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Endogenous firm creation and destruction over the business cycle[☆]

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Abstract

This paper revisits Schumpeterian destruction in a DSGE model based on monopolistic competition. Firms enter the market through a free entry condition and exit endogenously depending on their specific productivity level. The mechanism of endogenous destruction among heterogeneous firms is based on the probabilistic argument discussed in Melitz (2003). The models in the paper are successful in reproducing observed business cycle patterns for creation and destruction and other major economic variables. The models also feature typical characteristics of Schumpeterian economies as found in literature.

Keywords: *entry and exit, firm heterogeneity, the Schumpeterian destruction, business cycles*
JEL classification: D24, E23, E32, L11, L60

1. Introduction

High establishment and job turnover during the business cycle has been documented in the literature (Davis and Haltiwanger 1992, Davis et al. 1998, Dunne et al. 1998, 1999).

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Figure 1 confirms these facts using recent U.S. data. The upper panel shows the cyclical components of real GDP, as well as manufacturing establishment entry and exit from 1977 to 2009.[1] First, entry and exit of firms are highly volatile: their percent standard deviations are 4.62 and 5.22, respectively, whereas that of real GDP is 1.33. Second, they show a clear cyclical pattern: while entry is highly procyclical, exit is countercyclical with a smaller magnitude. Contemporaneous correlations of entry and exit with real GDP are 0.43 and -0.15 for the same period. The lower panel in the figure provides cyclical components of job creation and destruction; These can be interpreted as the employment-weighted establishment entry and exit rates. They show a similar pattern to establishment dynamics. Standard deviations of job creation and destruction are 8.52 and 11.53, respectively. Their correlations with real GDP are 0.73 and -0.51.

The dynamics of entry and exit and induced job fluctuations has motivated a number of theoretical models (Hopenhayn 1992a, 1992b, Caballero and Hammour 1994, 1996, 2005, Campbell 1998, Samaniego 2008, Lee and Mukoyama 2008). These models typically feature the so-called Schumpeterian destruction, i.e., endogenous exit of less productive production units, with which the observed pattern of destruction dynamics can be replicated.

In this paper, I present a simple analytical framework which captures the Schumpeterian destruction in a dynamic stochastic general equilibrium (DSGE) model based on monopolistic competition. A parsimonious extension to Ghironi and Melitz (2005) and Bilbiie et al. (2007) generates an endogenous destruction among heterogeneous firms.[2] I emphasize, besides creation, "destruction margins" in dynamics of extensive margins, i.e., fluctuations in the number of firms/product varieties. The theoretical models in this paper are capable of reproducing observed business cycle patterns for the U.S. economy,

[1] See Appendix A about the data. All series in the figure are detrended with the Hodrick-Prescott filter. Its smoothing parameter is set to 6.25.

[2] Although Ghironi and Melitz (2005) feature a Schumpeterian endogenous destruction of *exporters* based on heterogeneous productivity, the total number of domestic firms are forced to exit only by an exogenous destruction shock.

especially the high volatility and countercyclicality of destruction margins. The models perform as well as standard real business cycle models without endogenous destruction for other principal variables.

In this paper, the mechanism whereby the Schumpeterian destruction takes place is rather simple, relying principally on the probabilistic argument in Melitz (2003). Upon entry, new entrants draw a specific productivity level from a given distribution and pay sunk entry costs. For production in the next period, they must incur fixed operational costs. Following an aggregated shock, less efficient firms which fail to afford fixed operational costs are forced to shut down their production plant and exit. Only a subset of efficient firms among potential producers actually engage in production activity.

In the benchmark economy, all new entrants enter regardless of their specific productivity level. An identical entry process is assumed. As a natural extension, I consider "heterogeneous" entry in which a preselection at entry level occurs based on the firm's specific heterogeneous productivity level. As a result, in this extended version, we can know which firm enters as well as which firm exits. Although the entry selection model is richer in this instance, both Schumpeterian economies behave quantitatively in a very similar manner.

The models in this paper can replicate various characteristics which are typical to the Schumpeterian economy. A recessionary shock wipes less efficient firms out and allocates resources toward more efficient firms. This is the "cleansing effect of recessions" (Caballero and Hammour 1994). In contrast, there is "sclerosis", i.e. *the survival of production units that would not survive in an efficient equilibrium* (Caballero and Hammour 2005) in the non-Schumpeterian economy.

As is expected, creation and destruction margins are very sensitive to the cyclical proprieties of fixed operational and sunk entry costs. Indeed, destruction may *decrease* along the recovery because of cheaper fixed operational costs due to lower wages induced by a recessionary shock. The recovery from the recession may take place with a lower level of destruction rather than a higher level of creation. Such a pattern matches the "reverse-liquidationist view" argued in Caballero and Hammour (2005). Furthermore, when sunk entry costs rise sharply following a recessionary shock, a high reduction in creation margins that follows can "insulate" a rise in destruction (Caballero and Hammour 1994). Because of such a sharp reduction in creation margins, which alleviates the pressure on labor demand and realizes lower wages, destruction margins can end up being shielded along the pass of recovery.

The structure of the paper is as follows. In Sections 2 and 3, the benchmark and entry selection model are presented. I also present a model without endogenous Schumpeterian destruction in Section 4. Through Section 5, calibration exercises are conducted. Specifically, impulse response functions and second moments of the theoretical models are documented. Sensitivity analyses against parameters which govern the cyclical patterns of fixed operational and sunk entry costs are performed in Section 6. I conclude briefly in the last section.

2. The model

The economy is inhabited by one unit mass of atomic households. Extensive margins appear as a result of investment, which is driven by households smoothing their consumption. Each firm represents one product variety. Firms draw their specific productivity level from a distribution upon entry and pay sunk entry costs. Firms are also required to pay fixed operational costs from the next period. Both sunk entry and fixed operational costs are paid in terms of effective labor. Inefficient firms which cannot afford fixed operational costs are forced to shut down without producing.

2.1. Households

The representative household maximizes the expected discounted sum of utilities, $E_t \sum_{i=t}^{\infty} \beta^{i-t} U_t$, where β (< 1) denotes a discount factor. The utility at time t depends on consumption C_t and labor supply L_t as follows

$$U_t = \ln C_t - \chi \frac{L_t^{1+\frac{1}{\varphi}}}{1+\frac{1}{\varphi}}. \tag{1}$$

The parameter χ (> 0) represents the degree of non-satisfaction in supplying labor and φ stands for the Frisch elasticity of labor supply[3]. With the above specification, the marginal disutility in providing one unit of additional labor is increasing.

Consumption is defined over a continuum of goods Ω. At any given time t, only a subset of goods $\Omega_t \in \Omega$ is available as

$$C_t = V_t \left(\int_{\omega \in \Omega_t} c_t(\omega)^{1-\frac{1}{\sigma}} d\omega \right)^{\frac{1}{1-\frac{1}{\sigma}}}, \tag{2}$$

where $c_t(\omega)$ is individual demand for variety ω and $V_t \equiv S_t^{\psi - \frac{1}{\sigma-1}}$ in which S_t denotes the number of available varieties at time t. Following Benassy (1996), ψ represents the marginal utility associated with one additional increase in the number of varieties in the basket. When $\psi = 1/(\sigma-1)$, the preference coincides to those implied by Dixit and Stiglitz (1977). σ (> 1) stands for the elasticity of substitution among varieties.

2.1.1. Law of motion and budget constraint

N_t denotes the number of potential producers. "Potential", because only a subset of S_t efficient firms actually engage in production. New entrants, whose number is denoted by H_t, need one "time to build" in order to become potential producers in the next period. A fraction of δ among potential producers and new entrants are assumed to exit exogenously in each period. These assumptions imply that the number of potential producers at time t is given by

$$N_t = (1-\delta)(N_{t-1} + H_{t-1}). \tag{3}$$

Following Caballero and Hammour (2005), I distinguish between the number of firms destroyed via endogenous-Schumpeterian and those destroyed exogenously. Respectively, they are defined as

$$D_t^S \equiv N_t - S_t \quad \text{and} \quad D_t^\delta \equiv \delta(S_t + H_t). \tag{4}$$

[3] With $\varphi = \infty$ the marginal disutility of supplying labor becomes constant, χ. When $\varphi = 0$ the marginal disutility becomes infinite and the labor supply becomes inelastic.

Gross destruction at time t is then given by

$$D_t \equiv D_t^S + D_t^\delta. \tag{5}$$

I choose the price of consumption basket P_t as numéraire and let tilda ($\sim$) stand for the average level. Using this notation, the period-by-period real budget constraint for the representative household is given by

$$C_t + x_{t+1} v_t \left(N_t + H_t\right) = L_t w_t + x_t N_t \left(v_t + \widetilde{d}_t\right). \tag{6}$$

v_t denotes the real share price of a mutual fund among N_t potential producers and H_t new entrants. At time t, the household purchases consumption goods and a share of the mutual fund, x_{t+1}. w_t and $\widetilde{d}_t$ denote the real wage and the average real dividends among N_t potential producers, respectively. As revenue, the household receives labor income and the return of fund based on share holdings in the previous period, x_t.

2.1.2. First order conditions

The representative household maximizes U_t with respect to C_t, x_{t+1} and L_t under the budget constraint (6) for every period. The first-order condition with respect to labor supply L_t gives

$$\chi \left(L_t\right)^{\frac{1}{\psi}} = w_t C_t^{-1}. \tag{7}$$

Taking into account the motion of firms (3), the first-order condition with respect to share holdings x_{t+1} gives

$$v_t = \beta \left(1 - \delta\right) E_t \left(\frac{C_{t+1}}{C_t}\right)^{-1} \left(v_{t+1} + \widetilde{d}_{t+1}\right). \tag{8}$$

Iterating forward and ruling out the Ponzi schema in the above expression, we have

$$v_t = E_t \sum_{i=t+1}^{\infty} \left[\beta \left(1 - \delta\right)\right]^{i-t} \left(\frac{C_i}{C_t}\right)^{-1} \widetilde{d}_i. \tag{9}$$

The current asset price v_t can be expressed as the expected discounted sum of future dividends.

The optimal consumption for a variety ω is given by

$$c_t(\omega) = V_t^{\sigma-1}\left(\frac{p_t(\omega)}{P_t}\right)^{-\sigma} C_t. \tag{10}$$

The price index which minimizes nominal expenditures is

$$P_t = \frac{1}{V_t}\left(\int_0^{S_t} p_t(\omega)^{1-\sigma}\, d\omega\right)^{\frac{1}{1-\sigma}}. \tag{11}$$

Given a preference for variety, the price index rises (decreases) when the number of available varieties S_t decreases (rises).

2.2. Heterogeneous firms and Schumpeterian destruction

2.2.1. Entry

Firms are monopolistically competitive and each firm produces one specific product variety. Upon entry, new entrants draw a firm-specific productivity level z from a c.d.f, $G(z)$, which is defined as the following Pareto distribution:

$$G(z) = 1 - \left(\frac{z_{\min}}{z}\right)^k, \tag{12}$$

where $z_{\min}$ is the minimum productivity level and k $(> \sigma - 1)$ is the parameter which governs the shape of the distribution.[4] As k rises, the distribution becomes more skewed towards the minimum level and heterogeneity decreases. In this benchmark model, entry is assumed to be "identical"; After drawing its specific productivity level, every firm enters and pay a sunk entry cost which consists of $l_{E,t} \equiv f_{E,t}/A_t^{\vartheta}$ units of effective labor. In the above expression, $f_{E,t}$ is exogenous and represents (de)regulation on entry. A_t stands for the labor productivity level which is common for all firms and the parameter ϑ governs its spillover to the efficiency of workers in the firm setup activity.

In equilibrium, the following free entry condition (which equates current share price v_t and sunk entry costs) must hold, pinning down the number of new entrants H_t:

[4] Hopenhayn (1992b), Hopenhayn (1992a) and Hopenhayn and Rogerson (1993) consider uncertainty of the firm-specific productivity level. As we will see, in this paper's model, uncertainty holds only on the aggregated productivity level A_t.

$$v_t = \frac{w_t f_{E,t}}{A_t^{\vartheta}}. \quad (13)$$

2.2.2. Production

A firm's production technology, given a productivity level z, is summarized by

$$l_t(z) = \frac{y_t(z)}{A_t z} + \frac{f_t}{A_t^{\theta}}, \quad (14)$$

where $l_t(z)$ stands for labor demand for production. $y_t(z)$ denotes the scale of production, i.e., intensive margins. In addition to variable costs, $y_t(z)/A_t z$, production requires operational fixed costs which are defined in terms of effective labor: f_t/A_t^{θ}. These fixed costs are assumed to fluctuate along the aggregated labor productivity level A_t with a degree of spillover θ. f_t is exogenous and represents (de)regulation on production.

Provided (14), operational real profits of the firm are expressed as

$$d_t(z) = \left(\rho_t(z) - \frac{w_t}{A_t z}\right) y_t(z) - \frac{w_t f_t}{A_t^{\theta}}, \quad (15)$$

where $\rho_t(z)$ stands for real price. The goods market clearing condition requires that $y_t(z) = c_t(z)$ and, taking into account the demand addressed to each firm (10), the maximization of profits gives a standard pricing in monopolistic competition. The real price is markup over real marginal costs:

$$\rho_t(z) = \frac{\sigma}{\sigma - 1} \frac{w_t}{A_t z}. \quad (16)$$

Using the above optimal pricing, profits can be rewritten as

$$d_t(z) = \frac{1}{\sigma} S_t^{\psi(\sigma-1)-1} \rho_t(z)^{1-\sigma} C_t - \frac{w_t f_t}{A_t^{\theta}}. \quad (17)$$

Since $\sigma > 1$, lower real price induces a rise in profits. The term $S_t^{\psi(\sigma-1)-1}$ captures additional impact on profits arising from fluctuations in extensive margins. When $\psi = 1/(\sigma - 1)$, this term is unity.

2.2.3. The cutoff firm and the number of survivors-producers

Provided with a specific productivity level z, the firm produces if $d_t(z) > 0$, otherwise it shuts down the plant and exits. Survival depends on how low of a price firms can charge, which in turn depends on their marginal costs. Inefficient firms which have drawn a lower productivity level than the cutoff ($z \leq z_{s,t}$) exit without producing. Endogenous Schumpeterian destruction takes place following a "strict productivity ranking" as in Caballero and Hammour (1994, 1996, 2005).

Operational profits become zero for the firm with the cutoff productivity level $z_{s,t}$ providing the following zero profit cutoff (ZCP) condition in equilibrium:

$$d_t(z_{s,t}) = \frac{1}{\sigma} S_t^{\psi(\sigma-1)-1} \rho_t(z_{s,t})^{1-\sigma} C_t - \frac{w_t f_t}{A_t^{\theta}} = 0. \tag{18}$$

We rewrite the above ZCP condition in terms of the average firm specific productivity among survivors-producers, $\widetilde{z}_{s,t}$. Following Melitz (2003) and Ghironi and Melitz (2005), $\widetilde{z}_{s,t}$ is defined as follows,

$$\widetilde{z}_{s,t} \equiv \left[\frac{1}{1-G(z_{s,t})} \int_{z_{s,t}}^{\infty} z^{\sigma-1} dG(z)\right]^{\frac{1}{\sigma-1}} = z_{s,t} \left[\frac{k}{k-(\sigma-1)}\right]^{\frac{1}{\sigma-1}} \tag{19}$$

The second identity comes from the use of the Pareto distribution defined previously.

Average real profits among surviving producers are expressed as follows

$$\widetilde{d}_{s,t} = \frac{1}{\sigma} S_t^{\psi(\sigma-1)-1} \widetilde{\rho}_{s,t}^{1-\sigma} C_t - \frac{w_t f_t}{A_t^{\theta}},$$

where average real price is given by

$$\widetilde{\rho}_{s,t} = \frac{\sigma}{\sigma-1} \frac{w_t}{A_t \widetilde{z}_{s,t}}. \tag{20}$$

At the same time, by definition of the price index (11), we have $\widetilde{\rho}_{s,t} = S_t^{\psi}$. Using this latter expression, average profits are rewritten as

$$\widetilde{d}_{s,t} = \frac{1}{\sigma} \frac{C_t}{S_t} - \frac{w_t f_t}{A_t^{\theta}}, \tag{21}$$

Finally, using (18), (19) and (21), the ZCP is rewritten as

$$\frac{1}{\sigma}\frac{C_t}{S_t} = \frac{k}{k-(\sigma-1)}\frac{w_t f_t}{A_t^{\theta}}. \tag{22}$$

Using average firm productivity and the Pareto density function, the Schumpeterian survival rate is

$$\frac{S_t}{N_t} = z_{\min}^{k}\left[\frac{k}{k-(\sigma-1)}\right]^{\frac{k}{\sigma-1}}\widetilde{z}_{s,t}^{-k}. \tag{23}$$

In the end, average operational profits among *potential* producers are given by

$$\widetilde{d}_t = \frac{S_t}{N_t}\widetilde{d}_{s,t}. \tag{24}$$

2.3. Labor market clearing

Labor markets should be clear in equilibrium. L_t units of endogenously supplied labor forces are employed in the production of goods (intensive margins) and creation of firms (extensive margins):

$$L_t = S_t l_t\left(\widetilde{z}_{s,t}\right) + H_t l_{E,t}. \tag{25}$$

The above condition can be further developed as follows[5]

$$L_t = S_t\left[(\sigma-1)\frac{\widetilde{d}_{s,t}}{w_t} + \sigma\frac{f_t}{A_t^{\theta}}\right] + H_t\frac{v_t}{w_t}. \tag{26}$$

This condition is equivalent to the aggregated identity which can be obtained by summing budget constraints among households: $Y_t \equiv C_t + v_t H_t = L_t w_t + S_t\widetilde{d}_{s,t}$, whereby Y_t stands for real GDP measured in welfare basis from expenditures and income. In total, the model consists of 11 equations and 11 endogenously determined variables among which the number of potential producers, N_t, behaves like a state variable. Table 1 summarizes the benchmark model.

[5]Note that

$$\widetilde{d}_{s,t} = \frac{\widetilde{\rho}_{s,t}}{\sigma}\widetilde{y}_{s.t} - \frac{w_t f_t}{A_t},$$

where $\widetilde{y}_{s,t}$ is average intensive margins.

Table 1: Summary of the benchmark model

Average pricing	$\widetilde{\rho}_{s,t} = \frac{\sigma}{\sigma-1}\frac{w_t}{A_t \widetilde{z}_{s,t}}$
Variety effect	$\widetilde{\rho}_{s,t} = S_t^{\psi}$
Average survivors' profits	$\widetilde{d}_{s,t} = \frac{1}{\sigma}\frac{C_t}{S_t} - \frac{w_t f_t}{A_t^{\theta}}$
Average profits	$\widetilde{d}_t = \frac{S_t}{N_t}\widetilde{d}_{s,t}$
Free entry condition	$v_t = \frac{w_t f_{E,t}}{A_t^{\vartheta}}$
Motion of firms	$N_{t+1} = (1-\delta)(N_t + H_t)$
Euler equation	$v_t = \beta(1-\delta) E_t \left(\frac{C_{t+1}}{C_t}\right)^{-1}\left(v_{t+1} + \widetilde{d}_{t+1}\right)$
Optimal labor supply	$\chi (L_t)^{\frac{1}{\psi}} = w_t C_t^{-1}$
ZCP	$\frac{1}{\sigma}\frac{C_t}{S_t} = \frac{k}{k-(\sigma-1)}\frac{w_t f_t}{A_t^{\theta}}$
Schumpeterian surviving rate	$\frac{S_t}{N_t} = z_{\min}^k \left[\frac{k}{k-(\sigma-1)}\right]^{\frac{k}{\sigma-1}} \widetilde{z}_{s,t}^{-k}$
Labor market clearing	$L_t = S_t\left[(\sigma-1)\frac{\widetilde{d}_{s,t}}{w_t} + \sigma\frac{f_t}{A_t^{\theta}}\right] + H_t\frac{v_t}{w_t}$

3. Entry selection

In the benchmark model, we know which firms exit: less efficient firms. However, we do not know which firms enter since entry is assumed to be identical. As an extension, I introduce preselection in entry.

Upon entry, "potential" entrants draw a productivity level from the same Pareto distribution $G(z)$. Among $N_{E,t}$ potential entrants, however, only a subset of H_t firms actually enter and their entry costs are financed by households. In equilibrium, the expected firm value multiplied by the probability of successful entry must be equal to sunk entry costs, providing the following free entry condition:[6]

$$\frac{H_t}{N_{E,t}} v_t = \frac{w_t f_{E,t}}{A_t^{\vartheta}}. \tag{27}$$

Less efficient potential entrants who have drawn a lower productivity level than the cutoff give up to enter. I assume for the sake of simplicity that firms never try to enter

[6] This is considered an R&D process to get an innovative idea which materializes. Lee and Mukoyama (2008) also consider such preselection in entry.

again once they are eliminated in this preselection. The firm with the cutoff productivity level $z_{h,t}$ sees $v(z_{h,t}) = 0$, implying $E_t d_{t+1}(z_{h,t}) = 0$, which gives the following zero cutoff profit condition for entry (ZCPE)[7]

$$\frac{1}{\sigma} E_t \left[\frac{S_{t+1}}{N_{t+1}} \frac{C_{t+1}}{S_{t+1}} \left(\frac{\widetilde{z}_{h,t}}{\widetilde{z}_{s,t+1}} \right)^{\sigma-1} \right] = \frac{k}{k-(\sigma-1)} E_t \left[\frac{S_{t+1}}{N_{t+1}} \frac{w_{t+1} f_{t+1}}{A_{t+1}^{\theta}} \right]. \tag{28}$$

Using the Pareto distribution $G(z)$ defined previously, we have

$$\frac{H_t}{N_{E,t}} = z_{\min}^{k} \left[\frac{k}{k-(\sigma-1)} \right]^{\frac{k}{\sigma-1}} \widetilde{z}_{h,t}^{-k}. \tag{29}$$

The above two equations determine $\widetilde{z}_{h,t}$ and H_t.

Because the number of new entrants which do enter always amounts to H_t, the labor market clearing condition (26) remains the same as in the previous model while the free entry condition is modified as in (27). Finally, with the extended version, the model contains two additional equations, (28) and (29), and two additional variables, $N_{E,t}$ and $\widetilde{z}_{h,t}$.

Accordingly, in the entry selection model, the number of destroyed firms at entry is defined as

$$D_t^H \equiv N_{E,t} - H_t. \tag{30}$$

Gross destruction at time t is then given by

$$D_t \equiv D_t^S + D_t^\delta + D_t^H. \tag{31}$$

where D_t^S and D_t^δ have the same definition as in the benchmark model.

4. A model without Schumpeterian destruction

It would be particularly useful to consider a model without endogenous Schumpeterian destruction. Such a model is obtained by removing operational fixed costs. That is, setting

[7] See Appendix B for the derivation.

$f_t = 0$ for all periods. This implies that $N_t = S_t$ since every potential producer produces regardless of their specific productivity level. From (23), the average productivity level of producers remains at its steady state level: $\widetilde{z}_{s,t} = \widetilde{z}_s$. Therefore, a non-Schumpeterian economy contains two less equations compared to the benchmark model.

5. Calibration

5.1. Choice of parameters' values, the non-stochastic steady state and productivity process

Table 2: Parametrization for the benchmark economy

β	discount factor	0.96
φ	Frisch elasticity of labor supply	2
σ	elasticity of substitution among varieties	3.8
ψ	love for variety	$1/(\sigma - 1)$
δ	death shock	0.01

Calibration is performed on an annual basis. The parameters in the models are chosen as in Table 2. The value of discount factor (β) and the Frisch elasticity of labor supply (φ) are set to 0.96 and 2, respectively. These values are well in the range used in the literature.

The elasticity of substitution among varieties (σ) is set to 3.8, following Ghironi and Melitz (2005) who choose it based on empirical findings of Bernard et al. (2003) about U.S. manufacturing plants and macro trade data. Bernard et al. (2003) also document that the standard deviation of log U.S. plant sales is 1.67. The corresponding standard deviation in the theoretical model is given by $1/(k - \sigma + 1)$, according to which the value of k is provided. I set ψ, the love for variety, at $1/(\sigma - 1)$ according to the Dixit-Stiglitz preference. The destruction rate (δ) is set to 0.01, implying that one percent of potential producers exit exogenously per year on average.

Variables in the non-stochastic steady state are expressed without a time index. I assume that $A = f_E = z_{\min} = 1$ without loss of generality. The average annual destruction rate of U.S. manufacturing establishment is 0.093 in the data. In the benchmark model, I set f (the steady state value of subsides) to 0.0073 so that the Schumpeterian endogenous destruction rate, $1 - S/N$, becomes 0.083 provided the value of δ. In the same manner, for the extended version of the model, f is set to 0.0079 so as to replicate the annual destruction rate in the data. The parameter value χ is determined such that the steady state labor supply becomes unity. See Appendix C for detail on the steady state.

The productivity process is estimated using a Solow residual such as $\ln A_t = \ln Y_t - 0.64 \ln L_t$ where Y_t and L_t represent time series of U.S. real GDP and hours worked for the period 1977 to 2009. The $\ln A_t$ is assumed to follow an AR(1) process: $\ln A_t = a + \rho \ln A_{t-1} + \epsilon_t$. The OLS estimation provides the value of the AR(1) coefficient, ρ, as 0.98 and the standard deviation of the shock, ϵ_t, as 0.019. The spillover coefficients of productivity on these costs are chosen to be $\vartheta = 0.25$ and $\theta = 0.50$ arbitrarily. Since they control the degree of entry and exit margins, these coefficients are of particular interest and sensitivity analyses with respect to these values are performed in the following section.

5.2. Impulse response functions

Through Figure 2 to Figure 4, impulse response functions following one percent negative productivity shock, one percent permanent reduction in entry costs f_E and operational fixed costs f are reported. These are obtained for two Schumpeterian economies (solid blue lines for the benchmark and marked green lines for the entry selection model) and the non-Schumpeterian economy (dotted red lines). In these figures, vertical axes measure percent deviations from the steady state values and horizontal axes represent years. In addition, I present those of GDP, $Y_{R,t}$, consumption, $C_{R,t}$, and investment, $I_{R,t} \equiv v_{R,t} H_t$ which are measured in "empirical-basis" abstracting the welfare impact arising from fluctuations in extensive margins. Following Ghironi and Melitz (2005), any real variable X_t measured in welfare-based CPI, P_t, are transformed to those $X_{R,t}$ deflated with the empirical-based CPI, $\widehat{P}_t$, by the following operation: $X_{R,t} \equiv P_t X_t / \widehat{P}_t$.

5.2.1. Recessionary productivity shock

In the non-Schumpeterian economy, gross destruction D_t remains almost stable, however, it rises sharply in Schumpeterian economies following a recessionary shock. The negative shock raises fixed operational costs on impact (captured in a rise in l_t) inducing the exit of less efficient firms. Accordingly, the average productivity level of producers $\widetilde{z}_{s,t}$ increases. As a result, surviving firms can charge a lower price $\widetilde{\rho}_{s,t}$ and their profits $\widetilde{d}_{s,t}$ and intensive margins $\widetilde{y}_{s,t}$ decline less than those in the non-Schumpeterian economy. Here, we observe the "cleansing effect of recessions" (Caballero and Hammour 1994). A recessionary shock wipes less efficient firms out and allocates resources toward more efficient firms. For welfare-based consumption C_t and wages w_t, however, three economies experience a similar pattern. In the non-Schumpeterian economy, these reductions are largely due to the reduction in intensive margins of each firm. On the other hand, the destruction of extensive margins S_t are compensated by the above mentioned smaller reduction in intensive margins $\widetilde{y}_{s,t}$ in the Schumpeterian economies.

Comparing the two Schumpeterian economies, the number of new entrants H_t decreases more sharply in the entry selection model than the benchmark. The average productivity level of new entrants $\widetilde{z}_{h,t}$ rises following a recessionary shock with preselection at entry.[8] Since potential producers who are going to face Schumpeterian destruction are already somewhat efficient, gross destruction D_t is less pronounced and the average productivity level of producers $\widetilde{z}_{s,t}$ rises less compared to the benchmark model.

5.2.2. Permanent entry deregulation

A permanent entry deregulation which makes sunk entry costs lower (a decline in $l_{E,t}$) boosts on impact the number of new entrants H_t who achieve a higher level at a new steady state in all three economies. Labor demand coming from these new firms pushes wages w_t up in the long run. A high wage rate induces the exit of less efficient firms which have failed to afford fixed operational costs in the Schumpeterian economies (a rise in D_t and $\widetilde{z}_{s,t}$). Accordingly, efficient producers make higher profits $\widetilde{d}_{s,t}$ and expand their production scale $\widetilde{y}_{s,t}$. Although the number of producers S_t remains almost unchanged,

[8] Lee and Mukoyama (2008) report that the relative productivity of entering plants in recessions are about 10-20% higher than that of entering plants in booms. In contrast, they find that the relative productivity of exiting plants is similar across business cycle fluctuations.

due to a simultaneous increase in both entries and destructions, firms are more efficient in a new steady state in Schumpeterian economies. In contrast, there is "sclerosis", i.e. *the survival of production units that would not survive in an efficient equilibrium* (Caballero and Hammour 2005) in the non-Schumpeterian economy. Producers in the non-Schumpeterian economy make less profits and reduce their intensive margins due to the non-replaced or non-renewed inefficient producers.[9]

The number of new entrants H_t rises less in the entry selection model than the benchmark model. With an increase in the expected future fixed costs induced by a rise in w_t, the average productivity level of new entrants $\widetilde{z}_{h,t}$ increases as well. As is the case for a recessionary shock, because of this preselection, the rise in gross destruction D_t and productivity level of producers $\widetilde{z}_{s,t}$ are less pronounced in the entry selection model.

5.2.3. Permanent subsidy

Figure 4 presents impulse response functions following a permanent one percent reduction in fixed operational costs f. In the Schumpeterian economies, gross destruction D_t decreases and the number of producers S_t rises as a result of such a subsidy policy. Accordingly, incumbents become less efficient (a decrease in $\widetilde{z}_{s,t}$), make less profits $\widetilde{d}_{s,t}$ and reduce their production scale $\widetilde{y}_{s,t}$ at a new steady state. Caballero et al. (2008) analyze "zombie lending", i.e. financial support for inefficient firms/zombies. They argue that congestion created by zombies has depressed the restructuring process in Japan. The implication of the subsidy policy considered here is very similar to that obtained under zombie lending. Since there are no such costs, all variables in the non-Schumpeterian economy remain at their steady state levels.

For both Schumpeterian economies, factor price w_t becomes expensive because of labor demand coming from these less efficient producers. In the benchmark model, such a rise in input costs is high to the extent that it discourages firm entry (a stable H_t). In the entry selection model, the same policy induces a higher number of new entrants (a rise in H_t),

[9]In contrast to Caballero and Hammour (2005), there is no "scrambling" that reduces the effectiveness of the restructuring process related to financial constraints of firms.

however, they are less efficient (a decrease in $\widetilde{z}_{h,t}$), due to expected subsidies in production. Since producers are already somewhat inefficient, a decrease in gross destruction D_t and average productivity level $\widetilde{z}_{s,t}$ are less pronounced in the entry selection model compared to the benchmark model.

5.3. Second moments of the theoretical models

Table 3: Second moments

		Y_R	C_R	I_R	L	H	D
St.div (%)	U.S. Data	1.33	0.73	5.25	0.38	4.62	5.22
	Benchmark	1.17	0.94	5.35	0.19	4.62	5.10
	With entry selection	1.47	0.80	11.80	0.57	11.32	3.41
	No endo. destruction	1.30	1.10	6.14	0.18	5.25	0.05
Relative to Y_R	U.S. Data	1	0.55	3.94	0.28	3.47	3.92
	Benchmark	1	0.80	4.59	0.17	3.96	4.37
	With entry selection	1	0.55	8.01	0.39	7.68	2.34
	No endo. destruction	1	0.85	4.74	0.14	4.05	0.04
Corr(Y_R. X)	U.S. Data	1	0.78	0.95	0.67	0.43	-0.15
	Benchmark	1	1.00	1.00	0.99	1.00	-1.00
	With entry selection	1	0.99	0.99	0.99	0.99	-0.99
	No endo. destruction	1	1.00	1.00	0.99	1.00	0.59

Table 3 provides second moments of principal variables for the U.S. data as well as benchmark, entry selection and non-Schumpeterian economies.[10] With the productivity process and parameters' values previously specified, both Schumpeterian economies can be successful in reproducing a high standard deviation for destruction margins D as observed in the data (3.92 relative to GDP). They are 4.37 in the benchmark and 2.34 in

[10] All series are detrended by HP filter. Smoothing parameter is set to 6.25. Second moments of the theoretical models are computed by the frequency domain techniques proposed by Uhlig (1998). For the U.S. series, see Appendix A.

the entry selection model. In contrast, a non-Schumpeterian economy without endogenous destruction fails to capture this empirical fact. The standard deviation for entry margins H and investment I_R become higher in the entry selection model (7.68 and 8.01) compared to the benchmark and non-Schumpeterian economies. As has been explained in the previous sections, these are related to entry preselection which induces higher volatility in H. The standard deviations of other variables are similar in all three models and successful in replicating the data.

Firm entry is procyclical and exit is slightly countercyclical in the data (0.43 and -0.15, respectively). Lee and Mukoyama (2008) also report the same pattern about U.S. manufacturing firms. Using a data set that contains the universe of products with bar codes purchased by U.S. households, Broda and Weinstein (2010) document that product creation is highly procyclical and product destruction is countercyclical but with less important magnitude. All three models provide a procyclical pattern for entry of variety-representing firms, although it is more pronounced than in the data. Only the Schumpeterian economies, however, are successful in reproducing the countercyclical pattern for destruction (-1.00 in the benchmark and -0.99 in the entry selection model). The strong cyclicality in creation and destruction margins would be related to the absence of adjustment costs in the theoretical models. More fundamentally, as is clear, the cyclicality of these margins are very sensitive to cyclical properties of fixed operational costs, $w_t f_t / A_t^{\theta}$, and entry costs, $w_t f_{E,t} / A_t^{\vartheta}$. I investigate this point in the next section.

6. Shock transmission

6.1. Fixed operational costs

Figure 5 shows sensitivity analyses for standard deviations and correlations of entry and exist against the spillover coefficient of productivity shock on fixed operational costs (θ). The upper and lower panels are those obtained in the benchmark and entry selection model, respectively. Both models show very similar patterns.

When θ rises from 0 to 1, the correlations of destruction margins change from positive to negative and their variances increase. Because a higher θ implies more expensive operational costs following a negative productivity shock, destruction increases when θ is high and becomes highly volatile and countercyclical.

The same intuition extends to impulse response functions. Figure 6 provides those obtained under $\theta = 0.25$ and $\theta = 0.1$ following a negative productivity shock as in Figure 2. As previously, when $\theta = 0.1$, there is less endogenous destruction on impact of the shock since fixed operational costs rise less. In particular, recovery takes place with less destruction than the steady state level. Accordingly, the average productivity level of surviving firms $\widetilde{z}_{s,t}$ decreases as well. As a result, cumulative destruction decreases when $\theta = 0.1$ while it rises when $\theta = 0.25$.

Figure 6 shows that entry margins H, which decline on impact rise slightly along recovery in both Schumpeterian economies regardless of the value of θ. As a result, both cumulative destruction and entry remain low when $\theta = 0.1$. Such a pattern is consistent with the "reverse-liquidationist view" argued in Caballero and Hammour (2005). Recovery takes place with a lower level of destruction rather than a higher level of creation.

6.2. Sunk entry costs

Figure 5 also reports sensitivity analyses against ϑ, the spillover coefficient on sunk entry costs. Again the upper and lower panels are those obtained in the benchmark and entry selection model, respectively. When ϑ rises, the negative correlation of destruction margins with real GDP and the variance of destruction margins decreases.

The intuition would be better described by impulse response functions. Figure 7 provides those obtained under $\vartheta = 0.25$ and $\vartheta = 0.9$ for both Schumpeterian economies following a recessionary shock as in Figure 2. Since a higher value of ϑ implies a more expensive entry cost under a negative shock, creation margins H experience a sharper decrease on impact and cumulative creation becomes lower when $\vartheta = 0.9$, compared to those obtained under $\vartheta = 0.25$. Because of such a sharp decrease in creation margins, which alleviates the pressure on labor demand realizing a lower wage, destruction can end up being shielded along the pass of recovery. As a result, we observe a less countercyclical pattern of destruction when ϑ is high as in the Figure 5. This is exactly "the insulation effect of creation" on destruction margins argued in Caballero and Hammour (1994).

Figure 7 also show the "reverse-liquidationist" pattern of recovery as is the case for lower transmission of fixed operational costs.

7. Conclusion

This paper investigates destruction as well as creation margins with a DSGE model based on monopolistic competition. Destruction among variety-representing firms endogenously takes place depending on firm-specific productivity levels following shocks. The models in the paper are capable of reproducing high firm turnover as in the U.S. data and the properties which are typical of models of Schumpeterian economies.

Relying on monopolistic competition, it would be relatively easy to extend the models, especially to embody demand-driven recessions in the presence of nominal rigidities. Also, it would be interesting to incorporate multiproduct firms, as reported in Broda and Weinstein (2010) and Bernard, Redding and Schott (2006, 2010). Another important direction would be to consider vertical as well as horizontal differentiation in product varieties and see welfare consequences in a Schumpeterian environment.

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Appendix A. Data

The U.S. data about establishment entry and exit and job creation and destruction in manufacturing sector are taken from Business Dynamics Statistics (BDS) of the U.S. Census Bureau. The series of U.S. real GDP, consumption (private plus government expenditures), investment (fixed capital formation), labor (hours worked) are taken from the OECD data base.

Appendix B. Deriving the ZCPE

For the ZCPE, we argued that $E_t d_{t+1}(z_{h,t}) = 0$. This condition can be transformed as follows:

$$
\begin{aligned}
E_t d_{t+1}(z_{h,t}) = E_t \frac{S_{t+1}}{N_{t+1}} d_{s,t+1}(z_{h,t}) \\
= E_t \frac{S_{t+1}}{N_{t+1}} \left(\frac{1}{\sigma} S_{t+1}^{\psi(\sigma-1)-1} \rho_{t+1}^{1-\sigma}(z_{h,t}) C_{t+1} - \frac{w_{t+1} f_{t+1}}{A_{t+1}^{\theta}} \right) \\
= E_t \frac{S_{t+1}}{N_{t+1}} \left(\frac{1}{\sigma} \frac{k-(\sigma-1)}{k} S_{t+1}^{\psi(\sigma-1)-1} \rho_{t+1}^{1-\sigma}(\widetilde{z}_{h,t}) C_{t+1} - \frac{w_{t+1} f_{t+1}}{A_{t+1}^{\theta}} \right) \\
= E_t \frac{S_{t+1}}{N_{t+1}} \left[\frac{1}{\sigma} \frac{k-(\sigma-1)}{k} \frac{C_{t+1}}{S_{t+1}} \left(\frac{\widetilde{z}_{h,t}}{\widetilde{z}_{s,t+1}} \right)^{\sigma-1} - \frac{w_{t+1} f_{t+1}}{A_{t+1}^{\theta}} \right] = 0, \quad \text{(B.1)}
\end{aligned}
$$

where, for the third identity, I have used the equilibrium pricing conditions (20) and (19) and, for the fourth identity, the definition of the price index and real price.

Appendix C. Steady state

I start by arguing the steady state of the benchmark model. The Euler equation (8) gives

$$
\frac{1}{\beta} = (1-\delta)\left(1 + \frac{\widetilde{d}}{v}\right). \tag{C.1}
$$

Using (21), the ZCP (22) can be transformed as

$$
\frac{\widetilde{d}_s}{w} = \frac{\sigma-1}{k-(\sigma-1)}. \tag{C.2}
$$

We have $\widetilde{d} = S\widetilde{d}_s/N$ from (24) and $v = w$ from the free entry condition (13). Using these relations, (C.1) can be expressed as

$$
\frac{1}{\beta} = (1-\delta)\left(1 + \frac{S}{N}\frac{\sigma-1}{k-(\sigma-1)} f\right). \tag{C.3}
$$

The above equation provides the steady state Schumpeterian destruction rate, S/N, given f.

I set the value of χ so that the steady state labor supply equals to the unity. Note also from the law of motion (3), we have $H = \delta N/(1-\delta)$. Plugging these relations in the labor market clearing condition (26), we get

$$\frac{1}{N} = (\sigma - 1)\,\frac{S}{N}\frac{\sigma - 1}{k - (\sigma - 1)} f + \sigma \frac{S}{N} f + \frac{\delta}{1 - \delta} \tag{C.4}$$

Provided the value of S/N, the above equation yields the unique solution for N. Knowing S, the steady state values of other variables are easily found.

For the model with entry selection, only the free entry condition is modified as $Hv/N = w$ in the above procedure. In the place of (C.3) and (C.4), we have

$$\frac{1}{\beta} = (1 - \delta)\left(1 + \frac{H}{N_E}\frac{S}{N}\frac{\sigma - 1}{k - (\sigma - 1)} f\right), \tag{C.5}$$

and

$$\frac{1}{N} = (\sigma - 1)\,\frac{S}{N}\frac{\sigma - 1}{k - (\sigma - 1)} f + \sigma \frac{S}{N} f + \frac{\delta}{1 - \delta}\left(\frac{H}{N_E}\right)^{-1}. \tag{C.6}$$

Because there is no difference between entry and exit selection, the rate of destruction in entry and exit coincides as $S/N = H/N_E$ in such a non-stochastic steady state. Provided the value of f, the above equations give the value of N and those of other variables are easily found.

For the model without Schumpeterian destruction, it is assumed that $f = 0$. As a result we have $S/N = 1$, $\widetilde{d} = \widetilde{d}_s$ and from the Euler equation

$$\frac{1}{\beta} = (1 - \delta)\left(1 + \frac{\widetilde{d}_s}{v}\right). \tag{C.7}$$

Combined with the free entry condition and the law of motion, the labor market clearing condition gives

$$\frac{1}{N} = (\sigma - 1)\left[\frac{1}{\beta\,(1 - \delta)} - 1\right] + \frac{\delta}{1 - \delta}. \tag{C.8}$$

The above equation determines the value of N. It is relatively easy to find the steady state value for other variables.

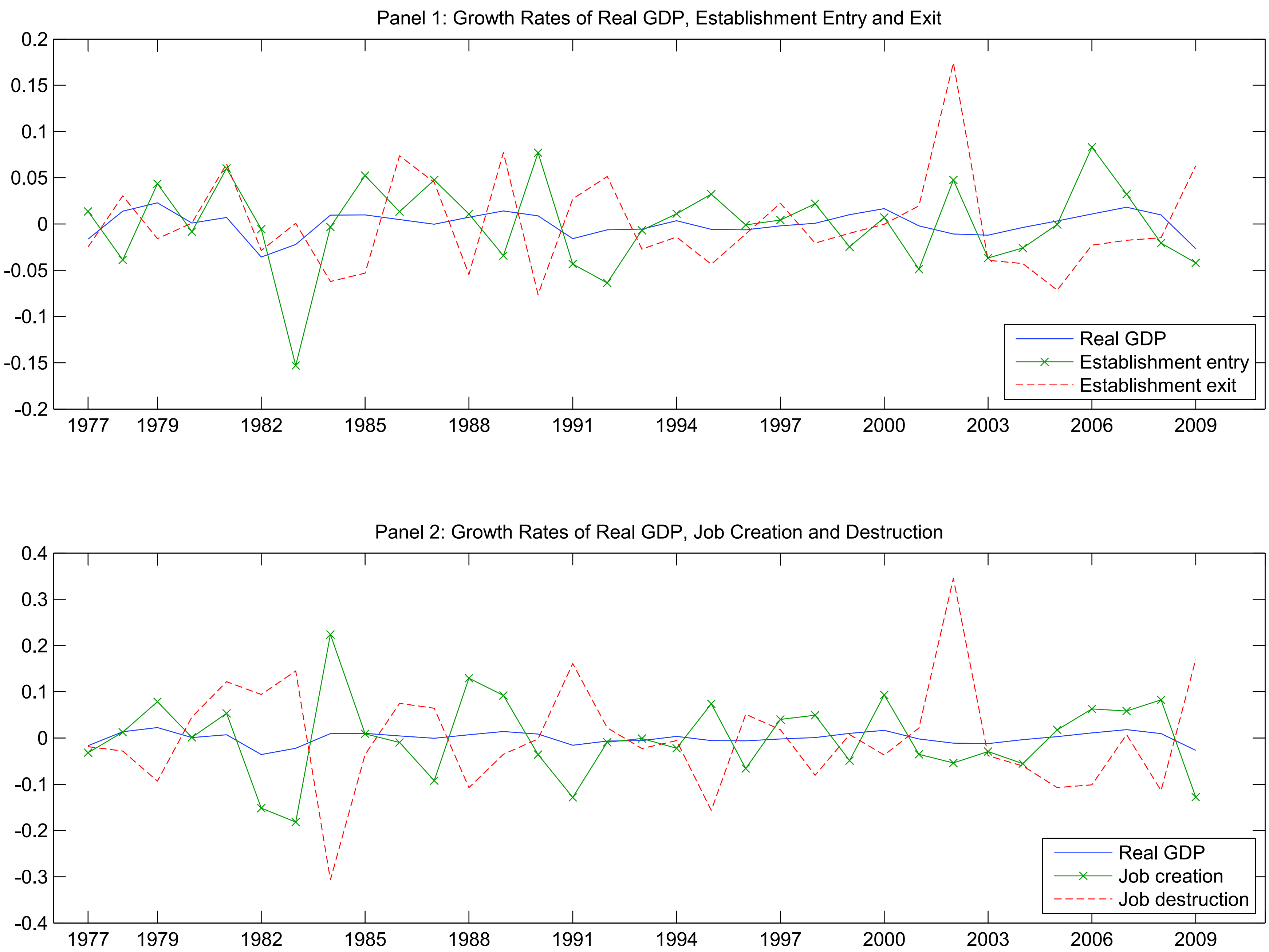

Figure 1: U.S. data

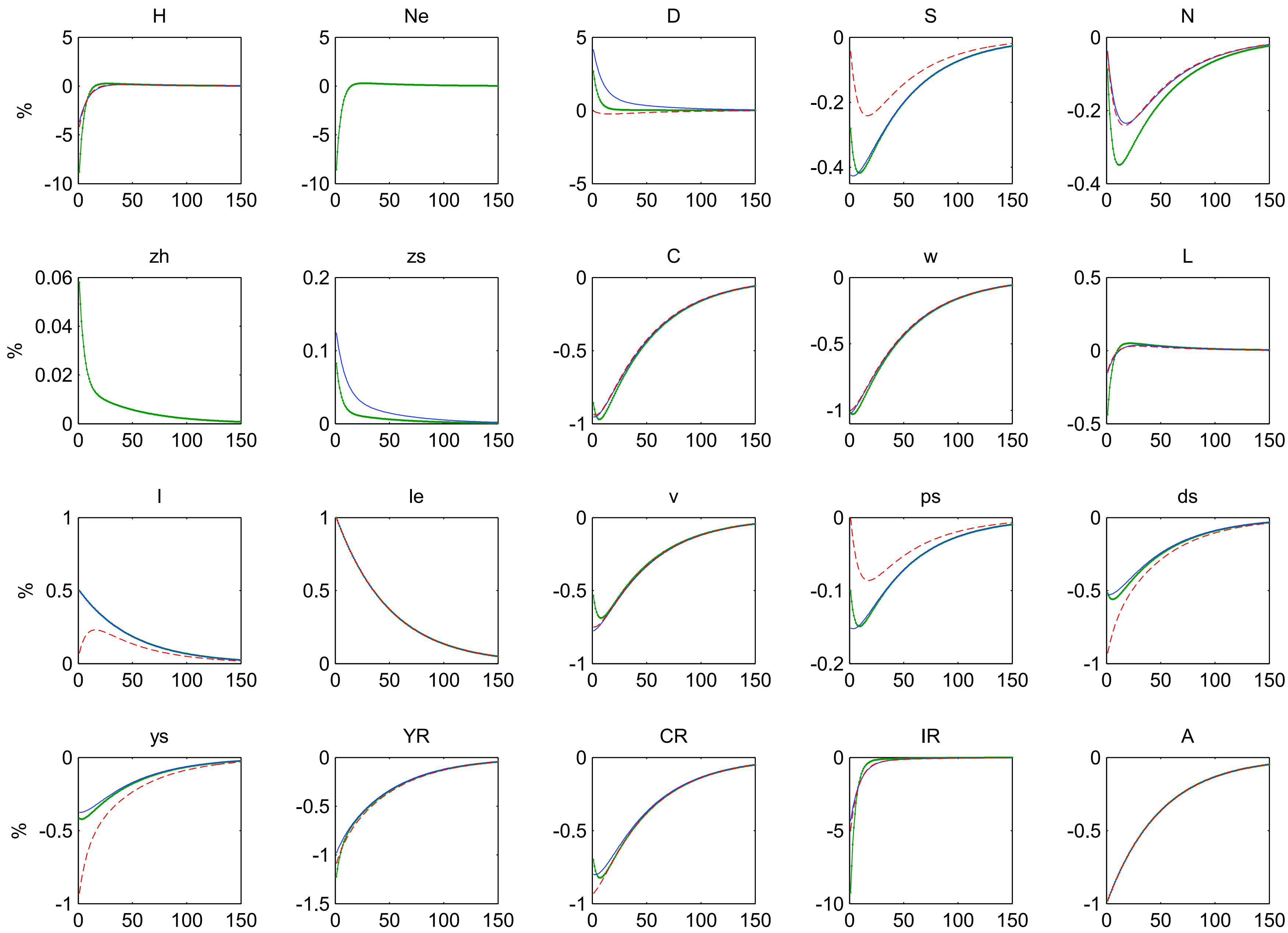

Figure 2: Recessionary Shock

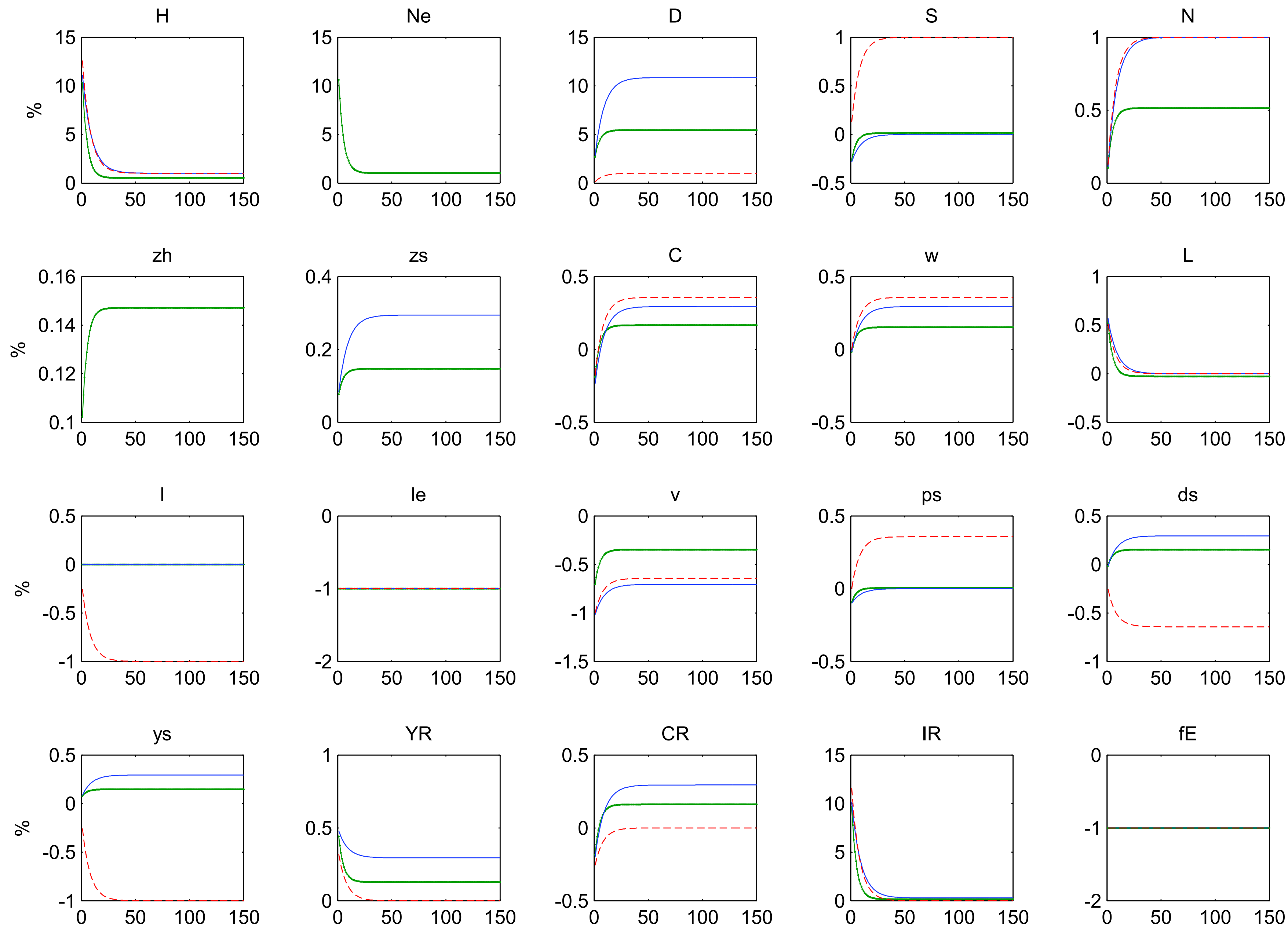

Figure 3: Permanent Deregulation Shock

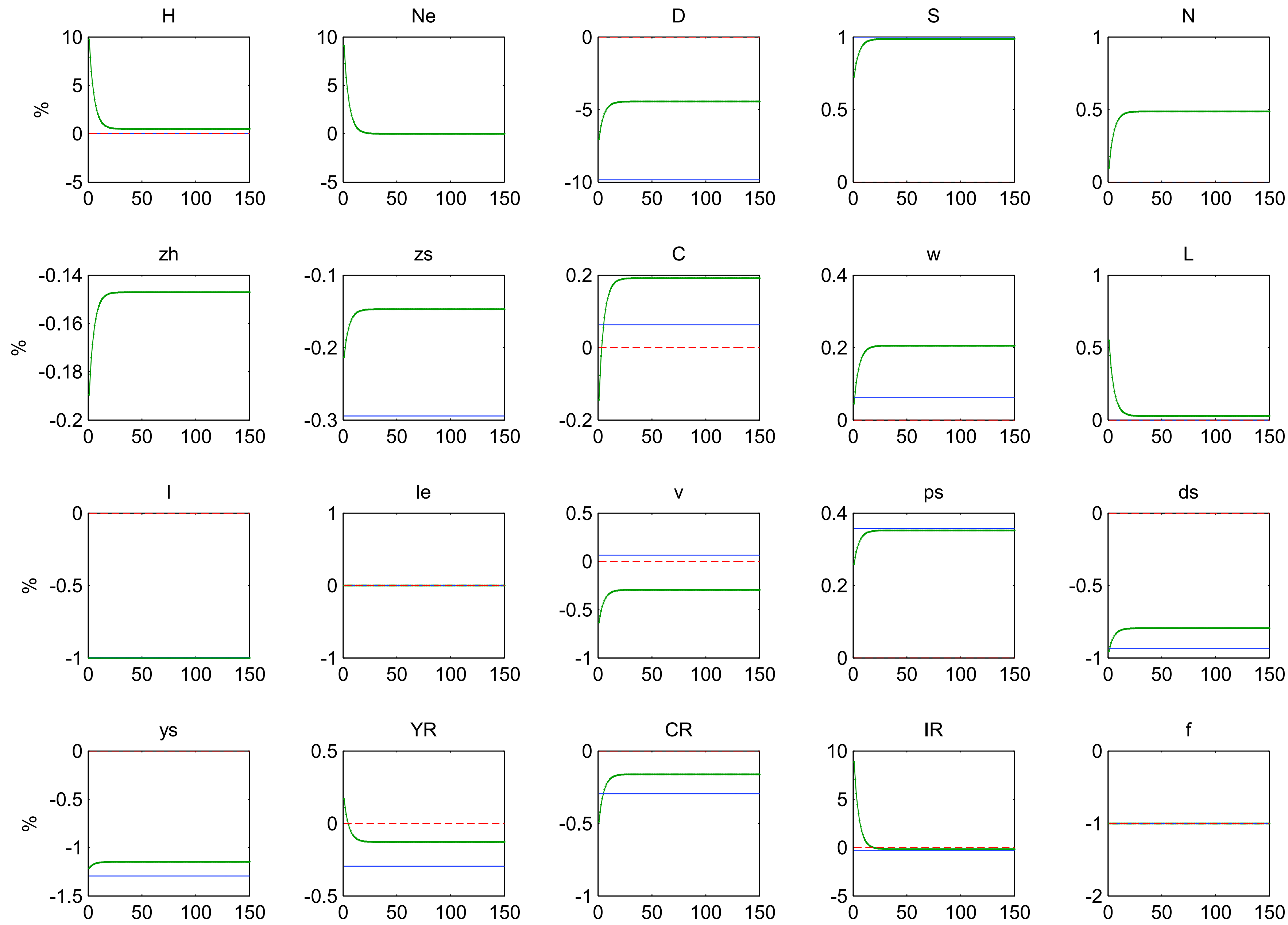

Figure 4: Permanent Subsidy Shock

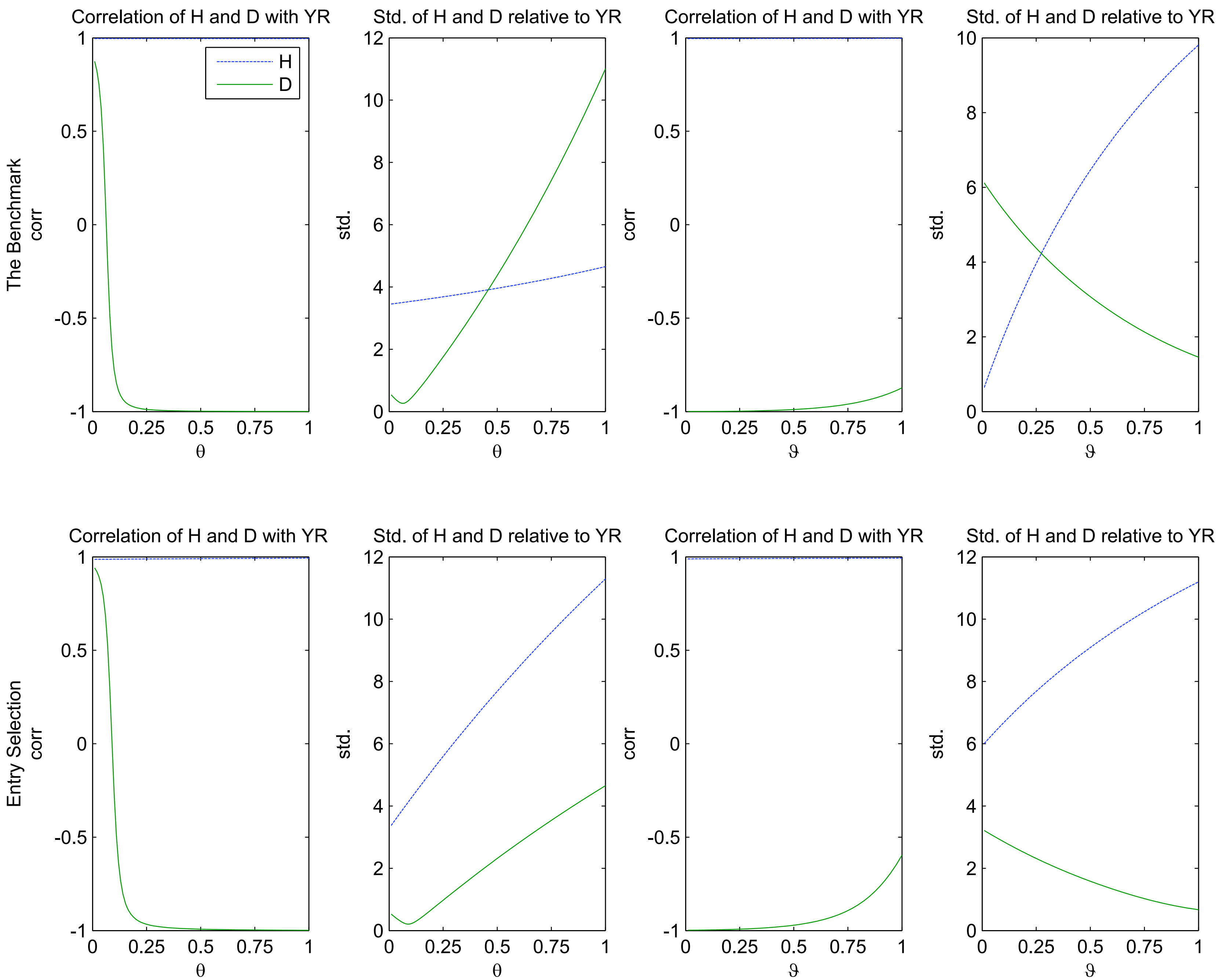

Figure 5: Sensitivity Analyses

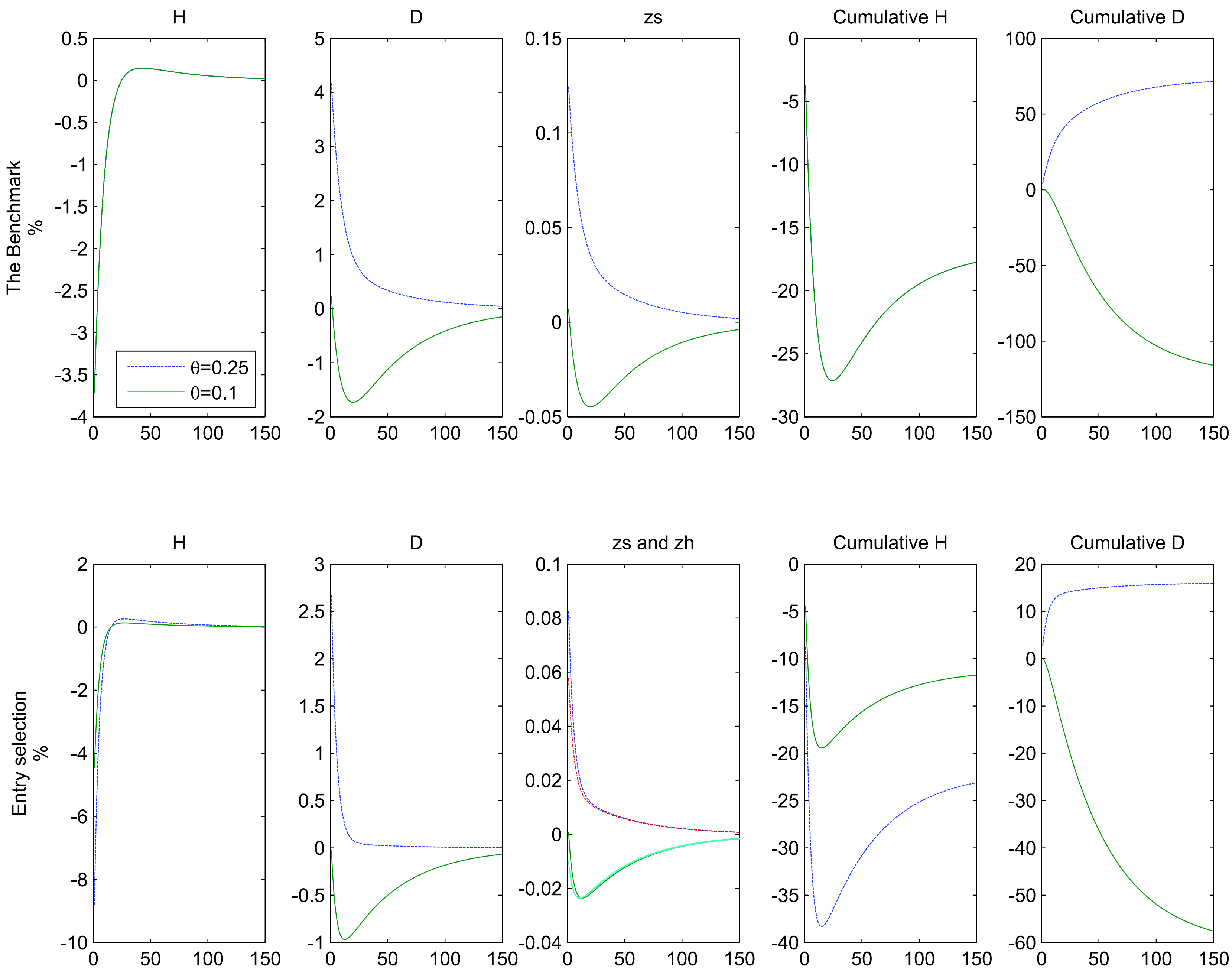

Figure 6: Recessionary Shock with θ=0.1

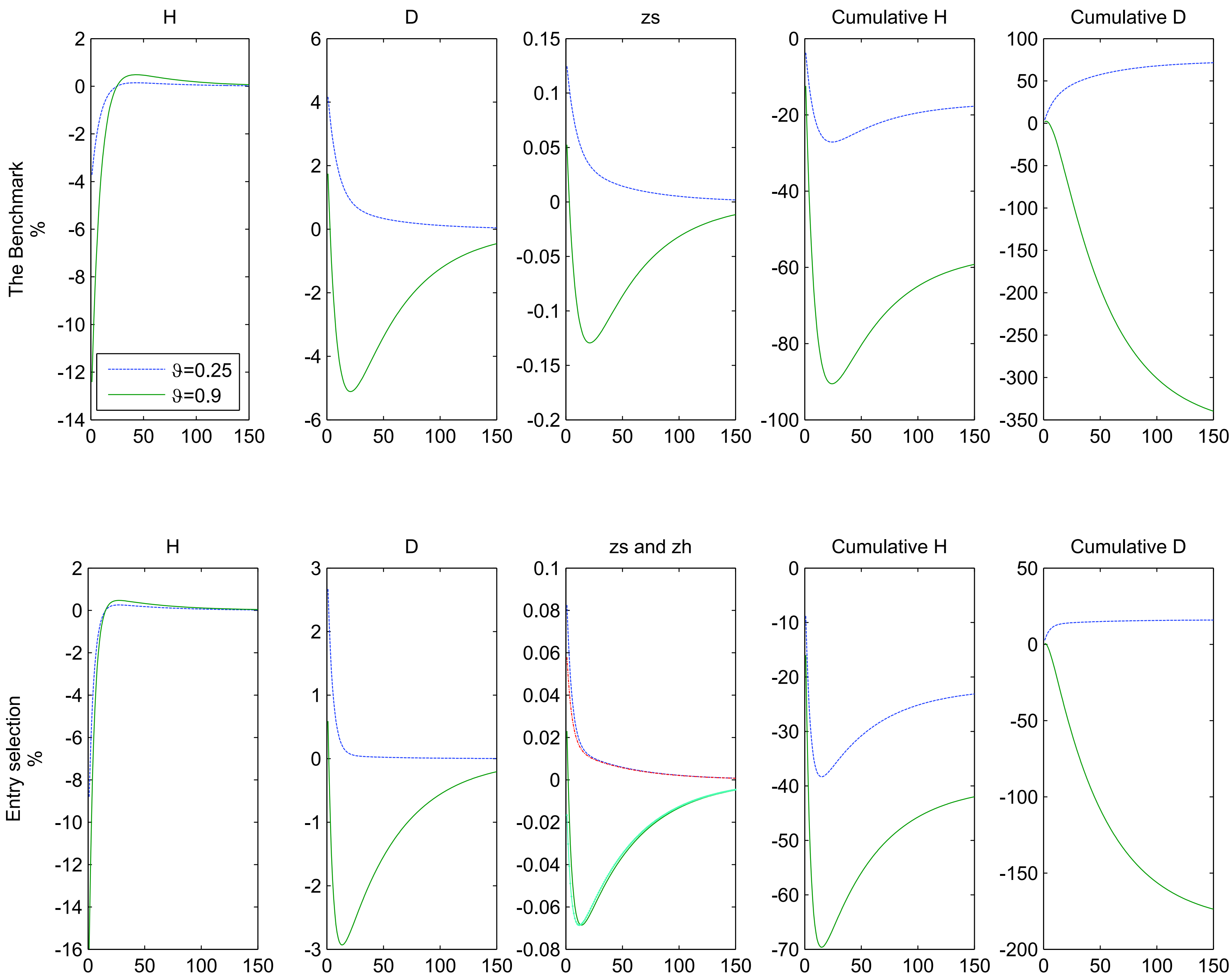

Figure 7: Recessionary Shock with ϑ=0.9