asset Sales	
	# of Obs
Low - σ	
High- σ	
T Test	
Signed Rank Test	
Likelihood Ratio Chi-Square	
Spearman Correlation	
Kendall's Tau	

Table 8: Regression Results on Average Asset Sales

This table reports the regression results on asset sales. The dependent variable is the percentage of average industry level of asset sales. For each year, asset sales rate is measured as the number of plants that change ownership divided by total number of plants in that year. ρ and σ are estimated shock persistence and volatility, respectively. CAPX is the average capital expenditure ratio. ATTURN is the average asset turn over rate, which measures total sales over total assets. OPMARG is the average operational margin, measured as a ratio of earnings over sales. ECON measures the ratio of expansion years over the total years in the sample. I define a year as expansion year if it has sales growth. T-stats are reported in parentheses and *, **, *** represent significance level of 10%, 5% and 1%, respectively.

	(1)	(2)	(3)
ρ			
σ			
CAPX			
ATTURN			
OPMARG			
ECON			
CONS			
# of Obs			
Adj. R^2			

Table 9: Persistence, Volatility and Industry Fixed Effect of Asset Sales

This table reports effect of persistence and volatility of idiosyncratic shocks on industry fixed effects of asset sales. Panel A shows results in a fixed effect regression with the specification: $s_{jt} = \alpha_j + \beta \cdot X_{jt} + \varepsilon_{jt}$, where s_{jt} is the percentage of asset sales of industry j from time t to $t+1$ and X_{jt} includes characteristics of industry j at time t. For each year, asset sales rate is measured as the number of plants that change ownership divided by total number of plants in that year. CAPX is the capital expenditure ratio. ATTURN is the asset turn over rate, which measures total sales over total assets. OPMARG is the operational margin, measured as a ratio of earnings over sales. D_ECON is dummy variable measuring economic condition in the industry, which equals to 1 when the change in total sales from $t-1$ to t is positive and zero otherwise. HERF is the Herfindahl Index based on asset sizes. MPCT is the percentage of plants in the industry that are owned by multi-segment firms. Panel B reports the results of regression such that $\widehat{\alpha_j} = \beta_0 + \beta_1 \cdot \rho_j + \beta_2 \cdot \sigma_j + \varepsilon_j$, where $\left(\rho_j, \sigma_j\right)$ are estimated persistence and volatility of idiosyncratic shocks and $\widehat{\alpha_j}$ is the estimated fixed effects from Panel A. T-stats are reported in parentheses and *, **, *** represent significance level of 10%, 5% and 1%, respectively.

Panel A: Fixed Effect Regression
Dependent Variable: Pct. of Asset Sales
CAPX
ATTURN
D_ECON
HERF
OPMARG
MPCT
CONS
Obs
R^2 (within)
R^2 (between)
R^2 (overall)
F (all $\alpha_i = 0$)

Panel B: Shock Persistence, Volatility and Fixed Effects	
Dependent Variable: Industry Fixed Effects of Asset Sales	
ρ	***
σ	***
CONS	
# Obs	
R^2	

Table 10: Persistence, Volatility and Asset Sales

This table reports effect of persistence and volatility of idiosyncratic shocks on asset sales in an OLS regression with the following specification: $s_{jt} = \beta_0 + \beta_1 \rho_j + \beta_2 \sigma_j + \beta_3 \cdot X_{jt} + \varepsilon_{jt}$, where s_{jt} is the percentage of asset sales of industry j from time t to $t+1$; (ρ_j, σ_j) are estimated persistence and volatility of idiosyncratic shocks of industry j and X_{jt} includes characteristics of industry j at time t. For each year, asset sales rate is measured as the number of plants that change ownership divided by total number of plants in that year. CAPX is the capital expenditure ratio. ATTURN is the asset turn over rate, which measures total sales over total assets. OPMARG is the operational margin, measured as a ratio of earnings over sales. D_ECON is dummy variable measuring economic condition in the industry, which equals to 1 when the change in total sales from $t-1$ to t is positive and zero otherwise. HERF is the Herfindahl Index based on asset sizes. MPCT is the percentage of plants in the industry that are owned by multi-segment firms. T-stats are reported in parentheses and *, **, *** represent significance level of 10%, 5% and 1%, respectively.

Dependent Variable: Pct. of Asset Sales			
	(1)	(2)	(3)
ρ			
σ			
CAPX			
ATTURN			
D_ECON			
HERF			
OPMARG			
MPCT			
CONS			
R^2			

Figure 1a: Persistence, Shock Magnitude and Asset Sales

This figure shows the relationship between persistence, shock magnitude and asset sales in both periods based on the two-firm three-period example. For each sub-panel, the amount of asset sales at t=0 and expected amount of asset sales at t=1 are plotted given shock magnitude zi and a grid points of persistence level (ρ_i) The parameters used for simulation are: $z_a = 0.1$, $k_1^0 = k_1^0 = 3.25$, $f_x = 0.05$, $\delta = 0.1$, $\beta = 0.9$, $\alpha = 0.5$. The shock magnitude used for sub-panels are $(0.1, 0.2, 0.3, 0.4)$ respectively.

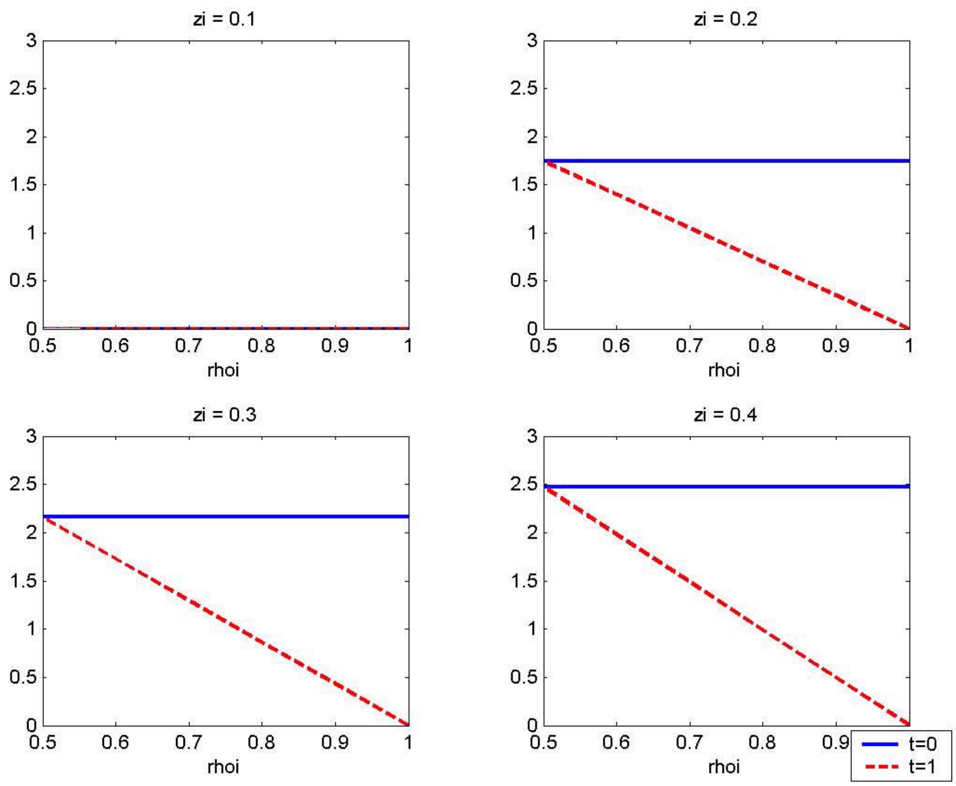


Figure 1b: Fixed Cost, Aggregate State and Asset Sales

This figure shows the relationship between fixed cost and the amount of asset sales based on the two-firm three-period example. The amount of asset sales at t=0 is plotted given aggregate state z_a and a grid points of fixed costs. The parameters used for simulation are: $z_i = 0.3$, $k_1^0 = k_1^0 = 3.25$, $\delta = 0.1$, $\beta = 0.9$, $\alpha = 0.5$. The aggregate shocks used for this plot are $(-0.1, 0.1)$.

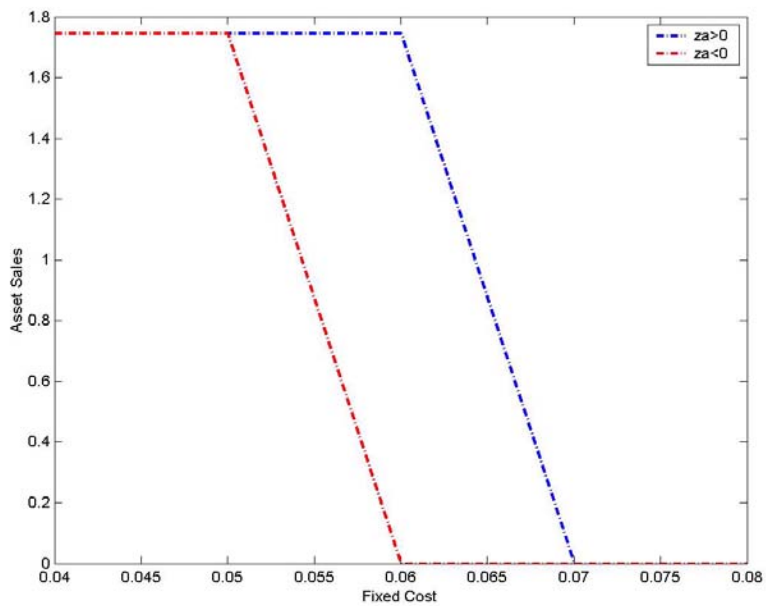


Figure 2a: Predicted Law of Motion for Mean Capacity

This figure plots the log of next period's mean capacity against the log of this period's mean capacity using simulated data based on benchmark model. The line shows the predicted law of motion and the scatter plot shows the realized law of motion as implied by value function.

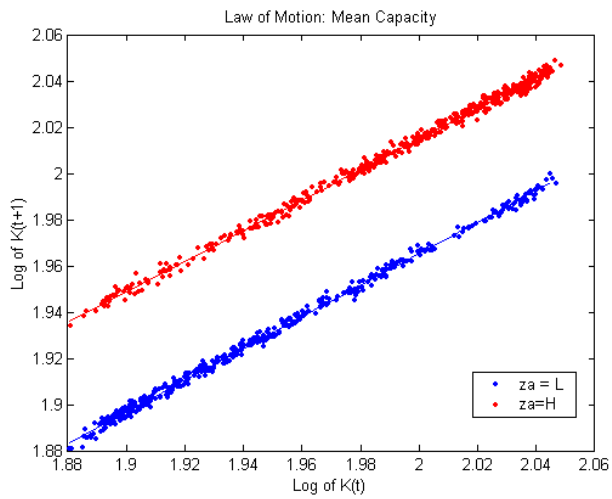


Figure 2b: Predicted Price Function

This figure plots the price of existing asset against the log of current mean capacity using simulated data based on benchmark model.The line shows the predicted price equation and the scatter plot shows the realized price from market clearing condition.

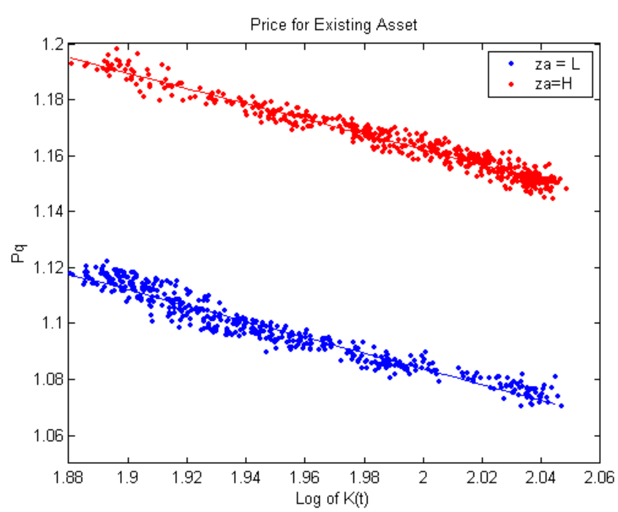
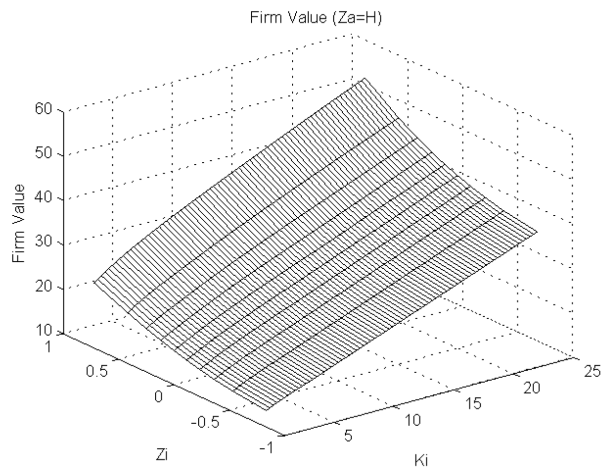


Figure 3: Firm's Value Function

This figure plots out value function $V(k_i, z_i; z_a, \overline{k})$ based on size (k_i), idiosyncratic shocks (z_i) and aggregate shocks (z_a). For this figure $\overline{k}$ is set to be 7.85 for both cases.

Expansion $\left(z_a = z_a^H > 0\right)$



Recession $\left(z_a = z_a^L < 0\right)$

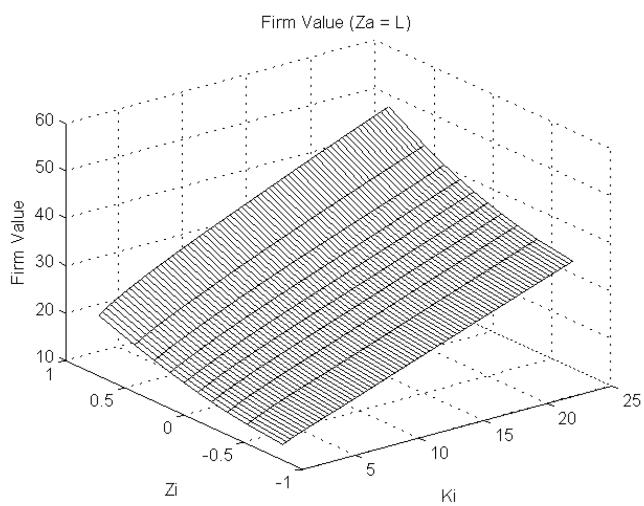


Figure 4: Optimal Decision Rule on Asset Transfer

This figure illustrates firm's optimal decision rule on asset transfer given current capacity (k) and idiosyncratic shock (z_i) derived from value function in ($2C$). Four sub-panels represent firms in different size quartile. For each sub-panel, idiosyncratic shocks are plotted on X-axis and ratio of asset transfer, which equals to the amount transferred divided by beginning capacity, is plotted on Y-axis. The vertical lines illustrate the range of expected idiosyncratic shocks given beginning capacity.

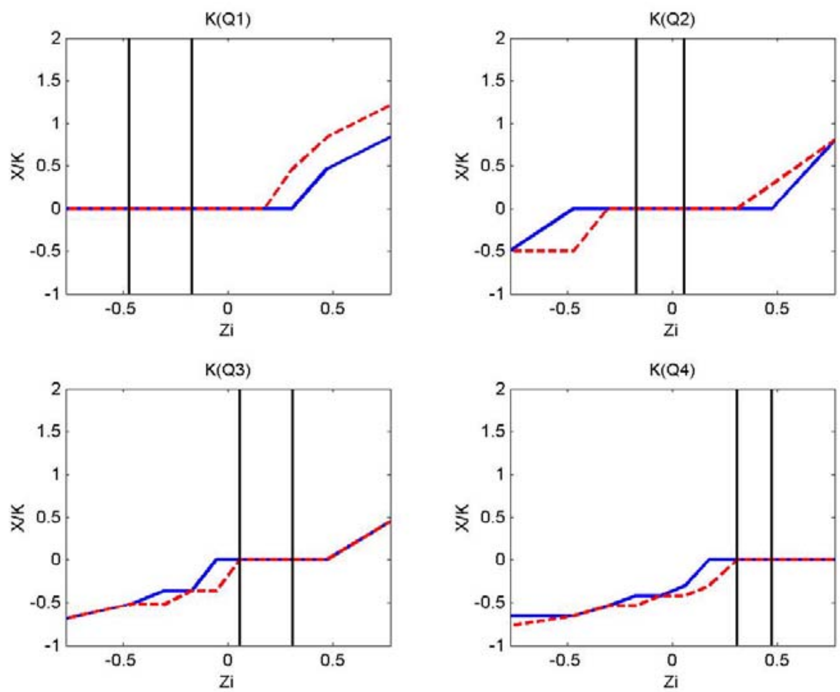
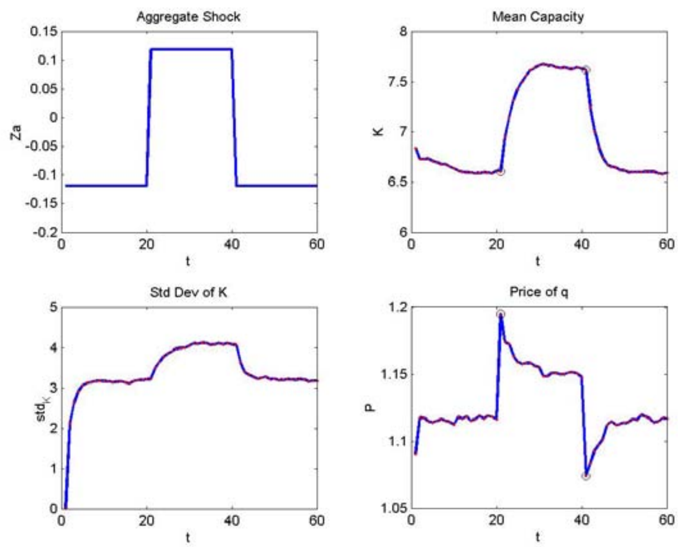


Figure 5: Dynamics of Aggregate Capacity and Price of Asset

This figure illustrates the dynamics of industry structure on a time path with aggregate shocks specified in (6) using simulated data with 5000 firms. Panel A describes the aggregate shock and industry structure. Sub-panel (1,1) illustrates the time series of aggregate shocks. Sub-panel (1,2) and (2,1) show the time series of the average and standard deviation of capacity, respectively. Sub-panel (2,2) describes the asset prices. Panel B shows the aggregate asset sales on this time path.

Panel A: Industry Structure



Panel B: Aggregate Asset Sales