The Role of Establishment Heterogeneity in Sudden Stops

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Abstract

The 1997-1998 Asian crisis countries experienced drastic collapses of macroeconomic aggregates followed by highly persistent underperformance of economies relative to their pre-crises periods. In this paper, we introduce establishment level heterogeneity in a model with endogenous entry which can explain the transition dynamics of the number of establishments across sizes following the sudden stop in Korea, the larger the size, the slower the recovery for the number of establishments. The model suggests that the transition dynamics of the establishment composition can explain both drastic short run declines, and medium run underperformance of the macroeconomic aggregates.

JEL classifications: E13, E32, F41, F44.
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1. Introduction

The Asian crisis in 1997-1998 is associated with a drastic collapse followed by highly persistent underperformance of an economy relative to its pre-crises period. For instance, following the sudden stop in Korea, per capita GDP fell by 7.8 percent, consumption by 15.5 percent, investment by 26.8 percent and employment by 6.9 percent in 1998. Although Korean economy started to recover from 1999 and stabilized in several years, the macroeconomic aggregates are still far below from their pre-crisis trends. If we use a linear trend of Korean GDP with its pre-crisis period from 1980 to 1996, GDP in 2008 is 46.2 percent below from the trend. Even if we use a quadratic trend to take into account the developing stage of the economy, GDP in 2008 is still 32.3 percent below from its quadratic trend. Other Asian crisis countries, e.g., Indonesia, Malaysia and Thailand, also have similar patterns for the transition dynamics followed by the Asian crisis.

One important feature of the Asian crisis, at least for Korea, is that there have been drastic changes in the composition of establishments.[1] During the crisis in Korea, the number of establishments with 5 and more employees in the manufacturing sector fell by 18.3 percent in 1998 relative to that in 1996. The number of establishments started to rise from 1999 and it became stabilized in about 5 years. However, the recovery has been highly asymmetric across establishment sizes. Most of the recovery is from the increase in the number of small size establishments not from the large ones.[2] Although the total number of establishments in 2008 is 2.3 percent higher than that in 1996, the numbers with 100-499 employees and 500 and more employees in 2008 are still 9.4 and 53.3 percent less than those in 1996, respectively.

We can decompose 18.3 percent drop of the number of establishments with 5 and more employees into three components: i) the change in the overall number of establishments, ii) the overall shift of the size distribution (the change in the average size of employments), and iii) the change in the shape of the size distribution (compositional change). The establishment

[1] Our analysis on the establishment level heterogeneity is limited to Korean case since only Korean establishment level data are available.

[2] This argument also holds even if we take into account the relatively low employment levels during the post-crisis periods by rescaling the average size of establishments to match that in 1996.

data in Korea suggest that this 18.3 percent short run drop of the number of establishments with 5 and more employees can be decomposed into 10.6 percent drop from the change in the overall number of establishments across all sizes, and additional 7.7 percent drop from the shift of the overall size distribution. There were no significant compositional changes in the size distribution once we rescale the average employment size in 1998 to match that in the pre-crisis period. From the following period from the shock, however, the size distribution has changed due to more number of small size establishments and less number of large establishments.

In this paper, we introduce this dynamic feature of the establishment composition in Korea with an otherwise a standard small open economy model to examine the importance of the establishment level heterogeneity in the aftermath of the Asian crisis. We show that this new component can explain not just the short run response of the economy with a sudden stop but also the medium run responses. When the sudden stop is modeled as 3.9 percentage points rise of the interest rate charged by foreign lenders, without any changes in the composition of establishments, output drops only by 1.8 percent and the economy recovers almost fully in 30 years. Thus the standard model underpredicts the magnitudes of the short run response and over-predicts the speed of recovery. However, when we introduce the dynamics of the establishment level composition with 10 percent initial exogenous shutdown across all sizes in a model with endogenous entry of producers, the sudden stop creates output drop by 8.9 percent in the short run. Even after 30 years from the shock output is still 3.3 percent below from the steady state, and it recovers very slowly toward the steady state taking more that 250 years to be close to the steady state. Consumption, investment, and employment have similar transition dynamics qualitatively.

The evolution of establishments is the key reason for the results. Establishments typically start out small relative to incumbents and they grow over time. Furthermore, small establishments face greater probability to shut down compared to large ones. As the sudden stop in Korea destroyed not just small establishments but also large ones, the initial impact of the sudden stop was greatly magnified due to the fall in the number of establishments across all sizes. After the shock, the economy starts to recover from the recession and more producers are created. However, these entrants are relatively small, and it takes many years for them to fully grow on average. In the model we can decompose the total factor productivity (TFP) measured as Solow residual into the number of producers and the (general) mean of the productivity across producers.[3] Thus, the fall in the number of producers in the short run creates drastic drops in the TFP and other macroeconomic aggregates. In the medium run, although the total number of producers is recovered to its pre-crisis level, the mean of productivity is still below from its steady state level as the distribution is more skewed to the right due to asymmetric recovery across sizes. This drives underperformance of the economy in the medium run. The mean of productivity is highly persistent since it takes many years for entrants to fully develop. Thus, in the longer run, the number of establishments is below from its steady state level because of underperformance of the economy which comes from low levels of mean of productivity. In other words, in the longer run, persistent underperformance of the economy is governed by the persistence of the mean productivity which comes from the persistence of the productivity process.

In the model without changes in the composition of producers, the TFP does not change at all, and the output per worker initially rises by 0.7 percent due to the fall in labor and slow adjustment of capital. In the model with the changes in the composition of producers, the TFP and the output per worker fall by 2.6 and 2.8 percent, respectively, upon the impact of the sudden stop. After 30 years from the shock, they are still 0.6 and 1.2 percent below from their steady state levels, respectively, and converge to their steady state levels extremely slowly. This low level of productivity in the medium run is from the low level (general) mean of productivity by -0.7 percent even though of the number of producers is 0.4 percent above its steady state level. Thus the dynamics in the composition of producers provide a resolution to both the large decline in the output and the persistently underperforming economies after sudden stops.

[3] The general mean of productivity is based on the elasticity of substitution parameter in the model.

We extend the model with fixed costs in exporting to examine the role of extensive margins of exports during the sudden stop period. We find that the extensive margins have minimal effects on the performance of the economy with the sudden stop shocks. Although the number of exporters rises by 5.4 percent even with 10 percent shutdown of highly productive exporters, the highly productive previous exporters that shut down at the time of the sudden stop shock are replaced by relatively less productive previous non-exporters. Thus, there are not much effects on the overall exports from the extensive margin compared to the case where all producers export. This results in a very small role of the extensive margin on the economy during the sudden stops.

This paper is related to three lines of research. First, there have been many papers evaluating the aggregate consequences of sudden stops. Chari, Kehoe and McGrattan (2005) find that even though a standard model can explain the trade balance reversal following a sudden stop, the model with standard preferences generates a rise in output not a decline as in the data. Kehoe and Ruhl (2009) use a two sector model for Mexico's 1994-1995 crisis, and find that the sectoral reallocation of resources following the crisis cannot explain the decreases in GDP and TFP. Including labor friction and variable capital utilization does not help the performance of the model in explaining the falls in GDP and TFP. Unlike the results of Kehoe and Ruhl (2009) for Mexico's crisis in 1994-1995, Benjamin and Meza (2009) find that there was labor reallocation from productive manufacturing and construction sectors to less productive whole sale trades, public and agriculture sectors following Korean crisis 1997-1998. This resource reallocation can explain about 42 percent of the (Hodrick-Prescott filtered) TFP drops during the sudden stop in Korea.[4] Some research work directly applies the exogenous time paths of the TFP in a small open economy model and find that the dynamics of TFP are key for the responses of the macroeconomic aggregates following a sudden stop, e.g., Otsu (2008) and Meza and Quintin (2007).[5] Cook and Devereux (2006) and Gertler,

[4] Benjamin and Meza (2009) also use the variable capital utilization and working capital for wage bill and material input payments.

[5] Otsu (2008) applies an exogenous TFP process to explain the dynamics of the economy with a sudden stop. Meza and Quintin (2007) use an exogenous TFP together with variable capital utilization and labor

Gilchrist, and Natalucci (2007) use stick price models to explain the short run responses of macroeconomic aggregates following sudden stops.[6] Second, there is a closed economy literature that studies entry and exit of establishments over the business cycle. Cook (2001), Jaimovich (2007) and Jaimovich and Floetotto (2008) study the role of the entry and exit of establishments on the aggregate fluctuations but abstract from producer level heterogeneity. Lee and Mukoyama (2008) and Samaniego (2008) consider the business cycle properties in models with the producer level heterogeneity but abstract from international trades. The third line of research studies how the plant level heterogeneity influences the fluctuation of the aggregates in an open economy. Alessandria and Choi (2007, 2008), Cook (2002), Ghironi and Melitz (2005, 2007) study the international transmission of business cycles in two country models with heterogeneous producers. The Gopinath and Neiman (2011) studies the role of producer level heterogeneity in the composition of intermediate inputs on the TFP during the Argentina's crisis. They find that there are significant variations in the composition for the intermediate inputs imported by producers during the Argentine crisis. When the input costs and heterogeneity across producers are correctly measured, the variations of the composition can explain the TFP decline during the sudden stop in Argentina.

The paper is organized as follows. The next section discusses the behavior of macroeconomic aggregates and the key features of the establishment level dynamics in Korean manufacturing sector following the Asian crises. Section 3 develops a small open economy model with producer level heterogeneity. Section 4 discusses the quantitative results. Section 5 concludes.

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hoarding. They find that variable capital utilization and labor hoarding have amplification effects on the measured TFP (Solow residual) and the output.

[6] Cook and Devereux (2006) find that a sticky local currency pricing model with regional trades across Asian economies can explain the short run responses of the macroeconomic aggregates in Asian economies with sudden stops. Gertler, Gilchrist and Natalucci (2007) find that the financial accelerator significantly amplifies the effects of the interest rate shocks under the fixed exchange rate regime.

2. Data

Our analysis focuses on the aftermath of sudden stops in Asian economics in the late 1990s. Figure 1 show the time paths of the key macroeconomic variables in four Asian countries with the sudden stops, Indonesia, Korea, Malaysia, and Thailand. All data are in per capita and normalized with 1997 values after taking logarithm except for the trade balance to GDP ratio, for which it indicates level differences. All these countries experienced crises from 1997, but the major responses occurred in the following year. As shown in Figure 1 and Table 2, all these economies experienced drastic drops in GDP, consumption, investment and employment following the sudden stops. GDP dropped by $7.8 - 14.1$ percent, consumption by $6.4 - 15.5$ percent, and investment by $26.8 - 59.2$ percent. Employment dropped in Korea and Thailand by 6.9 and 5.2 percent, respectively, whereas it rose by 2.6 and 0.4 percent in Indonesia and Malaysia, respectively. These falls in the macroeconomic aggregates are even more drastic when we compare them with the growth rates in their pre-crisis periods. All these countries also experience the trade reversal following the sudden stops. The trade to GDP ratio rose by $10.0 - 21.1$ percentage points in 1998 in these countries.

Although all the variables are stabilized in about 5 years from the crises in terms of the growth rates, the data exhibit structural break like behaviors. Focusing on Korean economy, Figure 2 shows the data with linear and quadratic trends using pre-crisis periods, $1980 - 1996$. As shown in the panel, all the variables are far below from their trends. GDP per capita in 2008 is 46.2 and 32.3 percent below from its linear and quadratic trends. Consumption, investment, and employment all exhibit highly persistent underperformance following the crisis. Other countries also show that the macroeconomic aggregates have been persistently underperforming after the recovery from the crisis.

Figure 3 shows the labor productivity of four countries together with their linear and quadratic trends. With linear trends, the output per worker in Indonesia, Korea, Malaysia and Thailand are 5.3, 33.1, 4.7 and 54.2 percent below from their trends in 2008, respectively.[7]

[7] Malaysian data are for 2007.

With quadratic trends, they are 127.0, 2.5, 77.6, and 151.9 percent below from their trends, respectively.[8] Again, labor productivity data suggest that there are structural breaks like behavior following the sudden stops in these economies.

One interesting feature in Korea during the sudden stop periods is that there were drastic changes in the composition of establishments. Figure 4 shows the number of establishments in Korean manufacturing sector. In 1998, the number of establishments fell by 10.6 percent in 2 years from the sudden stop. This huge drop came from 18.3 percent drop for the establishments with 5 and more employees, and 7.0 percent drop for the establishments with less than 5 employees. This large drop for the 5+ employee establishments occurred across all sizes. Panel (B) in Figure 4 shows the numbers of establishments in several size bins. For all size bins except the sizes of 500 and more employees, the falls in the number of establishments were about the same as the overall drop, For establishments with 500 and more employees, the number dropped 5.9 percentage points more than the number for establishments with 5 and more employees. This large drop in the number of establishments with 5 and more employees comes from three components: i) the change in the overall number of establishments; ii) the overall shift of the size distribution; and iii) the change in the shape of the size distribution (compositional change),

$$(1) \quad \frac{N_t \Phi_t (z \geq z_{5t})}{N_{t-1} \Phi_{t-1} (z \geq z_{5t-1})} = \left(\frac{N_t}{N_{t-1}} \right) \left[\frac{\Phi_{t-1} (z \geq z_{5t})}{\Phi_{t-1} (z \geq z_{5t-1})} \right] \left[\frac{\Phi_t (z \geq z_{5t})}{\Phi_{t-1} (z \geq z_{5t})} \right],$$

where N_t is the total number of producers in period t, $\Phi_t (z \geq z_{5t})$ is the cumulative distribution function of the productivity in period t, and z_{5t} be the productivity of a producer which employees 5 workers in period t. To get a rough measure of these three components, we rescale the employment sizes in 1998 and 2008 so that the average sizes of establishments in these years are the same as that in 1996. Figure 5 shows the size distributions in 1996,

[8] Besides Korea, the quadratic trends for output per worker are estimated to be convex. This convexity creates even bigger deviation from their trends for output per worker. Since we have only 17 year data for pre-crisis periods and 11 year data for post-crisis periods, we do not attempt to estimate other trends that may better describe the general transitions of the developing economies.

1998, and 2008. We can clearly see that when the sudden stop shock hits the economy, the size distribution in 1998 is shifted leftward from that in 1996, and the gap between these two distributions is increasing in size. Interestingly, after rescaling the average size for 1998 data, the rescaled distribution lies almost on top of the one in 1996. This suggests that there are no significant changes in the shape of the size distribution (compositional changes) in 1998.[9] This implies that across all sizes, 10.6 percent of establishments shut down upon the impact of the sudden stop shock. Thus, 18.3 percent drop in the number of establishments with 5 and more employees comes from the 10.6 percent drop in the overall number of the establishments, and additional 7.7 percent drop from the overall shift of the overall size distribution. From the following period, however, there have been changes in the shape of the size distribution. In 2008, 11 years from the crisis, although the total number of small size establishments is greater than that in the pre-crisis period, the number of large establishments is still far below from its pre-crisis levels. The number of establishments with less than 100 employees is 2.6 percent higher than that in 1996, whereas the numbers with 100-499 and 500+ employees are 9.4 and 53.3 percent lower than their levels in 1996, respectively. These changes in the composition of establishments can be seen in Figure 5. Even if we scale up the size distribution in 2008 to match the average size of establishment in 1996, there are still less mass of productive establishments and more mass of unproductive establishments compared to the size distribution in 1996.

The changes in the number of establishments and the composition have significant implication for the total factor productivity of the economy. In the models with establishment heterogeneity, we usually find a very close relationship between the composition of establishments and the total factor productivity measured as the Solow residual. Let's assume that each establishment in a monopolistically competitive market has its Cobb-Douglas production

[9] Many models with producer level heterogeneity and CES aggregates predict that the employment level of a producer is proportional to its elasticity adjusted productivity level. Thus, we use the size distribution for the employment level in logarithm as a proxy for the productivity distribution.

function with the capital share parameter α,

$$(2) \quad y_i = a_i k_i^{\alpha} l_i^{1-\alpha},$$

where y_i is the output of establishment i, a_i is the productivity, and k_i and l_i are capital and labor hired for production with the rental rate of capital R and wage rate W from the perfectly competitive markets. Let's further assume that demand for each good is derived from a constant price elasticity,

$$(3) \quad y_i = \left(\frac{p_i}{P}\right)^{-\theta} D,$$

where p_i is the price of good i, P is the aggregate price index based on a CES function $P = \left(\int_i p_i^{1-\theta} di\right)^{\frac{1}{1-\theta}}$, D is the aggregate demand, and θ is the elasticity. Then, from the profit maximization problem of a producer, we can obtain the aggregate real output function of the economy in terms of aggregate capital $K = \int_i k_i di$ and aggregate labor $L = \int_i l_i di$ as

$$(4) \quad \begin{aligned} Y &= \frac{\int_i p_i y_i di}{P} \\ &= N^{\frac{1}{\theta-1}} \overline{\Psi} K^{\alpha} L^{1-\alpha}, \end{aligned}$$

where $N = \int_i 1di$ is the mass of producers, and $\overline{\Psi} = \left(\frac{1}{N}\int a_i^{\theta-1} di\right)^{\frac{1}{\theta-1}}$ is the CES parameter based (general) mean productivity of producers in the economy. Thus, the total factor productivity for the aggregate economy can be decomposed into the mass of producers, $N^{\frac{1}{\theta-1}}$, and the mean productivity, $\overline{\Psi}$. The size distributions in Figure 5 suggest that in 1998, the total factor productivity fell because of a fall in N, but not because of a change in $\overline{\Psi}$. However, the rescaled size distribution in 2008 suggests that the average productivity, $\overline{\Psi}$, is lower than its pre-crisis level. Thus the TFP in medium run can still be lower than its pre-crisis level if the rise in N is offset by the fall in $\overline{\Psi}$.[10] Figure 6 shows the growth rates of TFP and the

[10] In the simulation exercises, we have this feature in the model for the medium run: the TFP is less than

number of producers in Korean manufacturing sector.[11] The data show that the number of establishments is closely related to the total factor productivity. Both data drop drastically when the sudden stop hits the economy, recover from 1999, and slow down from 2000. The correlation between these two growth series between 1994 and 2008 is 0.79.[12] Thus, the data support the model prediction that the composition of establishments is an important factor for the dynamics of the productivity and the macroeconomic aggregates of an economy.

3. The Model

This section presents the small open economy model with heterogeneous producers that underlies our quantitative analysis. In the small open economy, the representative household consumes, works, accumulates capital, and trades one-period non-state contingent bonds with the rest of the world (foreign country). The bond pays one unit of foreign final good next period. There are many heterogeneous producers in the economy. They are differentiated in terms of goods, and technology. The producers hire capital and labor to produce goods under the constant returns to scale technology. In each period, some producers shut down and new ones are created. The survival rate of a producer, $n_s(z)$, is exogenous and increasing in the individual productivity level, z. To create an establishment, the fixed cost of f_e, measured in domestic labor units, should be paid. The entrants can start producing and selling their products in the home and foreign markets from the following period. We normalize the home and the rest-of world aggregate price levels to 1, $P_t = P_t^* = 1$.

its steady state level in the medium run because of low $\overline{\Psi}$, even though N is higher than its steady state level.

[11] The TFP is computed as the Solow residual using the Cobb-Douglas production function with the capital share parameter of 0.4. Unfortunately, we do not have the mean productivity of establishments in Korea as we do not have the detailed establishment level date for Korea to construct the productivity level of each establishment.

[12] If we drop 3 year observations, 1997-1999, for the drastic fall and recovery periods, the correlation becomes 0.44.

A. Household

The infinitely lived representative household in the small open economy has the expected lifetime utility based on consumption C_t and labor L_t.

$$(5) \quad \sum_{t=0}^{\infty} \beta^t U\left(C_t, L_t\right),$$

where $\beta \in (0,1)$ is the discount factor. The representative household issues a one-period non-state contingent bond, B_{t+1}, at the price of Q_t^* in units of foreign final goods. The price of the bond is determined by

$$(6) \quad \frac{1}{Q_t^*} = (1 + r_t^*) + \xi_B \left(e^{B_{t+1} - \overline{B}} - 1\right),$$

where r_t^* is the real interest rate imposed by the rest-of-world investors in terms of foreign final goods, and B_{t+1} and $\overline{B}$ are the bonds issued in period t and paid in period $t+1$, and the steady state.[13] Similar to the model in Aguiar and Gopihath (2007), the household takes the bond price, Q_t^*, as given and does not internalize the adjustment costs in the choice of B_{t+1}. The household rents capital, K_t, and supplies labor, L_t, to producers in competitive markets at real rental and wage rates R_t and W_t, respectively. The household receives real dividend payments, Π_t, from home producers. The household purchases final goods for consumption, C_t and investment, I_t. The budget constraint of the household is

$$(7) \quad C_t + I_t + q_t B_t = W_t L_t + R_t K_t + q_t Q_t^* B_{t+1} + \Pi_t,$$

[13] Here we abstract away from the risk premium by setting r_t^* as the risk premium adjusted interest rate. We set ξ_B to be very small so that the stationarity is guaranteed but it has negligible effects on the transition dynamics.

where q_t is the real exchange rate.[14] The capital accumulation is determined by

$$K_{t+1} = (1-\delta) K_t + I_t - \frac{\xi_K}{2} \left(\frac{K_{t+1}}{K_t} - 1 \right)^2 K_t, \tag{8}$$

where $\delta \in [0,1]$ is the depreciation rate of capital.

B. Final Good Producers

Final goods are produced using only home and foreign intermediate goods. The aggregation technology for the final good is given by a constant elasticity of substitution (CES) function

$$D_t = \left(\int_z y_{ht}^d (z)^{\frac{\theta-1}{\theta}} \psi_t (z) \, dz + \int_z y_{ft}^d (z)^{\frac{\theta-1}{\theta}} \psi_t^* (z) \, dz \right)^{\frac{\theta}{\theta-1}}, \tag{9}$$

where $y_{ht}^d (z)$ and $y_{ft}^d (z)$ are inputs of intermediate goods purchased from a home producer with technology z, and a foreign exporter with technology z, respectively.[15] The measures of home and foreign country producers with technology z equal $\psi_t (z)$ and $\psi_t^* (z)$, respectively. The elasticity of substitution between intermediate goods is θ.

The final goods market is perfectly competitive. Given the final goods prices normalized to 1, and the prices charged by each type of goods, the final good producer solves the following profit maximization problem

$$\max \Pi_{Ft} = D_t - \int_z p_{ht} (z) \, y_{ht}^d (z) \, \psi_t (z) \, dz - \int_z p_{ft} (z) \, y_{ft}^d (z) \, \psi_t^* (z) \, dz \tag{10}$$

subject to the production technology. Here, $p_{ht} (z)$ and $p_{ft} (z)$ are the prices of intermediated goods produced by home and foreign producers with their technology z, respectively. The

[14] An increase in q_t means a real depreciation of home.

[15] The final good production technology regulates the country's preferences over varieties.

final goods are purchased by the representative household for consumption and investment,

(11) $D_t = C_t + I_t.$

C. Home Intermediate Good Producers

Intermediate good producers produce their differentiated goods using capital and labor inputs. An incumbent's productivity z, follows a first order Markov process with a transition probability $\phi(z'|z)$, the probability that the productivity of a producer will be z' in the next period conditional on its current productivity z, provided that the producer survived. An entrant draws its initial productivity from the probability density function $\phi_e(z')$. At the end of each period, producers receive an exogenous death shock that depends on the producer's productivity z, $0 \leq n_d(z) \equiv 1 - n_s(z) \leq 1$. To be consistent with the observation in the data on establishments, small establishments face higher probability of shutdown relative to large establishments, $dn_d(z)/dz \leq 0$.

Each period a producer chooses the current price at home market $p_{ht}(z)$, the price at foreign market $p_{ht}^*(z)$, and inputs of capital $k_t(z)$ and labor $l_t(z)$ for production. A producer has a Cobb-Douglas production technology

(12) $y_t(z) = e^z k_t(z)^\alpha l_t(z)^{1-\alpha}$

and solves

(13) $\max \Pi_{It}(z) = p_{ht}(z)\, y_{ht}(z) + q_t p_{ht}^*(z)\, y_{ht}^*(z) - W_t l_t(z) - R_t k_t(z)$

subject to

(14) $y_t(z) = y_{ht}(z) + y_{ht}^*(z),$

the production technology, and the demands for its goods at home and abroad. The demand for its product in the foreign market has a constant price elasticity

$$(15)\quad y_{ht}^{*d}(z) = p_{ht}^{*}(z)^{-\theta} D_t^{*},$$

where D_t^{*} is the aggregate demand in the foreign country.

The value of the producer with productivity z is given as

$$(16)\quad V_t(z) = \Pi_{It}(z) + n_s(z)\, Q_t \int_{z'} V_{t+1}(z')\, \phi(z'|z)\, dz',$$

where Q_t is the objective discount factor at home. Since all domestic firms are owned by domestic households, the objective discount factor is given as

$$(17)\quad Q_t = \beta \frac{U_{Ct+1}}{U_{Ct}},$$

where $U_{Ct} = \partial U(C_t, L_t) / \partial C_t$.

D. Entrants

Each period, a new establishment can be created by incurring the sunk cost f_e. Once the entry cost is incurred, entrants receive their initial productivity from the probability distribution function $\phi_e(z')$. All the entrants are free from death shocks initially. The entry condition is given as

$$(18)\quad V_{et} = Q_t \int_{z'} V_{t+1}(z')\, \phi_e(z')\, dz' - W_t f_e \geq 0.$$

Let the mass of entrants who pay the entry cost in period t be N_{et}. The evolutions of mass of producers is given by

$$(19)\quad \psi_{t+1}(z') = \int_z n_s(z)\,\psi_t(z)\,\phi(z'|z)\,dz + N_{et}\phi_e(z').$$

The mass of producers N_t is given as

$$(20)\quad N_t = \int_z \psi_t(z)\,dz.$$

E. Foreign Exporters

There are many foreign producers in the rest of the world. The mass of foreign producers with productivity z is given as $\psi_t^*(z)$. With the home final good producer's demand for the imported goods derived from the final good producer's profit maximization problem, the demand for a foreign good is given as

$$(21)\quad y_{ft}^d(z) = p_{ft}(z)^{-\theta} D_t.$$

We assume that the measure of foreign producers, $\psi_t^*(z)$, is time invariant.[16] Similar to the the optimal pricing of home producers, the prices of foreign goods are proportional to their productivity levels,

$$(22)\quad p_{ft}(z) = \left(\frac{\theta}{\theta-1}\right) e^{-z} mc^* q_t,$$

where mc^* is the marginal cost of production for a foreign producer with its productivity $z = 0$.

[16] In the benchmark model, the distribution of foreign productivity does not matter for the results as long as it is time invariant. In the next section, we will extend the model with fixed costs in exporting so that the exporting decision is endogenous. In the extended model, the distribution matters for the results even if it is time invariant.

F. Equilibrium

In an equilibrium, variables satisfy several resource constraints. The final goods market clearing condition is given by $D_t = C_t + I_t$. Each individual goods market clears. The labor market clearing condition is $L_t = \int_z l_t(z)\,\psi_t(z)\,dz + f_e N_{et}$. The capital market clearing condition is $K_t = \int_z k_t(z)\,\psi_t(z)\,dz$. The profits of establishments are distributed to the shareholders, $\Pi_t = \Pi_{Ft} + \int_z \Pi_{It}(z)\,\psi_t(z)\,dz - W_t f_e N_{et}$. Finally, the international bond market clears. An equilibrium of the economy is a collection of allocations for home consumers C_t, L_t, K_{t+1}, B_{t+1}; allocations for home final good producers; allocations and prices for home intermediate good producers; allocations and prices for foreign intermediate good producers; labor used for entry costs; real wages W_t, real rental rates of capital R_t, real exchange rates q_t; and bond prices Q_t and Q_t^* that satisfy the following conditions: (i) the consumer allocations solve the consumer's problem; (ii) the final good producers' allocations solve their profit maximization problems; (iii) the home and foreign intermediate good producers'allocations and prices solve their profit maximization problems; (iv) the entry condition for intermediate good sector hold; and (v) the market clearing conditions hold.

G. Calibration

We now describe the functional forms and parameter values of our benchmark economy. The parameter values used in the simulation exercises are reported in Table 1.

In the benchmark model, the instantaneous utility function is given as

$$(23)\quad U(C,L) = \frac{1}{1-\sigma}\left(C - \frac{\eta_0}{1+\eta_1}L^{1+\eta_1}\right)^{1-\sigma},$$

where $1/\sigma$ is the intertemporal elasticity of substitution, and $1/\eta_1$ is the elasticity of labor supply. This Greenwood, Hercowitz, Hoffman (GHH) preference is often used in small open economy business cycle models such as Mendoza (1991), Neumeyer and Perri (2005), Aguiar and Gopinath (2007), and Garcia-Cicco, Pancrazi, and Uribe (2010), among others, as GHH preference improves the performance of the model in explaining the business cycle facts in small open economies.

An incumbent's productivity follows a unit root process,[17]

$$(24) \quad z' = z + \varepsilon, \qquad \varepsilon \overset{iid}{\sim} N\left(0, \sigma_\varepsilon^2\right).$$

The assumption that production technology follows an unit root process with shocks drawn from an iid normal distribution implies that this conditional distribution follows a normal distribution $\phi(z'|z) = N(z, \sigma_\varepsilon^2)$. It also implies that a survived establishment's productivity grows with the rate of $\sigma_\varepsilon^2/2$ on average. We assume that entrants draw productivity based on the unconditional distribution

$$(25) \quad z' = \varepsilon_E, \qquad \varepsilon_E \overset{iid}{\sim} N\left(0, \sigma_E^2\right).$$

We assume that producers receive an exogenous death shock that depends on a producer's elasticity adjusted productivity z so that the probability of death is given as

$$(26) \quad n_d(z) \equiv 1 - n_s(z) = \max\left\{0, \min\left\{\lambda e^{-\lambda e^{(\theta-1)z}} + n_{d0}, 1\right\}\right\}.$$

The choices for capital depreciation rate δ and the relative risk aversion σ are standard in the business cycle literature, $\delta = 0.10$ and $\sigma = 2$. The parameter for the adjustment of capital, ξ_K, is set to be 2 with which the immediate response of investment on the sudden stop shock in the benchmark model is about the same as the fall of investment in Korea in 2008, 26.8 percent. The labor elasticity parameter η_1 is set to be 0.6 which gives a labor-supply elasticity of $\frac{1}{\eta_1} = 1.7$ as in Garcia-Cicco, Pancrazi, and Uribe (2010) and Aguiar and Gopinath (2007). We set η_0 so that the labor supply in the steady state is 1/3 of available

[17] Unlike the establishment size distribution in the U.S. (see Rossi-Hansberg and Wright, 2007; and Alessandria and Choi, 2011 for the establishment size distributions in the U.S.), the size distribution in Korea shows a fat tailed distribution. To capture this size distribution, we use a unit root process for the evolution of establishment level productivity.

working hours, $L = 1/3$. The capital share parameter α is set to be 0.40 for the developing economy.

The elasticity of substitution across variety θ which also determines both the producer's markup is set to be $\theta = 5$ which gives the producer's markup of 25 percent.[18]

Neumeyer and Perri (2004) report the U.S. dollar denominated real interest rate imposed in Korea from 1994:Q1 to 2002:Q1.[19] We use the steady state real interest rate r^* before the sudden stop to be 5.8 percent, the average annual interest rate between 1994-1997. The time discount factor is set to be $\beta = \frac{1}{1+r^*}$ to maintain the steady state. We normalize the foreign aggregate D^*, with the normalization of the real exchange rate in the steady state $q = 1$, to match the average export to GDP ratio between 1990 and 1996 in Korea, 27 percent. The steady state debt outstanding, $\overline{B}$, is set to match the debt-GDP ratio in Korea from 1994 to 1996, 25 percent. This also pins down the marginal cost of foreign producers, mc^*, given the distribution of foreign producers, $\psi^*(z)$.[20] The total mass of producers, N, in the steady state is normalized to 1 with the entry cost parameter f_e.

The parameters σ_ε, σ_E, λ and n_{d0} govern the size distribution of producers. We choose these parameter values to match key features of Korean establishment level heterogeneity in the manufacturing sector: i) shutdown plants' labor share of 6.34 percent among establishments with 5 and more employees, and ii) the employment size distribution.[21] Figure 7 plots the distribution of establishments, newborn establishments and shutdown probability by productivity level for our benchmark model. The overall distribution is slightly skewed to the right due to the asymmetric shutdown probability. On average, the entrants' size is 18.5 percent of the incumbents'. Figure 8 shows the model implied size distribution and the

[18] This value of θ is consistent with Broda and Weinstein (2006) who estimate the elasticity of substitution for U.S. imports of 4-digit goods for the period 1990-2001.

[19] Neumeyer and Perri (2004) compute the real interest rate based on 90-day U.S. T-bill rate plus the J.P. Morgan EMBI Global Spread less the expected inflation rate computed by the average of inflation in the current period and in the three preceding periods.

[20] In practice, we set the value of the imported goods price index $P_f^* = q_t^{-1} P_{ft} = \left(\frac{\theta}{\theta-1}\right) mc^* \left(\int_z e^{(\theta-1)z} \psi^*(z)\, dz\right)^{\frac{1}{1-\theta}}$.

[21] We use 9 size bins of 1-4, 5-9, 10-19, 20-49, 50-99, 100-299, 300-499, 500-999, 1000 and more employees reported in Korean Statistical Information Service (KOSIS).

data in 1996. In the manufacturing sector, the establishments with less than 5 employees count 67.6 percent of establishments, and the establishments with 100 and more employees count 1.4 percent. Although the number of productive producers are relatively small, they are important in terms of employments and sales. The employment by the establishments with 100 and more employees counts 44.4 percent, whereas the employment by the smallest 67.6 percent of establishments counts only 12.6 percent. With the calibrated parameters, the model can very closely match the size distribution in the data which has a fat tailed distribution for large sizes and a log-normal like distribution for small sizes.[22]

The sudden stop shock is modeled as an exogenous rise in the real interest rate, r_t^*, together with additional exogenous shutdown of producers. Neumeyer and Perri (2004) report the U.S. dollar denominated real interest rate imposed in Korea from 1994:Q1 to 2002:Q1.[23] Figure 9 shows the annual U.S. dollar denominated real interest rates computed from Neumeyer and Perri (2005) and the rates applied in the model simulation. During the Korean crisis, the annual interest rate rose by 3.9 percentage points in 2008 compared to its average of 1994-1997. We set this value at the year of the sudden stop. Then, we assume that $\ln(1 + r_t^*)$ follows an AR(1) process with the persistence parameter, $\rho_r = 0.5$ which is consistent with the data.[24] For the exogenous death shocks to the producers, we assume that 10 percent of producers across all sizes shut down at the beginning of the sudden stop period as Korean establishment data show.

The model is solved using a version of shooting algorithm with a discretized individual productivity with 200 nodes. In the simulations, we assume that the steady state is reached in 500 periods.[25]

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[22] The mean squared error for the distribution is 0.28 percent.

[23] Neumeyer and Perri (2004) compute the real interest rate based on 90-day U.S. T-bill rate plus the J.P. Morgan EMBI Global Spread less the expected inflation rate computed by the average of inflation in the current period and in the three preceding periods.

[24] The currency crisis in Korea occurred in the 4th quarter of 1997. However, the US dollar real interest changed drastically in 1998 rather than 1997. The annualized quarterly interest rate in the 3rd and 4th quarter of 1997 rose by 0.15 and 1.83 percentage points, respectively, from 5.70 percent in the 2rd quarter of 1997. From the 1st quarter of 1998 the interest rate started to rise drastically and peaked in the 3rd quarter of 1998 to 11.2 percent. After that, it had been diminished over time.

[25] The simulation results show that all variables become very close to their steady state values in 300 years.

4. Results

We use the benchmark model to explore the impact of a sudden stop represented by an unexpected exogenous rise in the interest rate charged by foreign investors followed by additional 10 percent exogenous shutdown of producers. To investigate the importance of the producer level heterogeneity and its composition, we compare the benchmark results with two alternative cases: i) the benchmark model without additional shutdown of producers, and ii) a model where there are no entry or exit of producers, a monopolistic competition version of a standard model, dubbed *No-Cost*. We then extend the model with working capital, and the fixed cost in exporting, a small open economy version of Melitz (2003) model, to investigate how these additional features affect the results.

A. Benchmark Model

Figure 10 shows the transition dynamics of key variables following a sudden stop. Without any variations in the composition of producer heterogeneity, *No-Cost*, the unexpected 3.9 percentage points rise in the interest rate lowers consumption immediately by 2.1 percent. It is due to lower current and future income, worsening of debt outstanding, and high interest rates which raises saving motivation (panel B). Investment and employment fall by 21.6 percent and 1.1 percent, respectively, due to the rise in the interest rate and a lower wage rate (panel C and D). With the lower employment and capital, output falls following the shock (panel A). After reaching its trough in 3 years by 1.8 percent, the economy starts to recover from the recession. The trade balance to GDP ratio rises by 4.9 percentage points which comes from a rise in exports and a fall in imports (panel F). After thirty years from the shock, the economy becomes very close to the steady state. The total factor productivity does not change at all in *No-Cost* model as there are no changes in the composition of producer heterogeneity (panel H). The output per worker rises initially due to a fall in the employment together with no change in capital at the time of impact (panel I). From the following period the output per worker falls and reaches its trough, -0.7 percent, in 3 years. All of these drops in the macroeconomic aggregates are not large enough to account for the impacts of the sudden stops during Asian crises as in the data.

When the endogenous producer level heterogeneity is introduced in the model, the economy exhibits quite different responses of the variables on the sudden stop shock. Without any initial shutdown of producers, the sudden stop shock raises the output initially by 4.1 percent which is counter factual to the data (panel A). This problem arises due to the resource reallocation of labor from accumulation of establishment capital to production (panel D and E). The mass of producers falls due to falls in the future profits and rises in the current and future discount rates, although the cost of creating a producer falls with a drop in the wage rate. With the resource reallocation, employment in production rises by 6.9 percent, even though overall employment falls by 6.2 percent at the time impact. After the initial rise in output, the economy goes into the recession. Output falls by 3.8 percent in 4 years from the shock and starts to recover from the recession. Note that it takes a lot longer periods for output to recover fully from the recession. Even after 30 years from the shock, the output becomes 0.8 percent lower than its steady state level. This persistent underperformance of the economy is due to a drop in the total factor productivity which comes from persistently low average productivity, although the mass of producers recovers from the recession and reaches 0.5 percent above its steady state after 30 years from the shock (panel G). The mass of producers drops by 15.6 percent in one year from the shock, and it takes slow adjustments during the initial transition periods due to the resource reallocation. This creates less masses of highly productive producers in the later periods, and causes a lower level of average productivity of producers in the longer run. After 30 years from the shock, the average productivity is 0.2 percent lower than its steady state level (panel J). The total factor productivity is 0.1 percent lower than its steady state, and it results in a slightly lower output than its steady state by 0.8 percent. Unlike *No-Cost* case, the output per worker initially falls by 2.7 percent which comes from the counter factual rise in labor in production (panel I). Consumption falls more than *No-Cost* model (panel B). It falls by 5.6 percent upon impact, and starts to converge towards its steady state, but it takes long time to converge due to a lower total factor productivity coming from a lower average productivity in the medium run. After 30 years from the shock, consumption is still 0.7 percent lower than its steady state level. The trade balance responds more than *No-Cost* case. The trade balance to GDP ratio rises by 10.0 percentage points upon the impact. Overall, endogenizing the producer level heterogeneity alone makes the economy respond more closely to the date except the responses of the labor in production related variables.

When the sudden stop shock is presented with the interest rate shock and the initial 10 percent drop in the mass of producers across all sizes, the economy respond more drastically, and the drops of key macroeconomic aggregates become closer to the data during the Asian crisis. Following the shocks, output and consumption drop by 8.9 percent in 4 years and 8.2 percent immediately, respectively, and investment and employment fall by 30.5 percent and 5.8 percent, respectively. The model still predicts strong resource reallocation of labor. The labor in production rises by 0.4 percent initially even with a 5.8 percent drop in overall employment at the time of impact.[26] The response of trade balance to GDP ratio is about the same as the case without additional drops in the mass of producers. The mass of producers and the average productivity respond more drastically compared to the case without additional shutdown of producers. The mass of producers falls by 16.9 percent in 1 year following the shocks. The average productivity initially rises since there are less unproductive entrants in the initial periods. As there are more unproductive producers relative to productive producers in the economy over time, the average productivity falls to 1.9 percent in 9 years. Due to the initial drop in the mass of producers, the total factor productivity falls by 2.6 percent, and after 30 years from the shock the total factor productivity is still below its steady state level by 0.6 percent due to lower levels of average productivity by 0.7 percent although the mass of producers is 0.4 percent above its steady state level. This results in output and consumption to be 3.3 and 4.1 percent below from their steady state after 30 years from the shock. The labor productivity also falls upon the impact of the shocks. It drops by 2.8 percent initially, and after 30 years from the shocks, it is still 1.2 percent below

[26] In an extended model, we introduce the working capital condition to resolve this anomaly, a rise in labor in production at the time of the sudden stop shock.

from its steady state level. Overall, when we account for the 10 percent drop in the mass of producers across all sizes at the time of the sudden stop, the model with endogenous entry can explain the large drop in key macroeconomic aggregates, and persistent underperformance of the economy.

The fifty year horizon of the responses of the variables in Figure 10 may look like responses on a permanent shock, since the medium term responses are extremely persistent as in the Asian crisis country data. Figure 11 shows the responses of the key variables for 300 periods. The model without entry or exit, *No-Cost*, shows that the transition dynamics are very short lived. The economy becomes very close to the steady state in 30 years as shown in Figure 10. When the entry of producer is endogenized, the economy takes more time to recover from the shock. It takes about 70 years to be close to the steady state. In the benchmark model where there is initial 10 percent shutdown of producers across all sizes, the economy takes a long way to recover. Now, it takes more than 250 years to be close to the steady state. This is mainly due to the slow recovery of composition of producers as it takes a very long time for entrants to get to the long run productivity level on average. Thus, if we take only short time periods from the shocks, as we see in Figure 10, the economy may look like that there are structural breaks in levels or permanent shocks following a sudden stop.

B. Working Capital

We now add the working capital condition in the model to resolve the problem in the initial response of the labor in production. In the modified model, we assume that producers have to borrow working capital to finance their wage bill. Specifically, we assume that a producer which hires l workers for production has to borrow its wage bill wl from the economy at the beginning of each period after the realization of all shocks to the economy. After all the production and sales at the end of the period, the producer has to pay back $(1+r)\,wl$ to the lender, where r is the domestic interest rate. This condition makes producers more difficult to hire workers when the interest rises even if the wage rate falls. This working capital condition provides a resolution to the anomaly in the response of labor in production.

Figure 12 shows the results with the working capital in the benchmark and *No-Cost* models. With the working capital constraint, it becomes more costly to hire workers in production. This reduces the output more than the cases without working capital. In *No-Cost* model, introduction of working capital additionally reduces output by 0.5 percent in 3 years from the shock. In the benchmark model, the effect is much smaller, by additional 0.3 percent. Consumption takes a bigger effect. Consumption drops by 1.8 and 0.9 percentage points more than the case without working capital in *No-Cost* and benchmark models, respectively. Clearly, working capital directly affects the employment due to increased hiring costs. In *No-Cost* model employment falls by 3.1 percent compared to 0.4 percent drop without the working capital constraint. This larger drop in employment raises output per worker 1.2 percent upon the impact. Thus the working capital constraint alone cannot resolve the anomaly in the immediate response of output per worker if there is no endogenous entry in the model. With the working capital constraint, reallocation of labor from establishment capital accumulation to production is much dampened in the benchmark model. The total employment and employment in production immediately fall by 6.9 and 2.3 percent, respectively. Unlike *No-Cost* model, the output per worker drops by 1.7 percent with the fall in the employment in production. In the longer run (30 years), the total factor productivity and the output per worker are relatively lower than the case without working capital by 0.05 and 0.11 percentage points, respectively, because of relatively lower mass of producers by 0.28 percentage points in that period even though the average productivity is slightly higher with working capital by 0.02 percentage points. Overall, introducing working capital in the benchmark model makes the responses of employment in production more in line with the data without changing other variables' responses qualitatively.

Similar to the data, the model predicts that the mass of producers recovers to its pre-crisis level in 8 years . However, the recovery in the mass of producer is due to the rise in the mass of small establishments not the large ones as we saw in the establishment data. Figure 13 plots the responses of the masses of small (5-99 employees), medium (100-499 employees) and large (500 and more employees) producers. The responses of the masses are similar to the ones in the data qualitatively. For the initial impact, the model does not do a good job in explaining the fall in the masses of producers due to not enough short run response of labor in production. The model predicts a rise in the average size of producers at the time of the impact, since the the labor in production falls less than the mass of producers does. Thus, the size distribution shifts to the right (a rise in the average size of producers) whereas there was a leftward shift in the size distribution (a fall in the average size of producers) in the data. Nevertheless, the model can explain the general transition dynamics of numbers of establishments across sizes. For small establishments, the mass falls for a couple of years and then it recovers very quickly as in the data. For the medium size, it takes more years for the mass to start to recover and it is still below from the steady state even after 20 years from the shock. For large size, the mass falls even after 10 years from the shock and it recovers very slowly from 12 years from the shock. Thus the model can capture the general patterns for transition dynamics and different speeds of recovery for the masses of small, medium, and large size establishments.

C. Fixed Cost in Exporting

In international trade literature, the models with fixed/sunk costs in exporting predict that the responses of exports and imports following a shock to the economy can be greater compared to a standard open economy model as the extensive margin plays a key role in international trade volumes. Thus, the responses of other macroeconomic aggregates can also be greater if we introduce the fixed costs in exporting and endogenize the exporting decision. To find out the roles of extensive margins of exports and imports during the Asian crisis, we introduce fixed costs in exporting to home and foreign producers. We modify the benchmark model as follows.

If a home producer wants to export its good abroad, it has to pay fixed costs in exporting f_x measured in home labor units. After incurring the cost, the producer can export its goods in the following period. Foreign producers also face fixed costs in exporting, f_x, measured in the domestic labor. A home producer with its productivity z pays the fixed cost in exporting and engage in the foreign market in the next period as long as the expected discounted profit from exporting can cover the fixed cost of exporting. The marginal exporter's productivity, z_{xt}, satisfies

$$(27) \quad f_x W_t = n_s (z_{xt}) Q_t \int_{z'} \pi_{xt+1} (z') \phi (z'|z_{xt}) dz',$$

where $\pi_{xt} (z)$ is the profit from exporting for a producer with its productivity z in period t. For any producer in the home country with $z \geq z_{xt}$ pays the fixed cost in exporting. Similarly, the marginal foreign exporter's productivity, z^*_{xt}, satisfies

$$(28) \quad f_x W^*_t = \frac{1}{1 + r^{RW}_t} n^*_s (z^*_{xt}) \int_{z'} \pi^*_{xt+1} (z') \phi^* (z'|z^*_{xt}) dz',$$

where W^*_t is the wage rate in the foreign country, r^{RW}_t is the interest rate in the foreign country, $n^*_s (z)$ is survival probability for a producer with its productivity z in the rest-of-world, and $\phi^* (z'|z)$ is the productivity innovation probability in the foreign country.

Using Annual Report on Mining and Manufacturing Survey in Korea from 1990 to 1998, Hahn (2004) analyzes exporter characteristics in the Korean manufacturing sector for establishments with 5 and more employees. Among establishments with 5 and more employees in the manufacturing sector, 11.5 percent of establishments are exporters on average for 3 years before the currency crisis in Korea, 1994-1996. We calibrate the fixed cost parameter value f_x to match the exporter ratio among producers with 5 and more employees in the model. We do not have data available for the foreign exporters in Korea. In the simulation exercises, we assume that the distribution of foreign producers is the same as that in home country in the steady state and time invariant. We also assume that the survival probability of foreign producers is the same as that in home, $n^*_s (z) = n_s (z)$. We set time invariant fixed cost in exporting together with the interest rate in the foreign country, $f_x W^* \left(1 + r^{RW}\right)$, so that the export threshold for foreign producers, z^*_{xt}, is the same as the home threshold in the steady state. As in the benchmark model, we recalibrate the foreign aggregate demand to match the export to GDP ratio of 27 percent, the steady state debt outstanding, $\overline{B}$, to match the debt-GDP ratio in Korea from 1994 to 1996, 25 percent. Again these parameter values automatically pin down the marginal cost of foreign exporters, mc^*. We reset the level parameter η_0 in the utility function for labor so that the labor supply in the steady state is 1/3 of available working hours, $L = 1/3$ is maintained. The productivity process parameters, σ_ε, σ_E, λ, and n_{d0} are recalibrated to minimize the distance between the model implied size distribution and data. The other parameters are the same as in the benchmark model. Table 1 reports the parameter values for the fixed cost model.

Figure 14 shows the transition dynamics of macroeconomic aggregates in the model with the fixed costs in exporting. Interestingly, the extensive margins have very small role for the transition dynamics of the economy including the trade balances. Similar to the benchmark model, all the transition dynamics exhibit highly persistent underperformance of macroeconomic aggregates following the sudden stop due to highly persistent total factor productivity. Output and consumption are 2.4 percent and 3.6 percent lower than their steady state levels even after 30 years from the shocks, respectively, and they are extremely slowly recovering from the recession. The total factor productivity and the output per worker are 0.4 percent and 0.9 percent lower than their steady state levels after 30 years from the shock. The exporter ratio rises by 21.3 percent in 1 year from the shocks, meanwhile the mass of foreign exporters falls by 14.2 percent. Interestingly, the trade balance to GDP ratio does not change much with these changes in the extensive margins (8.8 vs. 8.4 percentage points for benchmark vs. fixed cost model) with similar short run responses of output. The mass of producers falls by 15.9 percent in 1 year from the shock. Thus, 21.3 percent increase in the exporter ratio implies 5.4 percent rise in the mass of exporters. Since 10 percent of highly productive previous exporters shut down at the impact of the sudden stop and 15.9 percent of additional exporters are mostly from less productive exporters that used be below the exporting threshold, the extensive margin for the exports has very small role for the overall exports (13.6 vs. 12.4 percent for benchmark vs. fixed cost model) and aggregate economy. For the imports, the mass of foreign exporters drops by 14.2 percent. However, the overall effect of the extensive margin for imports is also quite small (-22.7 vs. -21.5 percent for benchmark vs. fixed cost model) since the relatively unproductive foreign exporters stop exporting. Thus extensive margins have only small role for the aggregate economy when the sudden stop occurs.

5. Conclusion

The Asian crisis in 1997-1998 caused drastic declines in macroeconomic aggregates in the short run and highly persistent underperformance of the economy. It also came with shutdown of many establishments in the economy. Although, the total number of establishments in the economy recovered to its pre-crisis level in a couple of years from the shock, the recovery is from the rise in the number of small establishment, not from the large ones. The number of medium to large establishments is still far below from its steady state even after 10 years from the shock, 2008.

The central contribution of this paper is to explain both the short run and medium run transition dynamics of the economy following a sudden stop as observed in the Asian crisis countries. We find that the model with the endogenous establishment level heterogeneity can explain the drastic short run falls of the macroeconomic aggregates and highly persistent underperformance of the economy in the Asian crisis countries. The shutdown of establishments can explain the short run drops in the output as it causes a drastic drop in the total factor productivity of the economy. Similar to the data, the model predicts that the total number of establishments recovers quickly, but the recovery comes from the number of small establishments not the large ones as the entrants are relatively small and it takes many years for entrants to fully grow on average. Since there are less numbers of productive establishments in the medium run, the total factor productivity of the economy is persistently below from its pre-crisis level and that causes highly persistent underperformance of the economy.

In this paper, we focused on the effects of a sudden stop through the dynamics of the establishment composition given the exogenous process of individual producer level productivity. A natural next step is to endogenize the productivity, and to investigate how the growth rates of the economy are affected by the sudden stop in the medium and longer run. It might also be interesting to investigate how the composition of establishment affects aftermath of the recent financial crisis in the U.S. and the world. We leave this for future research.

Appendix

A1. Data

Data on GDP, consumption, investment, trade balance, and population are obtained from the World Development Indicators (WDI). Employment data are obtained from the WDI using GDP divided by GDP per person employed. Korean real interest rate data are from Neumeyer and Perri (2004). They compute the real interest rate based on 90-day U.S. T-bill rate plus the J.P. Morgan EMBI Global Spread less the expected inflation rate computed by the average of inflation in the current period and in the three preceding periods. Korean establishment data are from Korean Statistical Information System (KOSIS) available to the public in http://www.kosis.kr.

The Korean TFP in Section 2 is computed as the Solow residual from the Cobb-Douglas production function with the capital share parameter of 0.4. Here, capital stocks are constructed from investment, I_t, using the law of motion of capital, $K_t = (1 - \delta) K_{t-1} + I_t$, with $\delta = 0.1$ from 1960-2008. In constructing the capital stock, the initial capital stock, K_{1959}, is assume to be on its trend obtained from the initial 5 year investment data with the law of motion of capital.

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Table 1: Parameter Values

Common parameters
$\beta = 0.945$, $\sigma = 2$, $\delta = 0.10$, $\alpha = 0.40$, $\theta = 5$, $\xi_K = 2$,
$\xi_B = 0.001$, $\eta_1 = 0.6$, $r^* = 0.058$, $\rho_r = 0.5$
Benchmark model
$\eta_0 = 5.848$, $\sigma_\varepsilon = 0.069$, $\sigma_E = 0.422$, $\lambda = 3.007$, $n_{d0} = 0.063$,
$f_e = 0.283$, $D^* = 0.672$, $P_f^* = 0.259$, $\bar{B} = 0.487$
Fixed cost model
$\eta_0 = 3.655$, $\sigma_\varepsilon = 0.064$, $\sigma_E = 0.291$, $\lambda = 6.188$, $n_{d0} = 0.063$,
$f_e = 0.307$, $f_x = 0.231$, $D^* = 0.926$, $W^* f_x \left(1 + r^{RW}\right) = 0.413$,
$mc^* = 1.311$, $\bar{B} = 0.301$

Table 2: Growth Rates of Asian Crises Countries

	Y	C	I	L	TBY
1980-1996 average growth rate (%)					
Indonesia	6.69	7.87	8.63	3.97	-0.91
Korea	6.89	6.47	9.54	1.34	0.28
Malaysia	7.05	5.62	10.01	3.46	-0.06
Thailand	6.11	4.86	8.39	0.44	0.00
1997-1998 growth rate (%)					
Indonesia	-14.07	-6.35	-40.06	2.61	10.03
Korea	-7.82	-15.50	-26.77	-6.93	13.47
Malaysia	-7.64	-10.78	-56.15	0.36	21.08
Thailand	-11.72	-12.85	-59.18	-5.21	14.47
2004-2008 average growth rate (%)					
Indonesia	5.72	4.27	8.23	1.61	-0.88
Korea	3.73	3.45	1.63	0.80	-1.35
Malaysia*	5.65	8.40	7.20	1.81	-0.04
Thailand	3.40	2.20	3.32	0.71	-0.52

Notes: * Malaysia's recent growth rates are from 2004-2007. All the data are in per capita.

Figure 1: Asian Crises

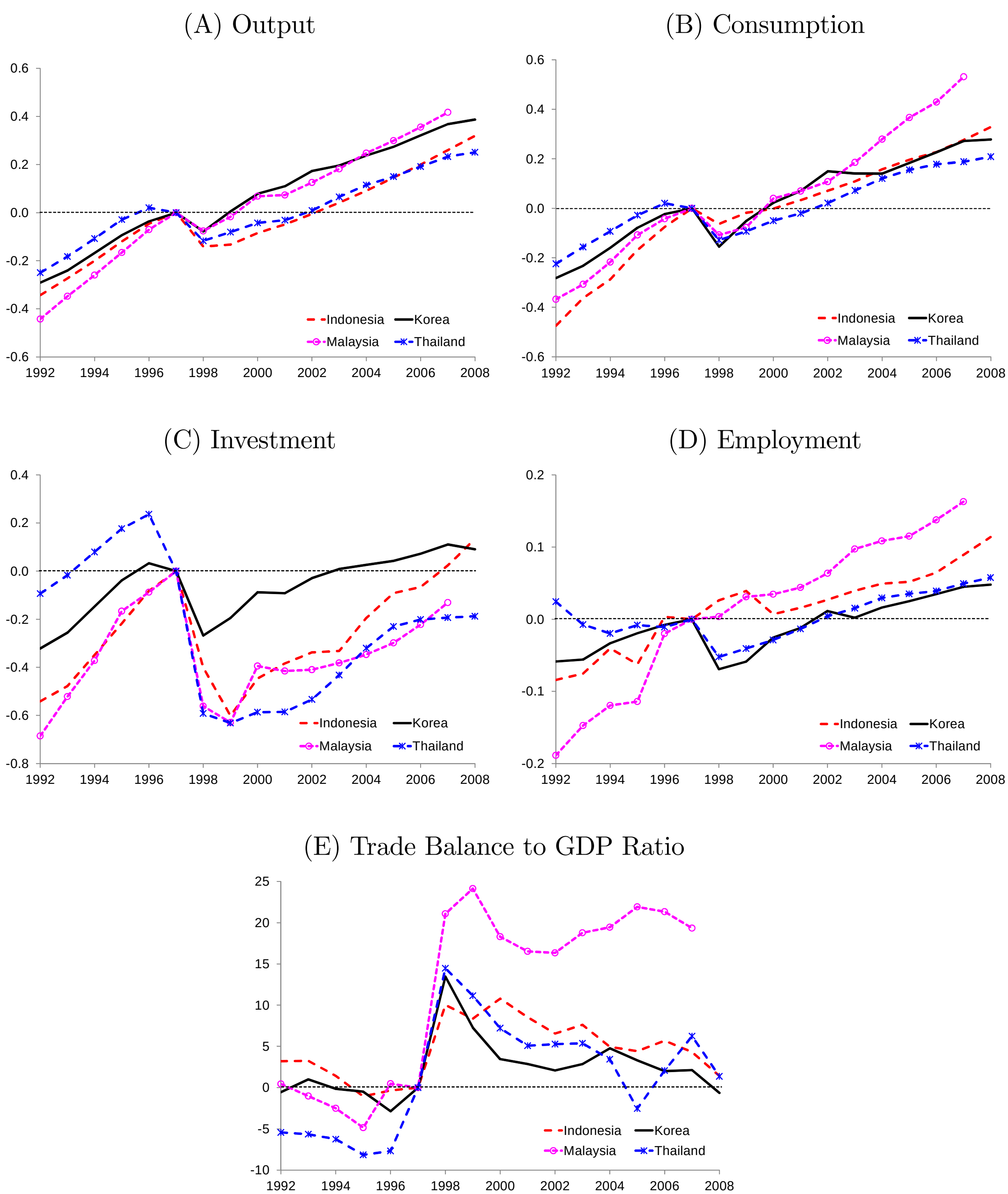


Figure 2: Sudden Stops in Korea

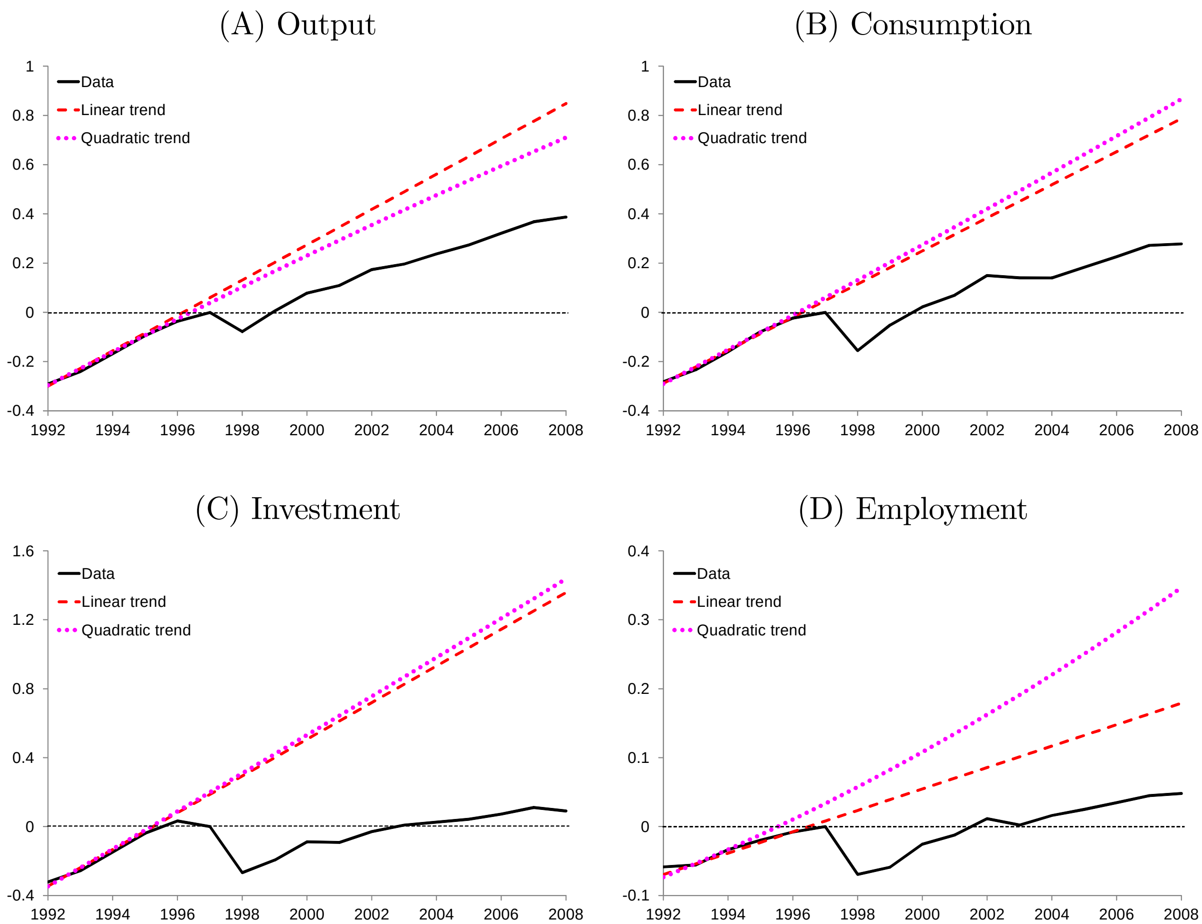


Figure 3: Output per Worker

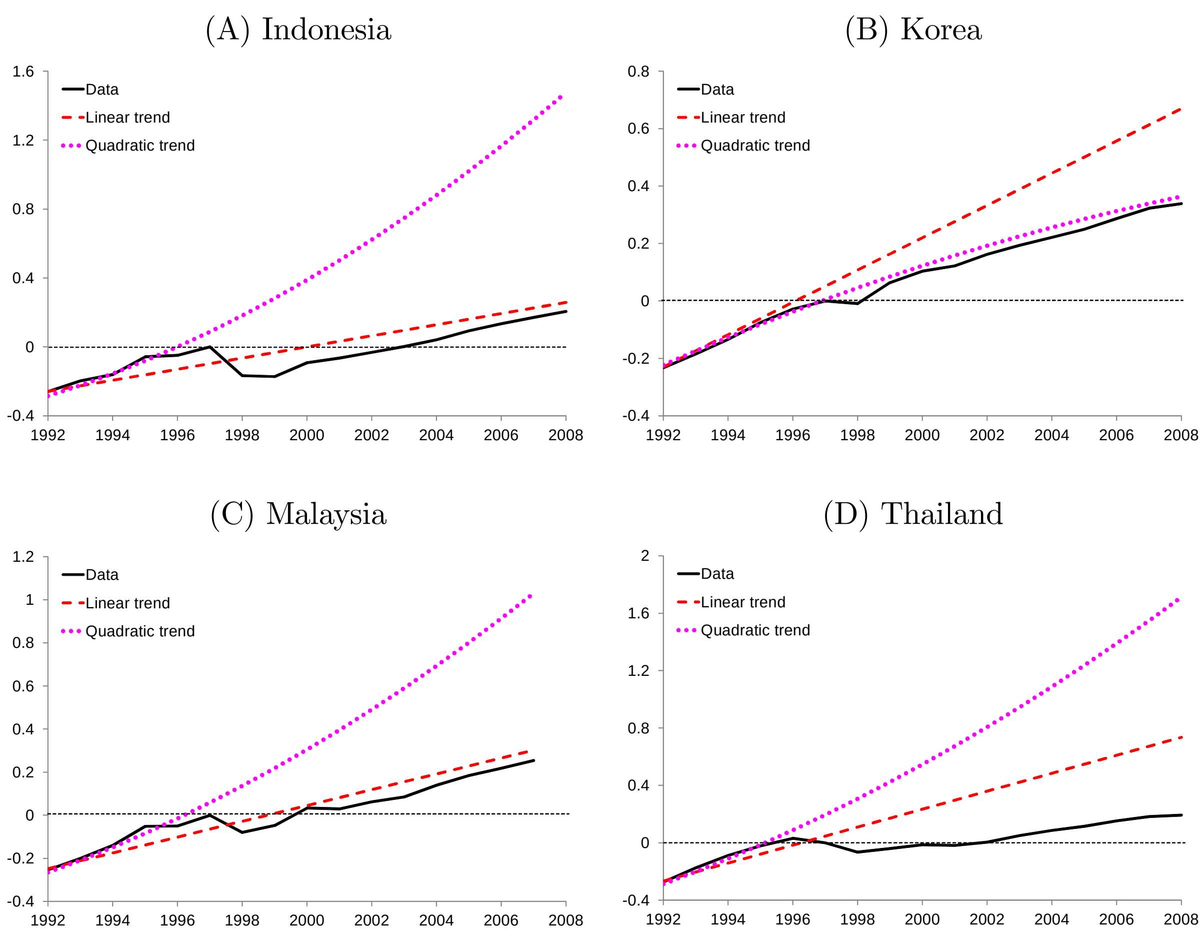
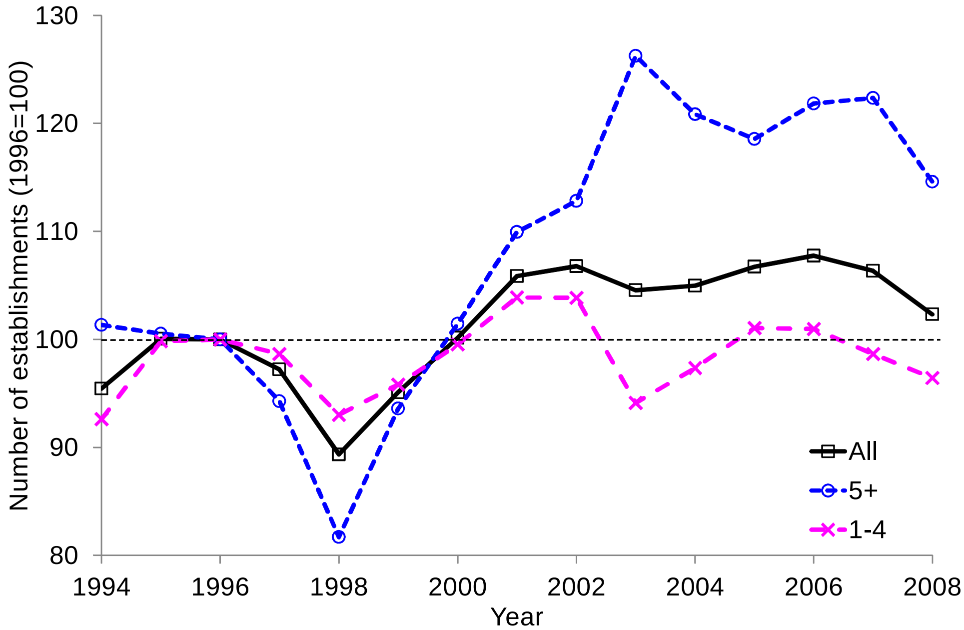


Figure 4: Number of Establishments in Manufacturing Sector

(A) All Establishments



(B) Establishments with 5+ Employees

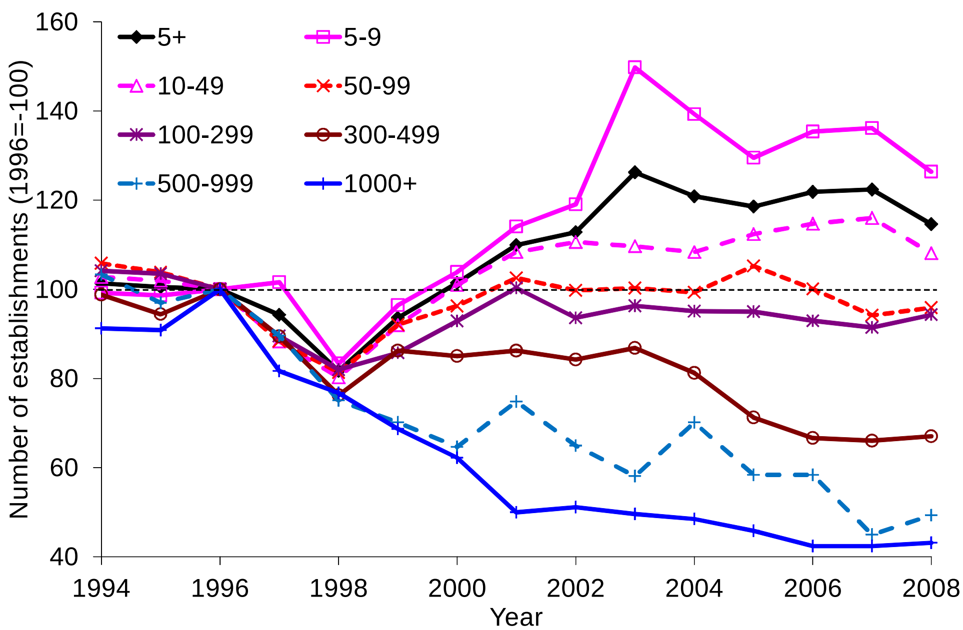


Figure 5: Size Distribution

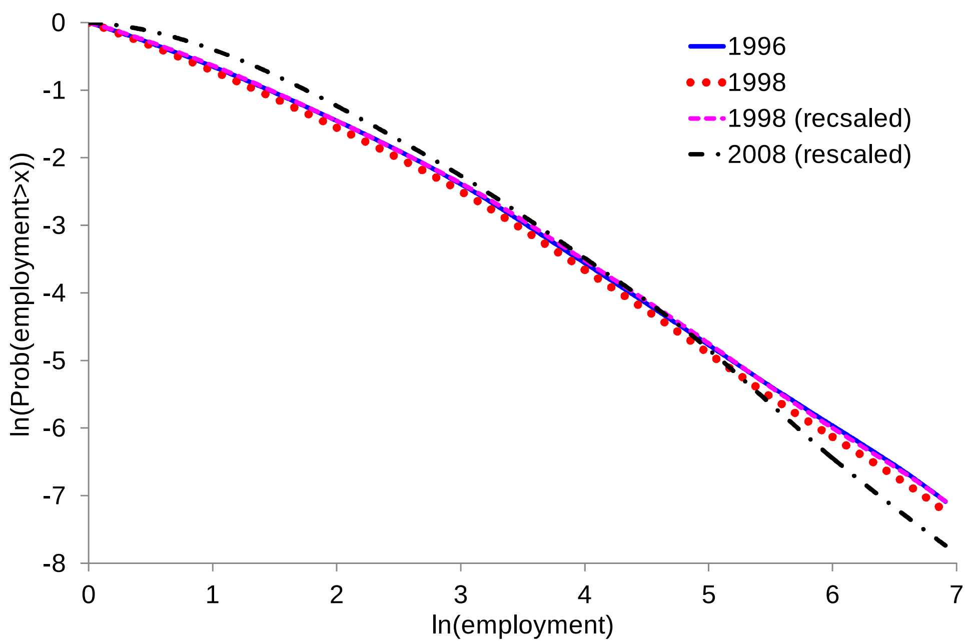


Figure 6: Growth Rates of TFP and Number of Establishments

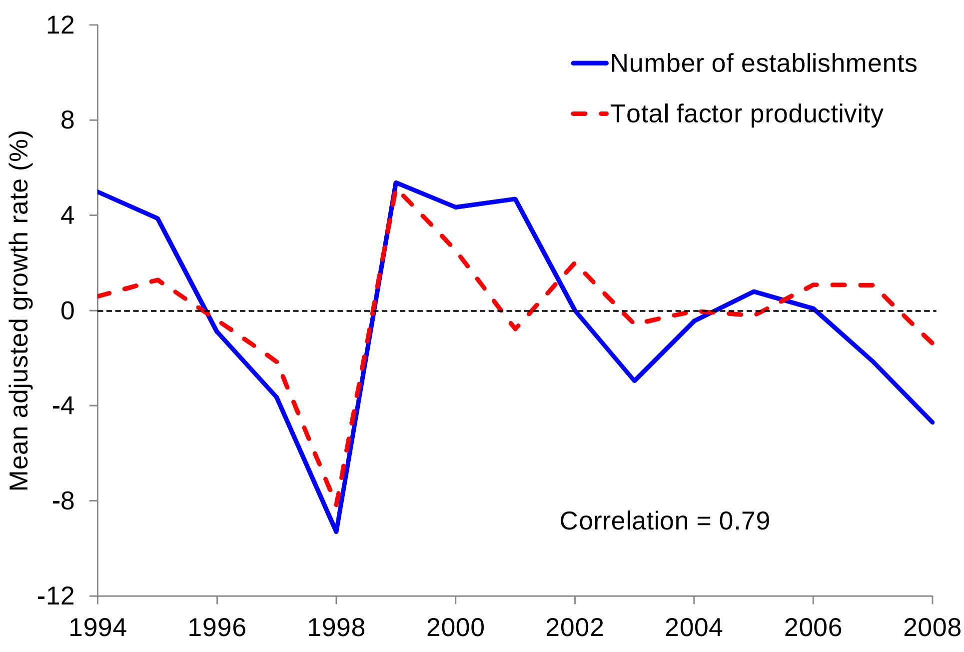


Figure 7: Establishment Distribution

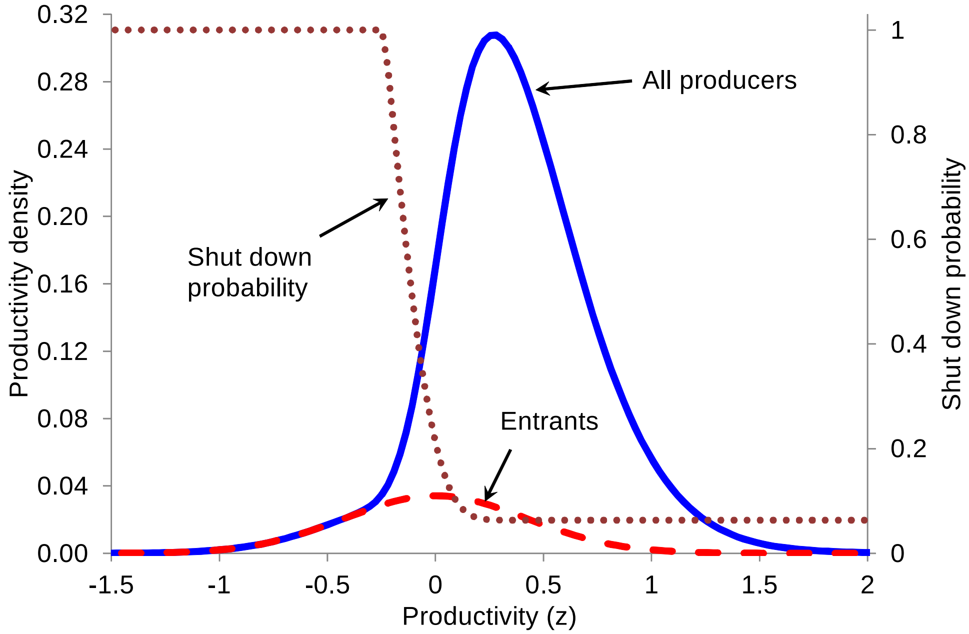
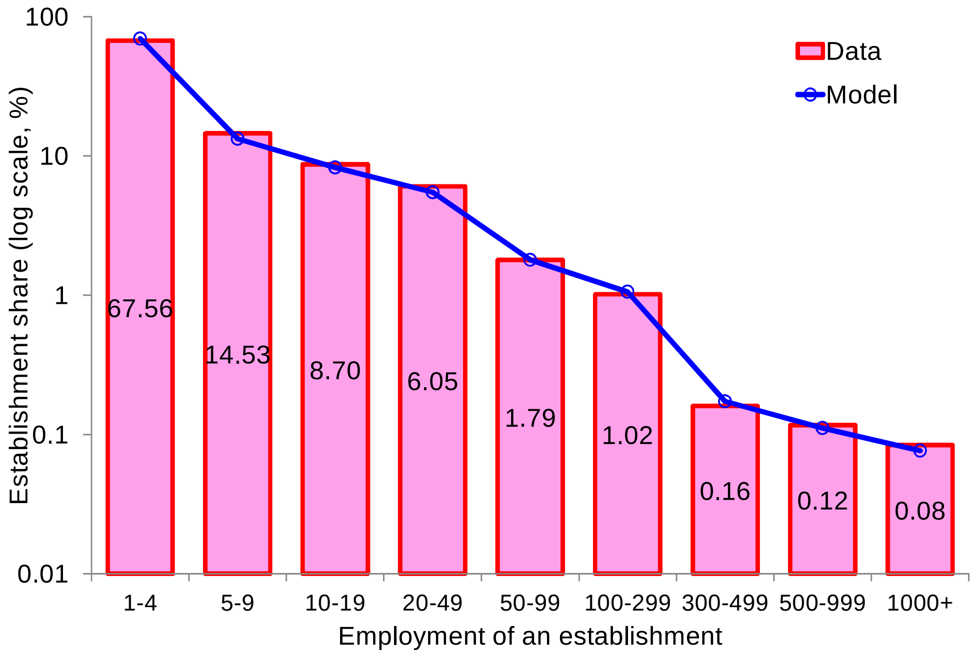


Figure 8: Employment Distribution (Model and Data in 1996)

(A) Establishment Share



(B) Size Distribution

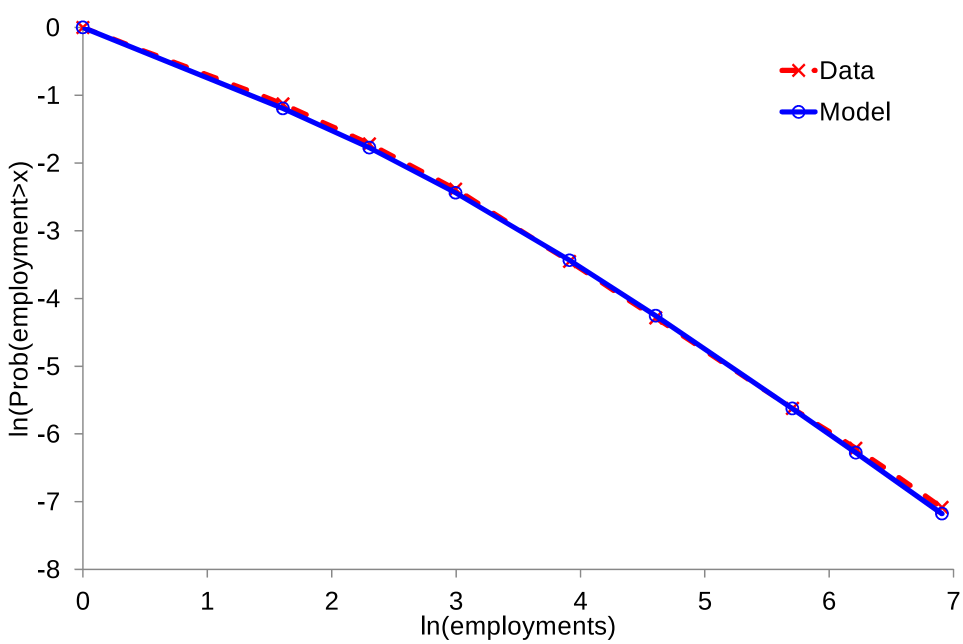


Figure 9: Real Interest Rates

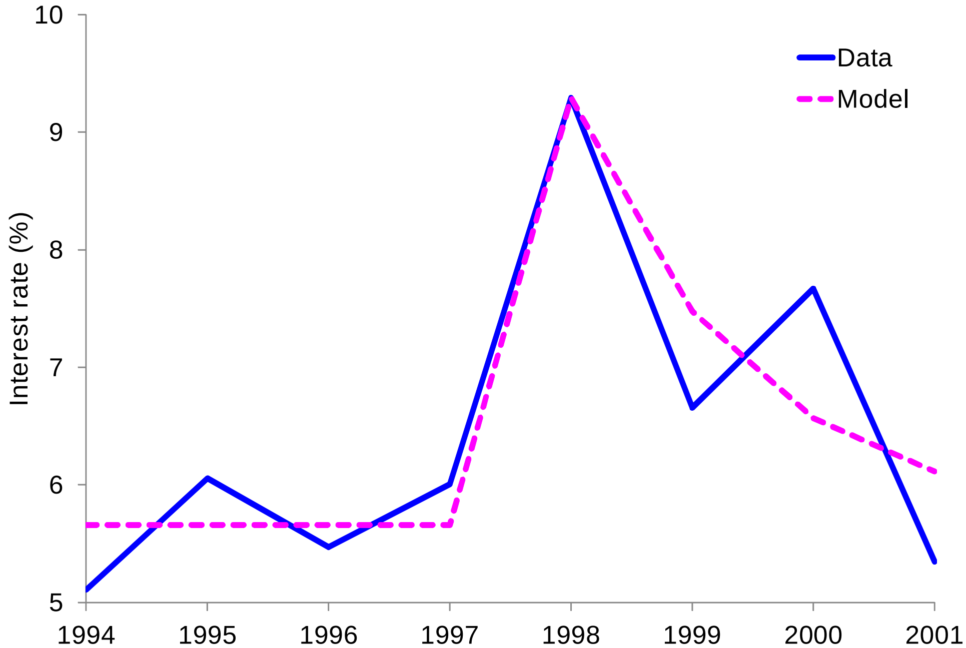
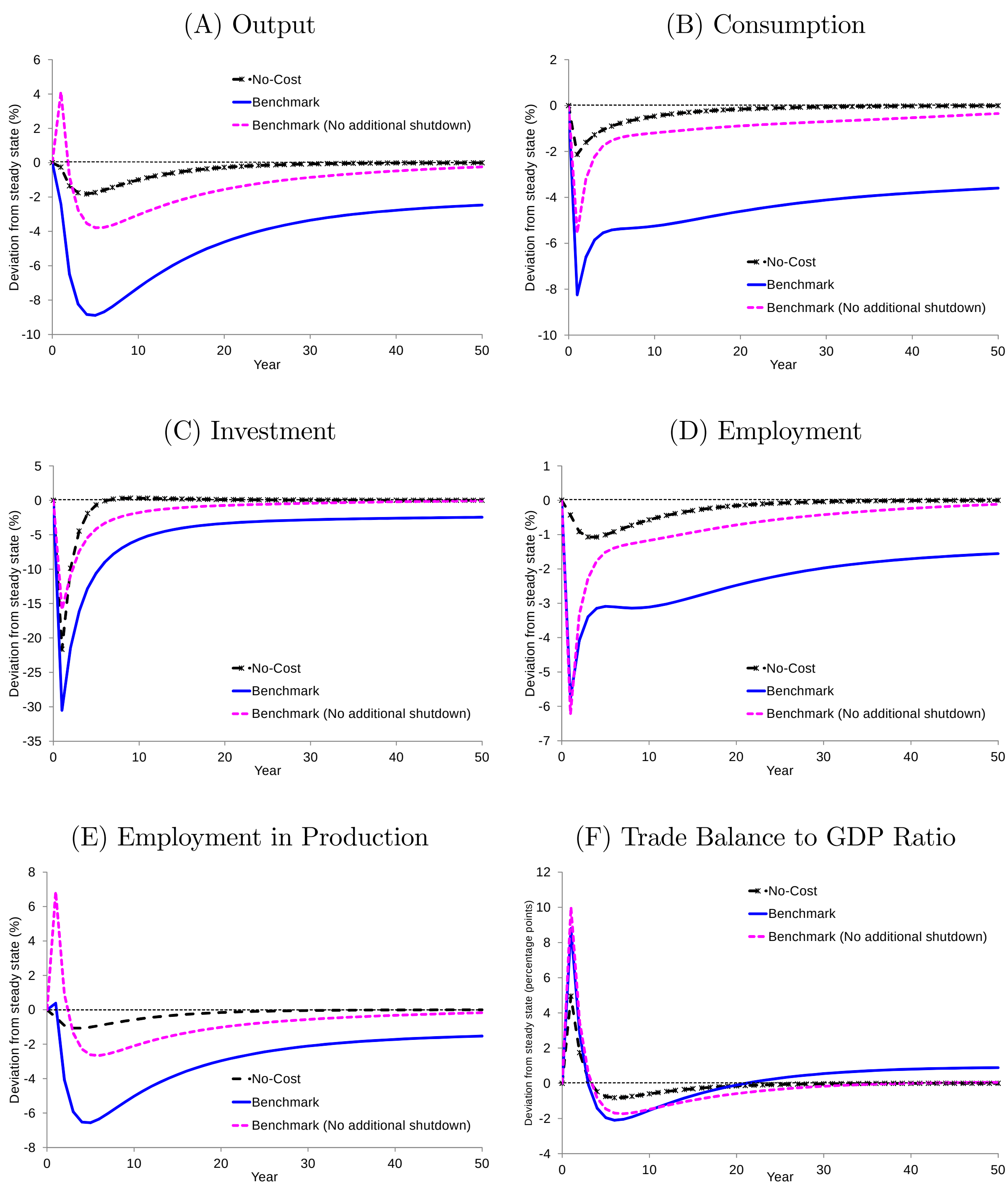
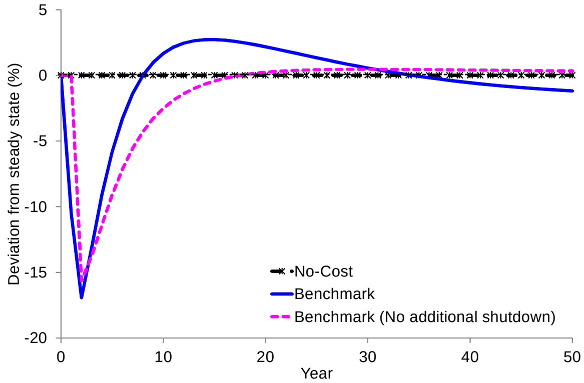


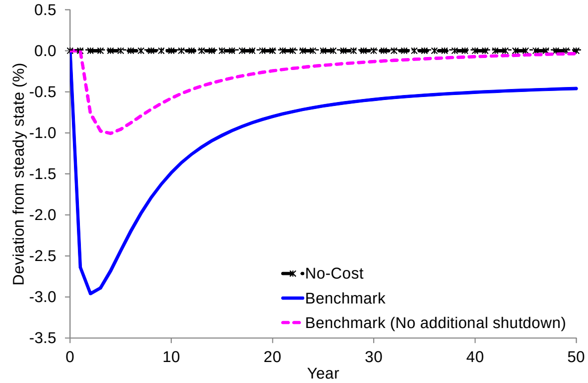
Figure 10: Transition Dynamics



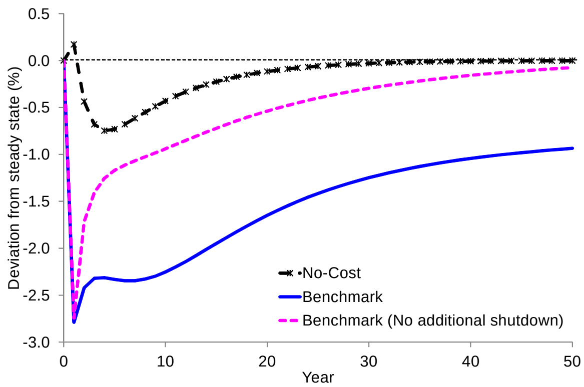
(G) Mass of Producers



(H) Total Factor Productivity



(I) Output per Worker



(J) Mean of Productivity

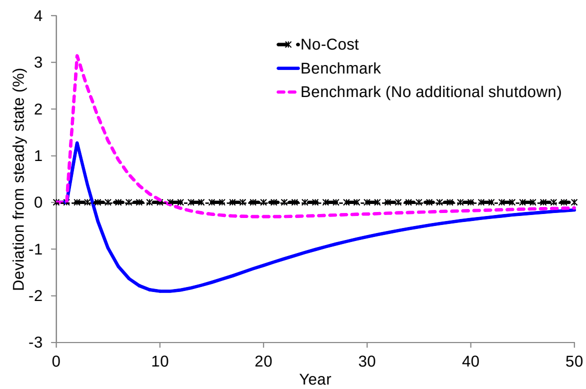


Figure 11: Transition Dynamics (longer run)

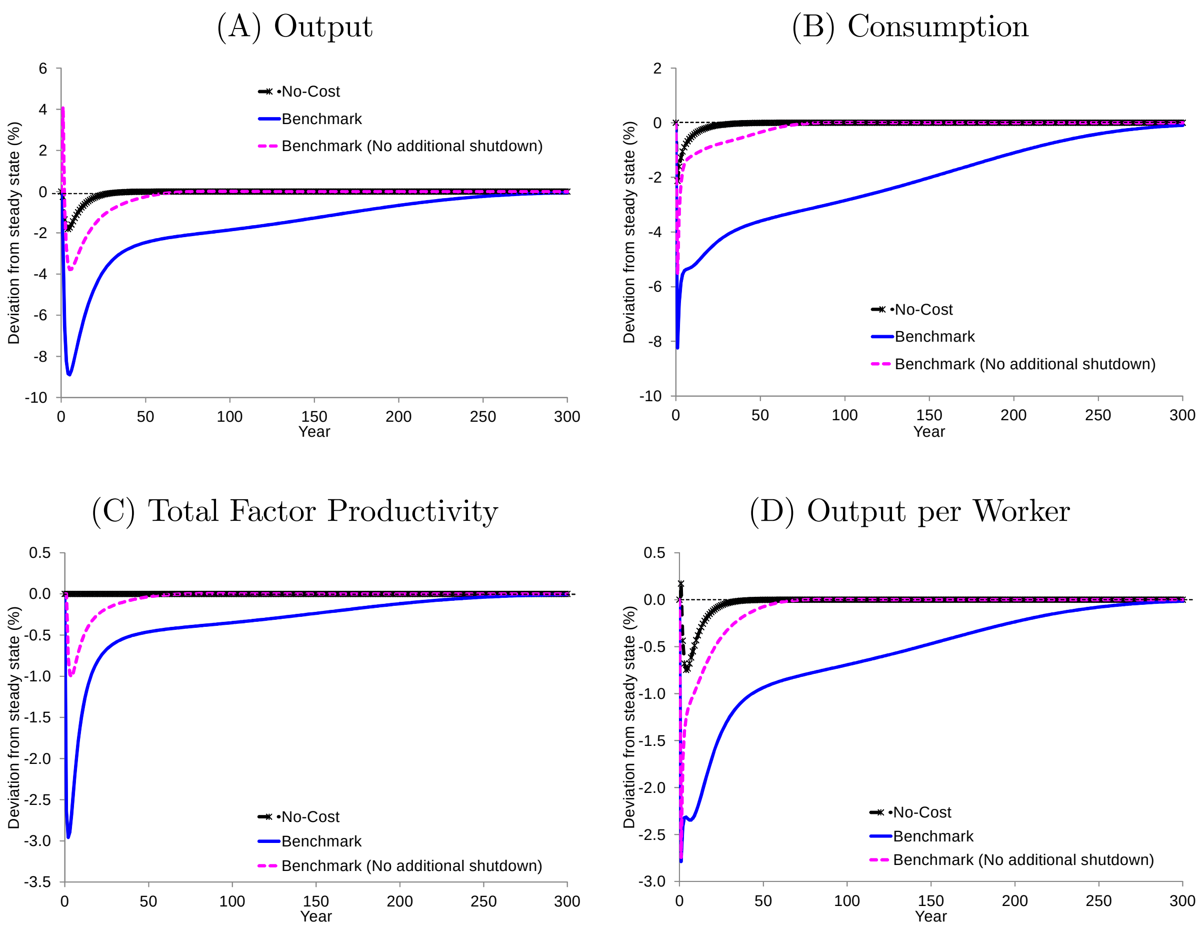
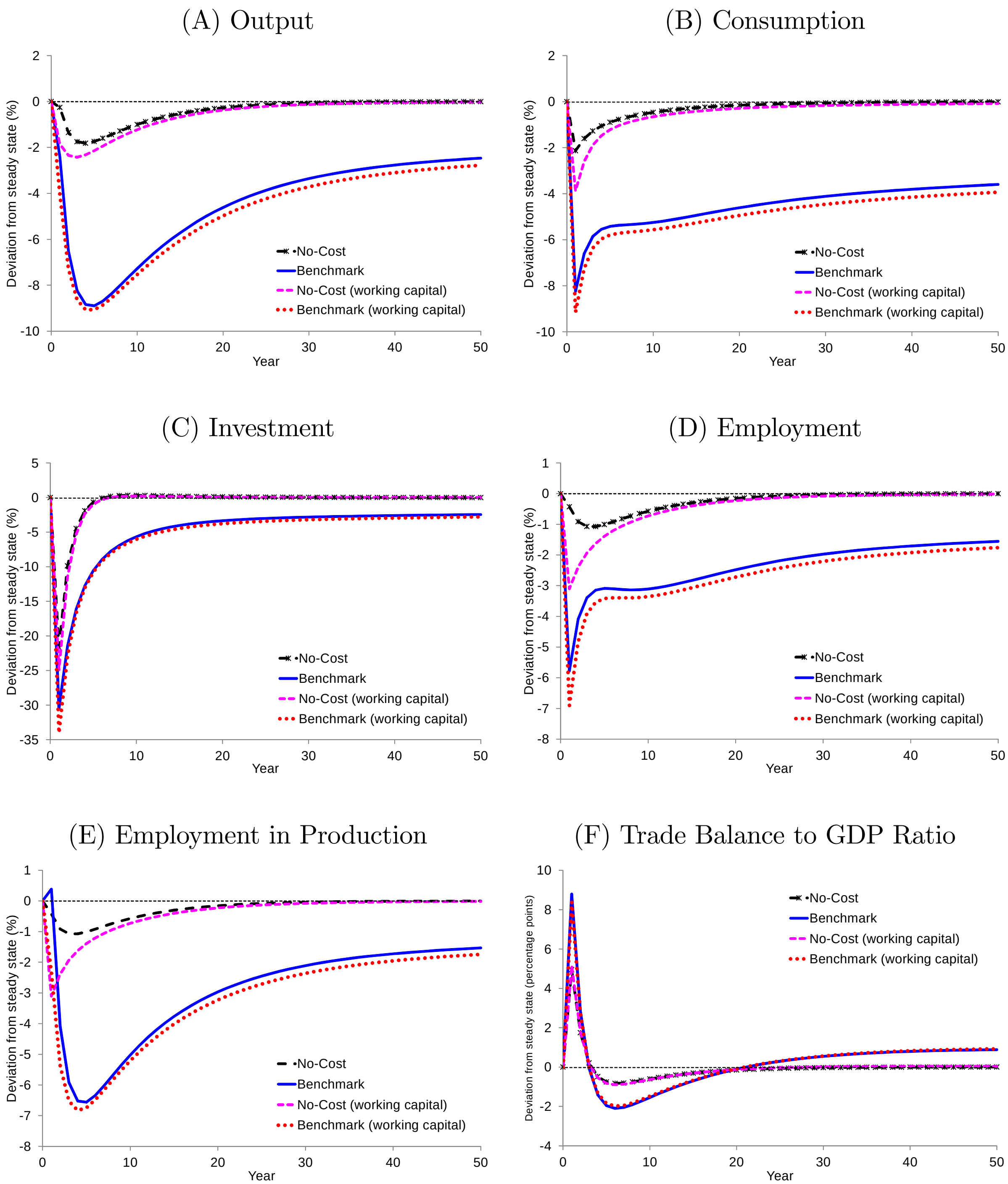
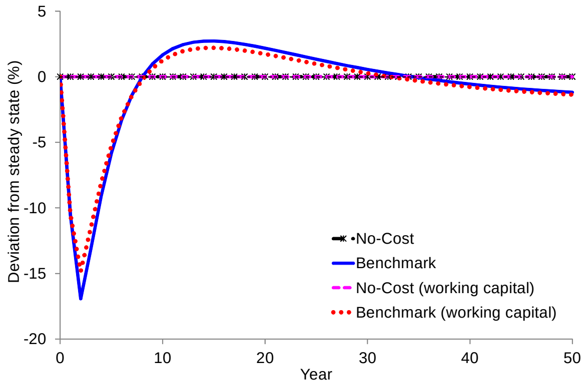


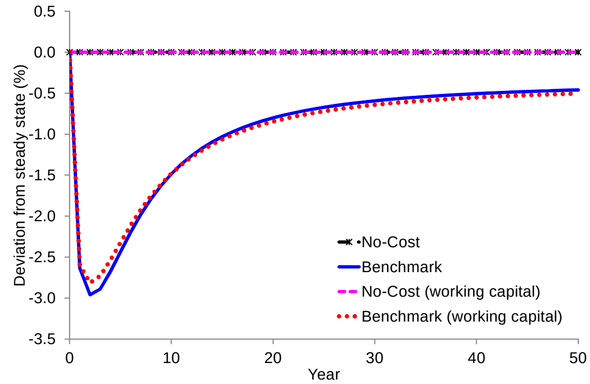
Figure 12: Transition Dynamics with Working Capital



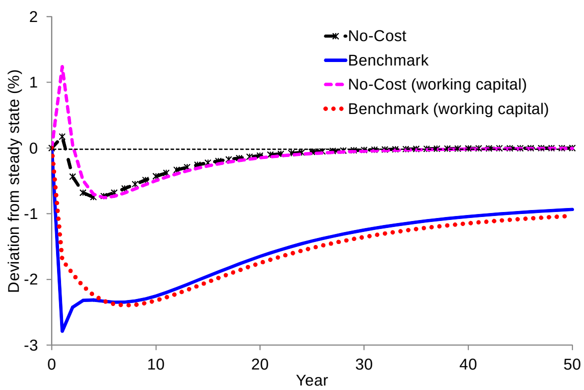
(G) Mass of Producers



(H) Total Factor Productivity



(I) Output per Worker



(J) Mean of Productivity

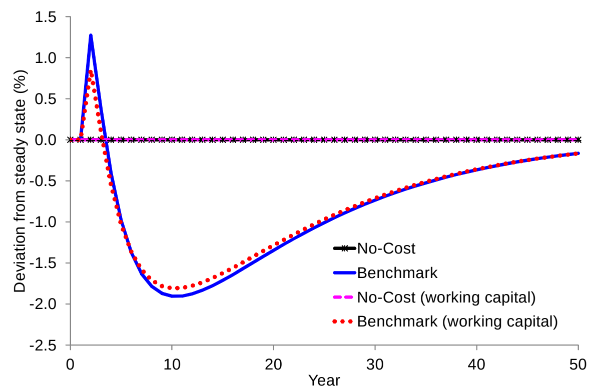


Figure 13: Transition Dynamics of Masses of Producers: Working Capital Model

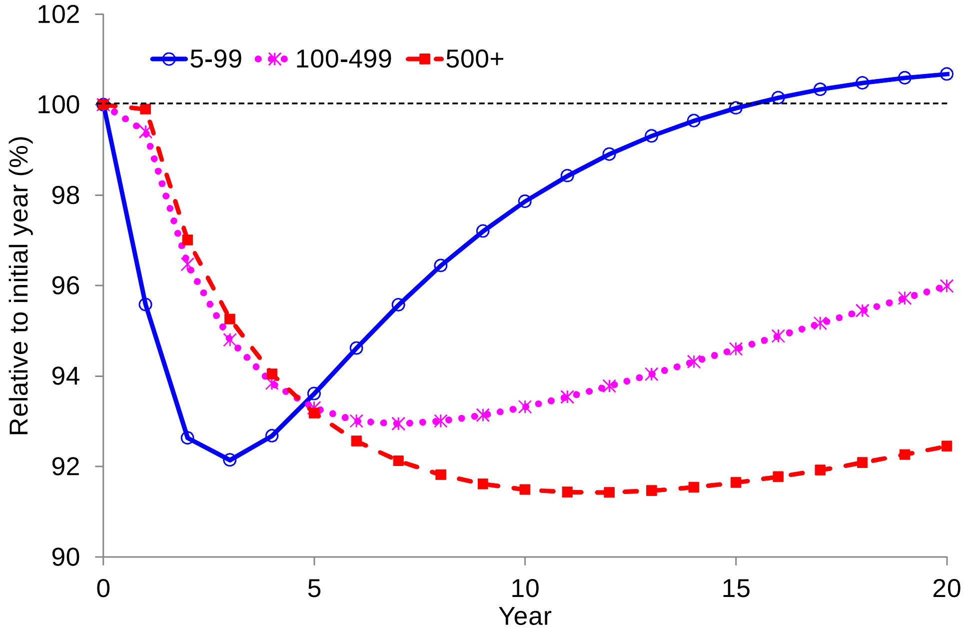
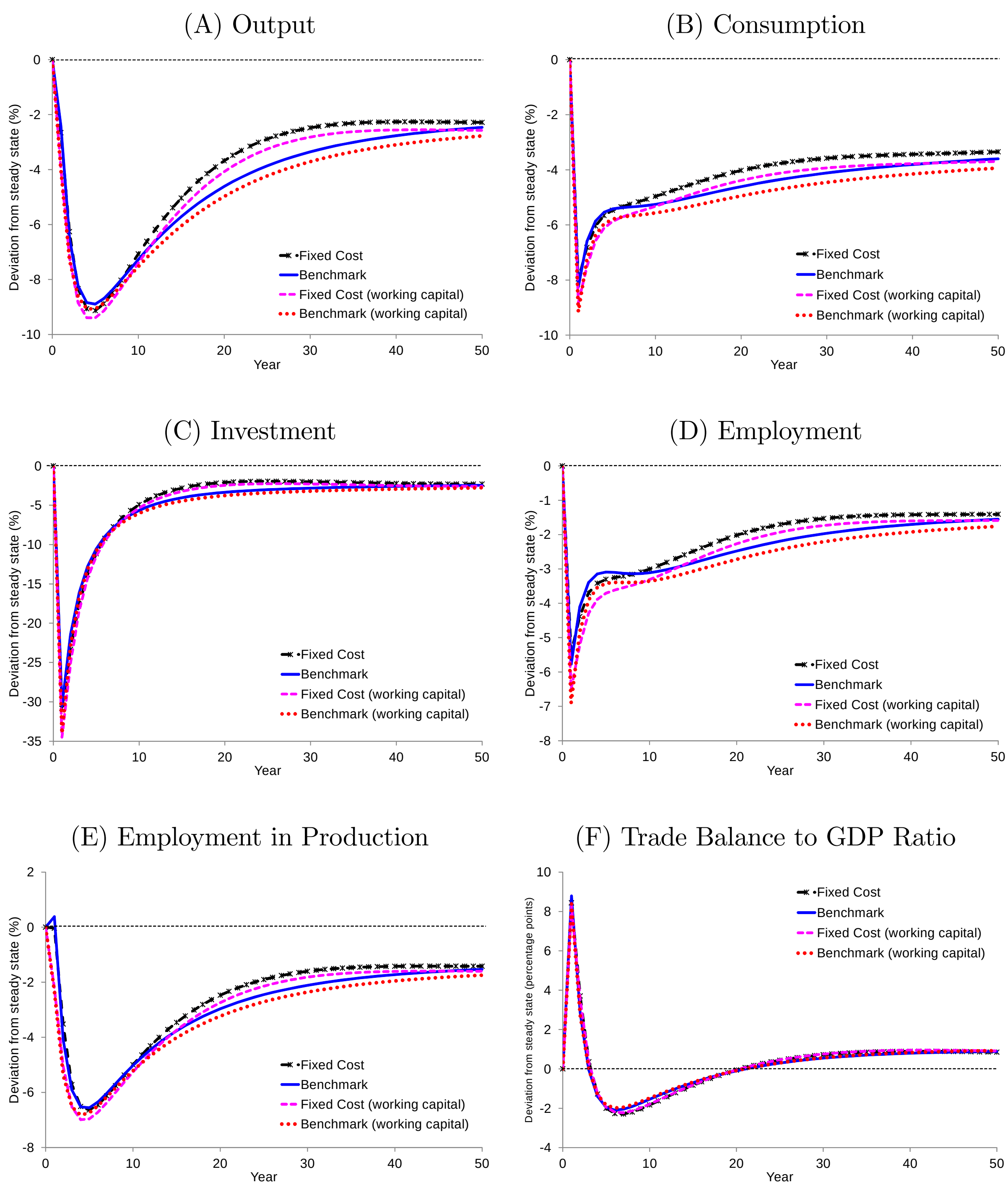
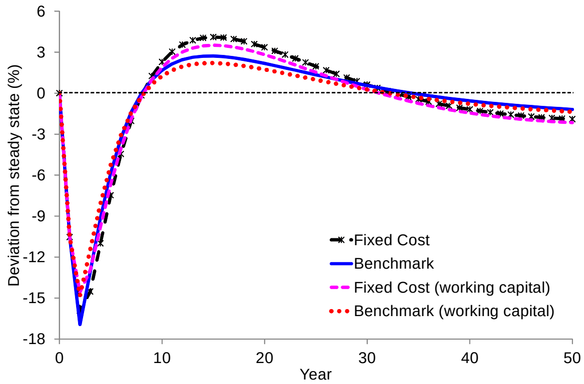


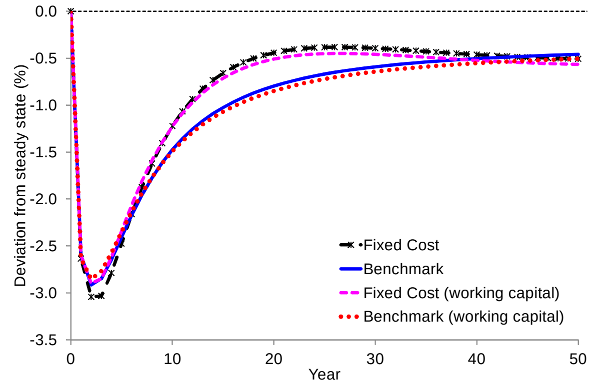
Figure 14: Transition Dynamics with Fixed Cost in Exporting



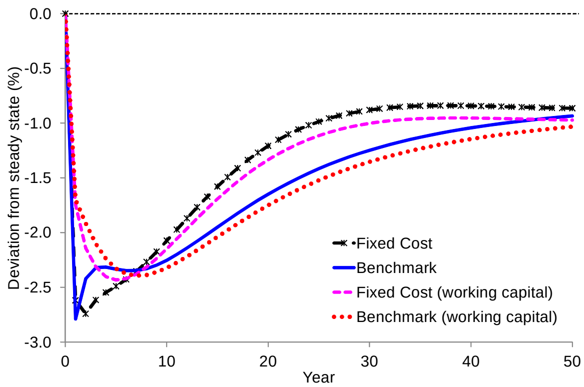
(G) Mass of Producers



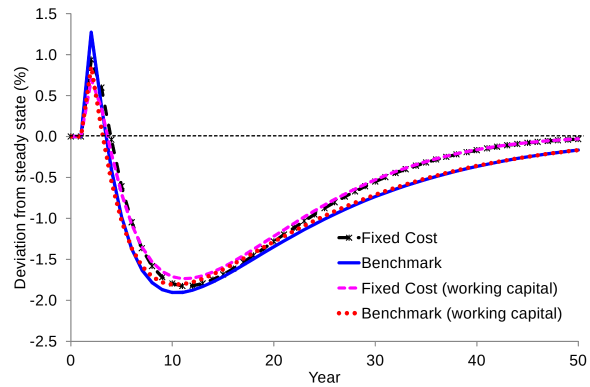
(H) Total Factor Productivity



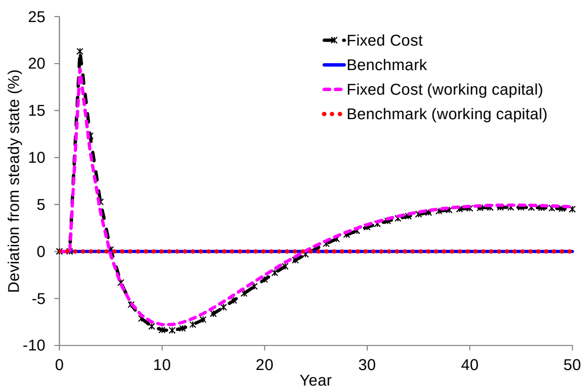
(I) Output per Worker



(J) Mean of Productivity



(K) Exporter Ratio



(J) Mass of Foreign Exporters