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**Endogenous Product Turnover and Macroeconomic Dynamics**

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# Endogenous Product Turnover and Macroeconomic Dynamics\*

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## Abstract

This paper introduces endogenous products entry and exit based on creation and destruction of product variety in a general equilibrium model. Recessionary technology shocks induce exit of unprofitable products on impact, allocating resources towards more productive production lines. However, during the recovery phase less productive production lines survive destruction, counteracting the original increase in productivity. The analysis shows that recoveries hinge on lower product destruction rather than higher product creation. Endogenous product destruction is critical to evaluate the effect of permanent policies of entry deregulation and subsidies aimed to stimulate the economy.

*Keywords:* Firm heterogeneity, endogenous product destruction, business cycles.

*JEL:* D24, E23, E32, L11, L60.

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# 1 Introduction

The importance of product creation and destruction as determinants of market performance is well recognized.<sup>1</sup> Recent research uses general equilibrium models to investigate the relevance of both margins of adjustment and show that either they play little role for business cycle fluctuations or product creation is the dominant margin of adjustment, thereby suggesting that a constant product destruction is a plausible modelling assumption.<sup>2</sup> This paper revisits the importance of product destruction for macroeconomic dynamics and it shows that product destruction generates significant macroeconomic dynamics. It takes a broader view on establishment entry and exit as product creation and destruction, which take place over the length of a cycle. As we describe in detail below, under this assumption, product destruction generates significant macroeconomic dynamics.

Our research is motivated by the observation that high establishment turnover, which is a good proxy for product turnover, is a robust stylized fact in aggregate data.<sup>3</sup> Figure 1 shows quarterly data on manufacturing establishment creation and destruction from the Business Employment Dynamics (BED) together with the real GDP for the period 1993:Q2 to 2012:Q3.<sup>4</sup> A few interesting patterns emerge. First, establishment creation and destruction rates are highly volatile. The standard deviations of establishment creation and destruction are equal to 4.19 and 4.68 respectively, which is more than four times higher than the standard deviation of real GDP and similar in magnitude to the

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<sup>1</sup>See Broda and Weinstein (2010) and references therein.

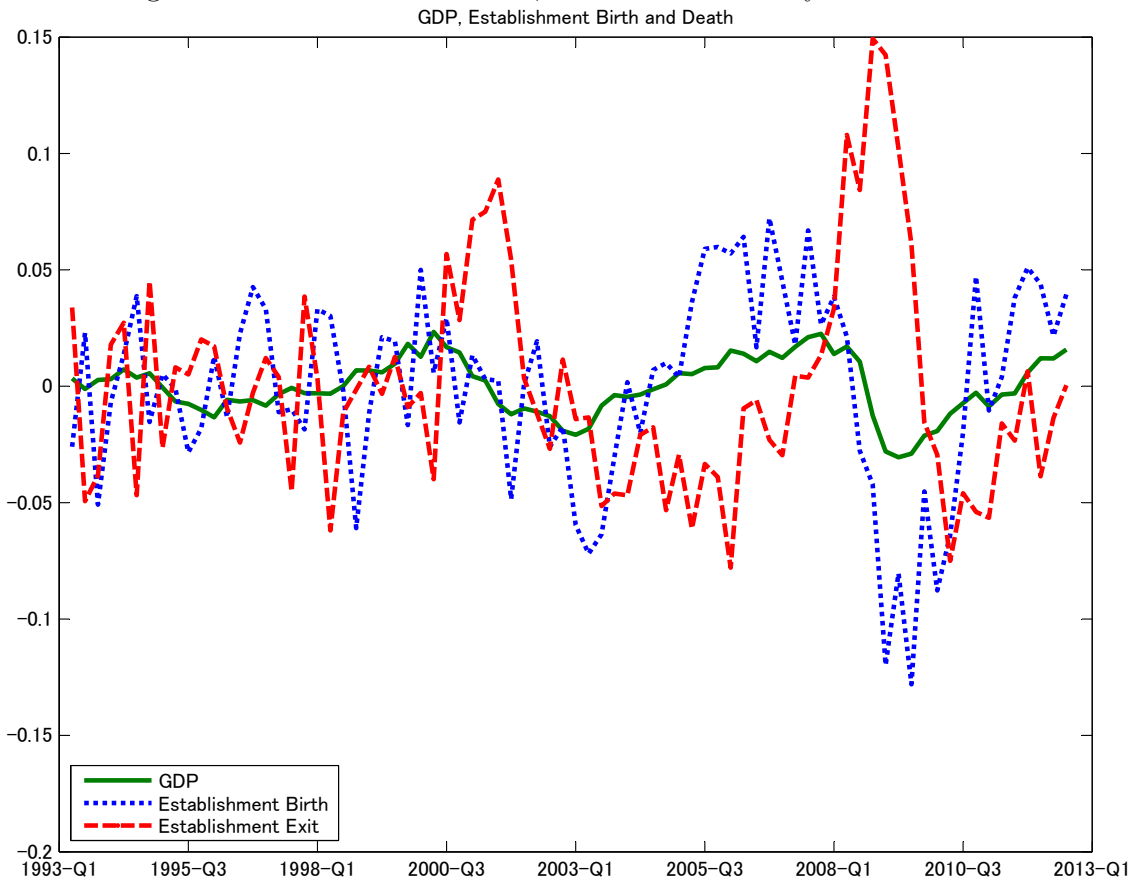
<sup>2</sup>See Ghironi and Melitz (2005) and Bilbiie et al. (2012) and references therein for a recent discussion of the issue.

<sup>3</sup>Data on establishment entry and exit provide a good proxy for product creation and destruction in single-product producing firms. Recent literature supports the multi-products and product-switching within a firm (Bernard et. al 2010). To the extent that firms have more than one production line, data on establishment entry and exit provide a conservative estimate of product turnover. See discussion in Broda and Weinstein (2010).

<sup>4</sup>Appendix A details the data. All series are detrended using the Hodrick-Prescott filter with smoothing parameter equal to 1600. Similar stylized facts are outlined in Davis and Haltiwanger (1992), Davis et al. 1998, Dunne et al. (1998, 1999).

standard deviation of investment. Specifically, in our data set, the standard deviation of destruction is more volatile than the standard deviation of creation. Second, the establishment creation rate is highly pro-cyclical and the establishment destruction rate is mildly countercyclical, with contemporaneous correlations to real GDP equal to 0.68 and -0.15, respectively. These statistics indicate that fluctuations in the establishment destruction rate are large, suggesting that product destruction, as proxied by establishment destruction, may play a non-trivial role for macroeconomic dynamics.

Figure 1: Growth rate of GDP, establishment entry and exit rates



Notes: The figure shows the business cycle component of the growth rate of GDP, establishment entry and exit rates. Data are from the Business Employment Dynamics.

Establishment entry and exit share similar patterns with job creation and job destruction and are highly correlated. The standard deviations of job creation and destruction are 8.52 and 11.53, and their correlations with real GDP are 0.73 and -0.51, respectively.

In addition, the contemporaneous correlation between establishment entry and job creation is 0.39 and the correlation between establishment exit and job destruction is 0.73. These statistics further suggest that movements in establishment exit are associated with large number of job losses, implying that product destruction may have significant effect on the economy.<sup>5</sup>

This paper sets up an innovative general equilibrium model that includes endogenous product destruction and creation and nests several tractable specifications as a special case. The baseline model embeds endogenous product destruction by introducing plant-specific heterogeneity, imposing that unprofitable production lines are terminated. The mechanism that generates endogenous product destruction is similar to the mechanism used in the trade literature by Melitz (2003) to generate exit dynamics in domestic and export markets.<sup>6</sup> In particular, we assume that production lines have different productivity levels and face a common operational cost. Following an aggregate technology shock, production lines that are unable to afford fixed operational costs shut down, making product destruction an additional margin of adjustment over the business cycle. Product creation is based on sunk entry costs faced by new production lines that limit the number of newly created products, as in Bilbiie et al. (2012). The model is extended to account for selective entry by assuming that product creation also depends on plant-specific productivity levels. Therefore newly created products must have sufficiently high productivity levels. With this extension, our model is able to investigate whether the plant-specific characteristics of newly created products generate substantial aggregate effects. This transmission channel is potentially important given the evidence that in recessions only profitable establishments are created. Thus, recessions increase the average productivity of newly

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<sup>5</sup>These statistics are based on annual data from the Business Dynamic Statistics of the US Census Bureau for the period 1977 to 2011. All series are detrended with the Hodrick-Prescott filter with smoothing parameter set to 6.25 (annual basis). The data is available at <http://www.census.gov/ces/dataproducts/bds/>.

<sup>6</sup>Ghironi and Melitz (2005) set up a model with endogenous change of exporting state based on heterogeneous productivity. However, the total number of domestic firms that are forced to exit is exogenously determined.

created firms that in turn increase the overall productivity in the economy. Finally, we extend the theoretical framework to study the effect of permanent entry deregulation and subsidies to production on the creation and destruction of products and macroeconomic dynamics.

The analysis establishes three main results. First, endogenous product destruction generates two competing effects on the allocation of resources. On impact, a recessionary technology shock eliminates less efficient production lines since it requires producers to have a higher plant-specific productivity level to retain profitability. The impact effect of a recession is to allocate resources toward more efficient products. However, in the aftermath of the shock, aggregate productivity recovers, requiring a lower level of plant-specific productivity to maintain profitable products. During the recovery phase, even less productive production lines are retained in the economy, and this effect counteracts the initial plant-specific productivity increase in the outset of recessions. The analysis shows that recoveries primarily are driven by a decrease in the destruction of unprofitable products rather than an increase in the creation of new products. In the aftermath of a recessionary shock, during the recovery phase, product creation steadily increases, returning to its original pre-recession level whereas product destruction declines at lower levels than its pre-recession level, therefore substantially contributing to the increase in products.<sup>7</sup> These findings are robust to the introduction of plant-specific productivity related with newly created products.

Second, we show that allowing for endogenous product destruction is critical to evaluate the effect of permanent policies targeted to stimulate the economy (i.e. from deregulation and subsidies to operational costs). In the presence of *exogenous* product destruction, market deregulation implemented with a permanent reduction in entry costs generates “sclerosis” (i.e. the survival of production units that would fail to survive in an efficient equilibrium) and leads to a lower firm-specific output in the long run.<sup>8</sup> A fall in entry costs stimulates product creation. However, if product destruction is constant, the

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<sup>7</sup>Caballero and Hammour (2005) document a similar empirical pattern that they call “reversed liquidationist view.”

<sup>8</sup>The term “sclerosis” was coined by Caballero and Hammour (2005).

number of products in the economy increases, pushing prices upwards and suppressing long-run profits and output. By contrast, in the presence of *endogenous* product destruction, higher product entry requires higher plant-specific productivity levels to make a product profitable, decreasing marginal costs and increasing long-run profits and output. Similarly, economic policies that permanently decrease operational costs have no effect on the economy if the product destruction rate is constant. However, in the presence of endogenous product destruction, a decrease in operational costs enables less productive firms to stay in the market, thereby reducing the long-run, plant-specific productivity in the economy.

Third, in our model, each firm is related to a production line. Therefore entry and operational costs are linked with set up and development costs associated with a particular variety, thus depending on exogenous productivity shocks. We show that the spillover effect of technology shocks to operational and entry costs are important for the cyclical properties of product destruction. In particular, if entry costs strongly increase in response to a fall in productivity, a fewer number of product are created, leading to lower product destruction. In other words, product destruction is “insulated” from aggregate shocks, similar to the effect estimated in Caballero and Hammour (1994). As we discuss below, our model is able to reconcile contrasting theoretical results in the literature. The model is able to generate pro-cyclical product destruction for relatively low values of fixed operational costs whereas it generates a-cyclical product destruction for a specific combination of fixed operational costs and sunk entry costs.

A number of studies investigate the interplay between product flows and business cycle dynamics. Recent research by Chatterjee and Cooper (2014), Bilbiie et al. (2012), Jaimovich and Floetotto (2008) and Lewis and Poilly (2012) shows that the interplay between endogenous product entry and the variation in the degree of competition generates a strong propagation of shocks in general equilibrium models. Although these studies allow for endogenous product creation, they assume constant product destruction. Compared to these studies, we extend the analysis to include endogenous product destruction and investigate its importance for macroeconomic dynamics.

Ottaviano (2011) introduces firm heterogeneity and endogenous markup using a linear quadratic demand function into a standard two-sector model. The analysis is similar to ours as it allows the interaction between demand and supply side of the economy. The focus is, however, on firm heterogeneity and the implication on the propagation mechanism of technology shock, while we study the interplay between entry and exit under different types of policy shocks with three alternative specifications of the model. Samaniego (2008) investigates the relevance of establishment entry and exit over the business cycle and finds that establishment dynamics play little role in aggregate fluctuations. Lee and Mukoyama (2008), Clementi and Palazzo (2013) and Rossi (2015) undertake a related analysis and assume that establishment destruction is controlled by stochastic operating costs that determine the profitability of establishments. They find that establishment creation is important for macroeconomic dynamics.<sup>9</sup> These studies investigate the relevance of endogenous establishment creation and destruction whereas we focus on the importance of product turnover for aggregate fluctuations. Compared to these studies, the creation and destruction of product variety directly contribute to the consumer's utility. We therefore model explicitly the household consumption and investment decisions, which turn out to have important general equilibrium effects.

Finally, our analysis relates to the realm of the literature that develops general equilibrium models with endogenous product creation to investigate the effect of policy reforms on aggregate fluctuations (Shao and Silos (2013), Cacciatore and Fiori (2010) and Cacciatore et al. (2015)) and to study optimal monetary policy (Lewis (2013) and Cacciatore et al. (2013)) and fiscal policy (Chugh and Ghironi (2015) and Colciago (2015)). Compared to these studies, we include endogenous product destruction and focus on its effect for aggregate dynamics.

The remainder of the paper is as follows. Section 2 presents the baseline model with endogenous product creation and destruction. Section 3 reports the results, and section 4 performs sensitivity analysis, with a final Section 5 concluding. The appendices outline

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<sup>9</sup>These latest works extend the analysis of earlier studies by Hopenhayn (1992a, 1992b), Hopenhayn and Rogerson (1993) and Campbell (1998).

the alternative specifications of the model with entry selection and exogenous product destruction.

## 2 The Model

The model embeds product creation and product variety diversification, as in Bilbiie et al. (2012), and it accounts for endogenous product destruction. The economy is populated by one unit mass of atomistic households that gain utility from consuming goods of different product variety. Each establishment produces one product variety.<sup>10</sup> Upon entry, establishments draw a specific productivity level from a Pareto distribution and pay sunk entry costs. During each period, producers pay fixed operational costs. Both sunk entry costs and fixed operational costs are paid in terms of effective labor, and establishments that cannot afford fixed operational costs become unprofitable and close.

### 2.1 Households

During each period  $t$ , the representative household maximizes the expected utility

$$E_t \sum_{i=t}^{\infty} \beta^{i-t} \left( \ln C_t - \chi \frac{L_t^{1+\frac{1}{\varphi}}}{1+\frac{1}{\varphi}} \right), \quad (1)$$

where  $C_t$  is consumption,  $L_t$  is labor supply,  $0 < \beta < 1$  is the discount factor,  $\chi > 0$  is the degree of disutility in supplying labor and  $\varphi$  is the Frisch elasticity of labor supply.<sup>11</sup> Consumption is defined over a continuum of goods,  $\Omega$ , and during each period  $t$ , only a subset of goods,  $\Omega_t \in \Omega$ , is available. The consumption aggregator is

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

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<sup>10</sup>Although we assume that each firm manufactures a single product, the model can also be interpreted as a single firm with multiple production lines.

<sup>11</sup>With  $\varphi = \infty$ , the marginal disutility of supplying labor becomes constant,  $\chi$ . When  $\varphi = 0$ , the marginal disutility becomes infinite and the labor supply inelastic.

where  $c_t(\omega)$  is individual demand for variety,  $\omega$ , and  $V_t$  is defined as  $V_t \equiv S_t^{\psi - \frac{1}{\sigma-1}}$ , where  $S_t$  denotes the number of available varieties at time  $t$ , and  $\sigma (> 1)$  is the elasticity of substitution among varieties. As in Benassy (1996),  $\psi$  represents the marginal utility of an additional increase in the number of varieties in the basket and if  $\psi = 1/(\sigma - 1)$ , the consumption aggregator (2) nests the standard Dixit-Stiglitz aggregator. The consumption-based price index is

$$P_t = \frac{1}{V_t} \left( \int_0^{S_t} p_t(\omega)^{1-\sigma} d\omega \right)^{\frac{1}{1-\sigma}}, \quad (3)$$

which shows that for a given preference on variety  $\omega$ , the price index rises (decreases) when the number of available varieties,  $S_t$ , decreases (rises). The household demand for each variety,  $\omega$ , is

$$c_t(\omega) = V_t^{\sigma-1} \left( \frac{p_t(\omega)}{P_t} \right)^{-\sigma} C_t. \quad (4)$$

The consumption-based price index,  $P_t$ , is chosen as the numéraire, and the superscript tilda ( $\sim$ ) denotes average variables. The household receives income from supplying labor,  $L_t$ , at the real wage rate,  $w_t$ , from acquiring average dividends income among producers,  $\tilde{d}_t$ , and selling its initial share position,  $v_t$ , of each mutual fund share holdings,  $x_t$ , of producers,  $N_t$ . The household spends its income on consumption,  $C_t$ , buying  $x_{t+1}$  shares of the mutual funds of producers,  $N_t$ , and new entrants,  $H_t$ , at the share price  $v_t$ .<sup>12</sup> Thus, the household budget constraint is

$$L_t w_t + x_t N_t (v_t + \tilde{d}_t) = C_t + x_{t+1} v_t (N_t + H_t). \quad (5)$$

### 2.1.1 Number of producers

New entrants,  $H_t$ , need a one-period “time to build” to become producers. During each period  $t$ ,  $D_t^\delta \equiv \delta(N_t + H_t)$  number of producers and new entrants are exogenously destroyed. During each time  $t$ , the number of producers is given by

$$N_t = (1 - \delta)(N_{t-1} + H_{t-1}). \quad (6)$$

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<sup>12</sup>The derivation of  $\tilde{d}_t$  and  $v_t$  is defined later in the section.

Establishments that engage in production,  $S_t$ , are a subset of the number of producers,  $N_t$ . Endogenous destruction takes place at the very beginning of the period. During each period  $t$ , there is  $D_t^S \equiv N_t - S_t$  number of infinitely short-lived producers that shut down and exit the market. As a result, in any given period  $t$ , the total number of destroyed establishments is the sum of those that are endogenously destroyed,  $D_t^S$ , and exogenously destroyed,  $D_t^\delta$ :

$$D_t \equiv D_t^S + D_t^\delta.$$

### 2.1.2 First order conditions

During each period  $t$ , the representative household chooses  $\{C_t, x_{t+1}, L_t\}_{t=0}^\infty$  to maximize the utility function (1) subject to the budget constraint (5). The first-order conditions with respect to consumption,  $C_t$ , and labor supply,  $L_t$ , can be re-arranged as:

$$\chi(L_t)^{\frac{1}{\psi}} = w_t C_t^{-1},$$

which is the standard labor supply equation. The first-order condition with respect to share holdings,  $x_{t+1}$ , once it is combined with the firms law of motion (6) and with the first-order condition for consumption, yields:

$$v_t = \beta(1 - \delta) E_t \left( \frac{C_{t+1}}{C_t} \right)^{-1} \left( v_{t+1} + \tilde{d}_{t+1} \right). \quad (7)$$

Bringing forward equation (7) and imposing the no-Ponzi scheme condition, we express the asset price,  $v_t$ , as the expected discounted sum of future dividends

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

## 2.2 Heterogeneous firms, endogenous entry and exit

### 2.2.1 Entry

Each firm produces one specific product variety and operates in a monopolistically competitive market. Upon entry, new entrants draw a firm-specific productivity level,  $z$ , from a cumulative density function,  $G(z)$ , as defined by the following Pareto distribution:

$$G(z) = 1 - \left( \frac{z_{\min}}{z} \right)^k, \quad (8)$$

where  $z_{\min}$  is the minimum productivity level and  $k (> \sigma - 1)$  is the parameter that governs the shape of the distribution.<sup>13</sup> As  $k$  rises, the distribution becomes more skewed towards the minimum productivity level and heterogeneity decreases. In the benchmark version of the model, entry is assumed to be identical since there is not heterogeneity in the productivity level of new entrants, but this assumption is relaxed in an extension to the model. After drawing a specific productivity level, each firm enters the market and pays the sunk entry cost (in units of effective labor) that consists of  $l_{E,t} \equiv f_{E,t}/A_t^\vartheta$ . The term  $f_{E,t}$  represents exogenous (de)regulation on entry,  $A_t$  is the aggregate productivity level, and the parameter  $\vartheta$  governs the spillover from the efficiency of workers to the costs of set-up activities.<sup>14</sup>

In equilibrium, the number of new entrants,  $H_t$ , is established by the free entry condition,

$$v_t = \frac{w_t f_{E,t}}{A_t^\vartheta}, \quad (9)$$

which equates the current share price,  $v_t$ , to sunk entry costs,  $w_t f_{E,t}/A_t^\vartheta$ .

## 2.2.2 Production and profit maximization

During each period  $t$ , the labor demand,  $l_t(z)$ , depends on the scale of effective production,  $y_t(z)/A_t z$ . The operational fixed costs are defined in terms of effective labor,  $f_t/A_t^\theta$ , so that

$$l_t(z) = \frac{y_t(z)}{A_t z} + \frac{f_t}{A_t^\theta}. \quad (10)$$

Note that the fixed costs fluctuate with the aggregated labor productivity level,  $A_t$ , with a degree of spillover of  $\theta$ . The term  $f_t$  is exogenous and proxies (de)regulation in production.

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<sup>13</sup>Hopenhayn (1992b), Hopenhayn (1992a) and Hopenhayn and Rogerson (1993) consider uncertainty of the firm-specific productivity level. In our model, uncertainty holds on the aggregated productivity level,  $A_t$ .

<sup>14</sup>This specification ensures that exogenous productivity shocks are truly aggregate in the model since they affect production of existing goods and the creation of new products. As detailed later, we use a similar specification for operational fixed costs of production.

The firm's real profits are the difference between the value and the cost of total production:  $d_t(z) = \rho_t(z) y_t(z) - w_t l_t(z)$ , where  $\rho_t(z)$  is the real price of one manufactured good. Using equation (10), the real profits are expressed as

$$d_t(z) = \left( \rho_t(z) - \frac{w_t}{A_t z} \right) y_t(z) - \frac{w_t f_t}{A_t^\theta}. \quad (11)$$

In a symmetric equilibrium, each firm,  $z$ , produces one variety,  $\omega$ , implying that  $z = \omega$ . The goods market clearing ensures that production is equal to consumption, implying that  $y_t(z) = c_t(z)$ . Hence, each firm maximizes profits (11) subject to the demand (4), which leads to the standard pricing decision under monopolistic competition:

$$\rho_t(z) = \frac{\sigma}{\sigma - 1} \frac{w_t}{A_t z}, \quad (12)$$

which states that the real price of production is a markup over real marginal costs. By inserting equation (12) into equation (11) we can write the firm's real profit as:

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

Since the elasticity of substitution among varieties is more than unitary ( $\sigma > 1$ ), lower real prices induce a rise in profits. The term  $S_t^{\psi(\sigma-1)-1}$  describes the contribution of fluctuations in extensive margins (i.e. the number of producing firms) on the firm's profits.

### 2.2.3 Exit: the cutoff firm and the number of survivors-producers

For any given specific productivity level,  $z$ , the firm produces if profits are positive,  $d_t(z) > 0$ . Otherwise it shuts down the plant and exits the market. Inefficient firms that have drawn a lower productivity level than the cutoff ( $z \leq z_{s,t}$ ) necessary to ensure positive profits exit without producing. Endogenous 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 that the following zero profit cutoff (ZCP) condition holds:

$$d_t(z_{s,t}) = \frac{1}{\sigma} S_t^{\psi(\sigma-1)-1} \rho_t(z_{s,t})^{1-\sigma} C_t - \frac{w_t f_t}{A_t^\theta} = 0. \quad (13)$$

To focus on aggregate dynamics across different firms, we rewrite the above ZCP condition in terms of the average firm specific productivity across survivors-producers,  $\tilde{z}_{s,t}$ . Following Melitz (2003) and Ghironi and Melitz (2005),  $\tilde{z}_{s,t}$  is defined as follows,

$$\tilde{z}_{s,t} \equiv \left[ \frac{1}{1 - G(z_{s,t})} \int_{z_{s,t}}^{\infty} z^{\sigma-1} dG(z) \right]^{\frac{1}{\sigma-1}} = z_{s,t} \left[ \frac{k}{k - (\sigma - 1)} \right]^{\frac{1}{\sigma-1}}, \quad (14)$$

where the second identity derives from the use of the Pareto distribution (8). Average real profits among surviving producers are expressed as follows

$$\tilde{d}_{s,t} = \frac{1}{\sigma} S_t^{\psi(\sigma-1)-1} \tilde{\rho}_{s,t}^{1-\sigma} C_t - \frac{w_t f_t}{A_t^\theta}, \quad (15)$$

where the average real price is given by

$$\tilde{\rho}_{s,t} = \frac{\sigma}{\sigma - 1} \frac{w_t}{A_t \tilde{z}_{s,t}}. \quad (16)$$

Similarly, the definition of the consumption-based price index (3) implies that  $\tilde{\rho}_{s,t} = S_t^\psi$ , which, once used in equation (15), enables us to write average profits as

$$\tilde{d}_{s,t} = \frac{1}{\sigma} \frac{C_t}{S_t} - \frac{w_t f_t}{A_t^\theta}. \quad (17)$$

Using equations (13), (14) and (17), the ZCP can be re-written as

$$\frac{1}{\sigma} \frac{C_t}{S_t} = \frac{k}{k - (\sigma - 1)} \frac{w_t f_t}{A_t^\theta}, \quad (18)$$

and using average firm productivity and the Pareto density function, the endogenous survival rate is

$$\frac{S_t}{N_t} = z_{\min}^k \left[ \frac{k}{k - (\sigma - 1)} \right]^{\frac{k}{\sigma-1}} \tilde{z}_{s,t}^{-k}. \quad (19)$$

Finally, average operational profits among all producers are given by

$$\tilde{d}_t = \frac{S_t}{N_t} \tilde{d}_{s,t}. \quad (20)$$

## 2.3 Aggregate equilibrium

To derive the aggregate equilibrium, we impose labor market clearing. Aggregate labor supply,  $L_t$ , is employed in either the production of consumption goods (intensive margins, i.e. production scale) or the creation of new firms (extensive margins):

$$L_t = S_t l_t(\tilde{z}_{s,t}) + H_t l_{E,t},$$

which can be expressed as:<sup>15</sup>

$$L_t = S_t \left[ (\sigma - 1) \frac{\tilde{d}_{s,t}}{w_t} + \sigma \frac{f_t}{A_t^\theta} \right] + H_t \frac{v_t}{w_t}. \quad (21)$$

Equation (21) is equivalent to the aggregated accounting identity for GDP that can be obtained by aggregating budget constraints among households:  $Y_t \equiv C_t + v_t H_t = L_t w_t + S_t \tilde{d}_{s,t}$ , where  $Y_t$  is real GDP measured in the welfare basis from expenditures and income. The model consists of 11 equations and 11 endogenous variables among which the number of producers,  $N_t$ , is a state variable. Finally, we assume that aggregate productivity follows the law of motion:  $\ln(A_t) = \rho \ln(A_{t-1}) + \varepsilon_t$ , where  $\varepsilon_t$  is a normally distributed innovation with zero mean and variance equal to  $\sigma_v^2$ . Table 1 summarizes the benchmark model.

Table 1: Summary of the benchmark model

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

<sup>15</sup>Note that  $\tilde{d}_{s,t} = \frac{\tilde{\rho}_{s,t}}{\sigma} \tilde{y}_{s,t} - \frac{w_t f_t}{A_t}$ , where  $\tilde{y}_{s,t}$  represents average intensive margins.

### 3 Results

In this section, we describe the calibration of the theoretical model and investigate how the presence of endogenous product creation and destruction contributes to macroeconomic dynamics. In particular, to isolate the effect of endogenous product destruction, we compare outcomes from the benchmark model against those of the model with entry selection and the model with exogenous product destruction rate. We perform the analysis by studying the variables' responses to recessionary productivity shocks, permanent entry deregulation and permanent subsidies as well as by comparing business cycle statistics across the different specifications of the model.

#### 3.1 Calibration

Table 2: Calibration of the model

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$\beta$	Discount factor	0.99
$\varphi$	Frisch elasticity of labor supply	2
$\sigma$	Elasticity of substitution among varieties	3.8
$k$	Distribution parameter	3.4
$\psi$	Marginal utility of an increase in varieties	0.36
$z_{\min}$	Minimum idiosyncratic productivity level	1
$\delta$	Exogenous destruction rate	0.0025
$A$	Steady state level of aggregate productivity	1
$\rho$	Persistence of aggregate productivity	0.979
$\sigma_v$	Standard deviation of productivity shocks	0.0072
$f_E$	Fixed entry costs	1
$\theta$	Propagation on fixed operational cost	0.237
$\vartheta$	Propagation on entry cost	0.203

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Table 2 provides a summary of the calibration of the benchmark model. We calibrate the model on quarterly frequencies. The value of discount factor,  $\beta$ , and the Frisch

elasticity of labor supply,  $\varphi$ , are set to 0.99 and 2, respectively. These values are within the range of those used in the literature. The elasticity of substitution among varieties,  $\sigma$ , is set to 3.8, based on empirical findings on U.S. manufacturing in Bernard et al. (2003). We calibrate the parameter  $k$  that determines the shape of the distribution of firm-specific productivity as in Ghironi and Melitz (2005). We set the parameter that establishes the marginal utility of an increase in the number of varieties,  $\psi$ , equal to 0.36 (i.e.  $1/(\sigma - 1)$ ), consistent with the standard Dixit-Stiglitz preferences in equation (2). The value of the parameter of the disutility of supplying labor,  $\chi$ , is set to 0.8549 to deliver a steady state labor supply equal to one.<sup>16</sup>

We normalize  $A$ ,  $f_E$  and  $z_{\min}$  to be equal to one.<sup>17</sup> We calibrate the total rate of product destruction to match the average annual exit rate for all U.S. establishments of 0.11 from BDS data for the period 1977 to 2011. Therefore, we set the exogenous destruction rate,  $\delta$ , to 0.0025, implying that, on average, one percent of producers are exogenously destroyed per year. We set the endogenous destruction rate,  $1 - S/N$ , equal to 0.025, implying that, on average, ten percent of producers are endogenously destroyed per year. To achieve this calibration, we set the steady state value of subsidies,  $f$ , to 0.0017. Similarly, for the version of the model with entry selection, a value of  $f$  equal to 0.0017 enables the model to replicate the annual product exit rate in the data.<sup>18</sup> For the version of the model with exogenous destruction, operational fixed costs are set equal to zero ( $f = 0$ ). Appendix C provides the derivation of the steady state for different version of the model.

We set the persistence parameter,  $\rho$ , and the standard deviation of innovations,  $\sigma_v$ ,

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<sup>16</sup>This choice is a mere normalization, with no effect on the system dynamics, as outlined in Bilbiie et al. (2012).

<sup>17</sup>To calibrate the establishment destruction rate, our calibration strategy is to normalize  $z_{\min}=1$  and set the steady state value of fixed operational costs to match the average quarterly establishment destruction rate in the data. A similar calibration strategy is used in Ghironi and Melitz (2005). Hence,  $z_{\min}$  plays no role on the level of establishment destruction whereas  $f_X$  is the parameter that determines the rate of establishment destruction.

<sup>18</sup>Note that, in principle, the values of  $\chi$  and  $f$  are allowed to be different across the benchmark model and the entry selection model. However, it turns out that the calibration is the same.

equal to 0.979 and 0.0072, respectively, as in King and Rebelo (1999). The coefficients that govern the propagation of productivity on fixed operational,  $\theta$ , and entry costs,  $\vartheta$ , are set to minimize the distance between some key moments in the observed data and those implied by the theoretical model. In particular, we numerically solve  $J = \min_{\theta, \vartheta} \left[ \widehat{\Psi} - \Psi(\theta, \vartheta) \right]' V^{-1} \left[ \widehat{\Psi} - \Psi(\theta, \vartheta) \right]$ , where  $\widehat{\Psi}$  is the vector containing the standard deviation of product entry and exit in the data,  $\Psi(\theta, \vartheta)$  is the vector containing the corresponding standard deviation implied by the theoretical model and  $V^{-1}$  is the inverse of variance covariance matrix of empirical data for product entry and exit. This procedure gives the value of  $\theta = 0.237$  and  $\vartheta = 0.203$ . Since these parameters control the degree of the firm's entry and exit margins, section 5 performs an extensive sensitive analysis at them.

### 3.2 Second moments of the theoretical models

To evaluate the properties of our baseline model, we compare the second moments of our artificial economies for some key macroeconomic variables and compare them to the corresponding series in the data. As outlined in Ghironi and Melitz (2005), Bilbiie et al. (2012), we define the data consistent variables by deflating them with the observed level price index,  $\widehat{P}_t$ . Therefore any real variable  $X_t$  measured in welfare-based CPI,  $P_t$ , is transformed to those  $X_{R,t}$  deflated with the empirical-based CPI,  $\widehat{P}_t$ , by the following operation:  $X_{R,t} \equiv P_t X_t / \widehat{P}_t$ . Hence, we present measures of GDP,  $Y_{R,t}$ , consumption,  $C_{R,t}$ , and investment,  $I_{R,t} \equiv v_{R,t} H_t$ , that are consistent with observed data since they abstract from the welfare effect imputed to fluctuations in the extensive margin of product variety.

Table 3 reports second moments of key variables for the U.S. data against those for the benchmark model, the model with entry selection and the model with exogenous destruction.<sup>19</sup> The performance of the three models to reproduce the standard deviation of aggregate output ( $Y_R$ ) and consumption ( $C_R$ ) is similar whereas the benchmark model

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<sup>19</sup>All series are detrended by HP filter, using a smoothing parameter equal to 1600. Second moments of the theoretical models are computed by frequency domain techniques. Data sources are specified in Appendix A.

Table 3: Second moments

		$Y_R$	$C_R$	$I_R$	$L$	$H$	$D$
St. dev. (%)	U.S. Data	1.23	0.93	5.30	1.83	4.19	4.68
	Benchmark	1.03	0.80	4.91	0.19	4.21	4.69
	With entry selection	1.13	0.76	7.05	0.32	6.39	2.45
	Exogenous destruction	1.05	0.85	5.62	0.18	4.87	0.04
relative to $Y_{Rt}$	U.S. Data	1.00	0.75	4.30	1.49	3.40	3.80
	Benchmark	1.00	0.78	4.78	0.18	4.10	4.56
	With entry selection	1.00	0.67	6.23	0.28	5.65	2.16
	Exogenous destruction	1.00	0.81	5.37	0.17	4.66	0.04
Corr( $Y_{Rt}, X_t$ )	U.S. Data	1.00	0.88	0.93	0.92	0.68	-0.15
	Benchmark	1.00	1.00	1.00	0.99	1.00	-0.98
	With entry selection	1.00	1.00	0.99	0.98	0.99	-0.94
	Exogenous destruction	1.00	1.00	1.00	0.99	1.00	0.24

reproduces investment fluctuations ( $I_R$ ) more closely.

The baseline model well reproduces the high standard deviation of product destruction and creation in the data as proxied by establishment data. The relative standard deviation of creation and destruction rates are equal to 3.40 and 3.80 in the data and to 4.10 and 4.56, respectively, in the baseline model. Similarly, the model with entry selection also has high relative standard deviation in the product creation (5.65), although it has low relative standard deviation in product destruction (2.16). As explained in the previous section, this occurs because the destruction margin is less active in the presence of selective entrance. Newly created products have already sufficiently high productivity level to remain in production, and therefore fewer establishments are subject to destruction. The model with exogenous product destruction displays a very low standard deviation in product destruction (0.04).

Product creation is pro-cyclical, and destruction is mildly countercyclical in the data (0.68 and -0.15, respectively). Lee and Mukoyama (2008) report a similar pattern for

establishment creation but pro-cyclical establishment destruction using U.S. manufacturing data. We impute the difference to the specific data set used. Similar to us, Broda and Weinstein (2010) document that product creation is highly pro-cyclical and product destruction is countercyclical, using a data set that contains the universe of products with bar codes purchased by U.S. households. All three models generate pro-cyclical product creation with a correlation between output and product creation equal to 1 approximately, which is slightly higher than the value of 0.68 in the data. However, only the models with endogenous destruction (i.e. the baseline model and the model with entry selection) are successful in reproducing the counter-cyclical pattern of product destruction (with correlation between output and product destruction equal to -0.98 and -0.94, respectively).

Table 4: Lead-lag correlation with output

Corr( $X_{t+j}, Y_{R,t}$ )									
$j = -4, \dots, 4$	-4	-3	-2	-1	0	1	2	3	4
<i>Y<sub>R</sub></i>									
U.S. data	0.32	0.51	0.72	0.88	1.00	0.88	0.72	0.51	0.32
Benchmark	0.12	0.28	0.48	0.72	1.00	0.72	0.48	0.28	0.12
With entry selection	0.11	0.27	0.47	0.72	1.00	0.72	0.47	0.27	0.11
Exogenous destruction	0.12	0.28	0.48	0.72	1.00	0.72	0.48	0.28	0.12
<i>H</i>									
U.S. data	0.34	0.49	0.60	0.68	0.68	0.64	0.46	0.30	0.10
Benchmark	0.16	0.32	0.51	0.73	1.00	0.69	0.44	0.23	0.06
With entry selection	0.18	0.34	0.52	0.74	0.99	0.67	0.40	0.19	0.02
Exogenous destruction	0.16	0.32	0.51	0.73	1.00	0.69	0.43	0.22	0.06
<i>D</i>									
U.S. data	-0.57	-0.53	-0.49	-0.34	-0.15	0.11	0.37	0.55	0.65
Benchmark	-0.22	-0.37	-0.54	-0.75	-0.98	-0.65	-0.38	-0.16	0.01
With entry selection	-0.27	-0.41	-0.56	-0.74	-0.94	-0.58	-0.29	-0.06	0.11
Exogenous destruction	-0.48	-0.39	-0.24	-0.04	0.24	0.43	0.55	0.61	0.63

Table 4 shows correlations of output with product creation and destruction at various leads and lags in the data and in different versions of the model. The benchmark version of the model with endogenous product destruction replicates well the autocorrelation of output and the positive correlation of output and product creation at various leads and lags. The model is able to match the negative correlation between current and lags of product destruction with output. However, the contemporaneous correlation of output with product destruction is -0.98 in the model, which is higher than -0.15 in the data. In addition, the model predicts negative correlations of output and product destruction at different leads whereas the correlations are positive in the data. As we show in the next section, the cyclicity of product destruction is sensitive to movements in fixed operational costs,  $w_t f_t / A_t^\theta$ , and entry costs,  $w_t f_{E,t} / A_t^\theta$ , and therefore alternative calibrations are able to improve the performance of the model. In addition, extending the theoretical framework to incorporate more sophisticated dynamics, such as the presence of adjustment costs, is outside the scope of this analysis but it would certainly improve the performance of the model. Overall, the analysis shows that the theoretical model replicates relatively well movements in output, consumption and investment in the data.

### 3.3 Impulse response functions

Figures 2-4 present impulse response functions to a one percent recessionary productivity shock,  $A_t$ , one percent permanent reduction in entry costs,  $f_E$ , and one percent permanent reduction in operational costs,  $f$ , respectively. Each entry reports responses for benchmark economy (solid line), the economy with selection entry (dashed line) and the economy with exogenous destruction (dotted line).

#### 3.3.1 Recessionary productivity shock

Figure 2 shows the response of key variables to a negative productivity shock. On impact, a recessionary technology shock raises fixed operational costs requiring higher plant-specific productivity level for the product to survive destruction, increasing the average productivity level of producers ( $\tilde{z}_{s,t}$ ). This process generates an increase in the destruction

of less efficient products ( $D_t$ ). As a result, surviving products charge lower prices ( $\tilde{\rho}_{s,t}$ ), which dampens the increase in profits ( $\tilde{d}_{s,t}$ ) and the scale of production ( $\tilde{y}_{s,t}$ ) due to a recessionary shock. The figure shows that when the product destruction rate is constant, the fall in prices is contained since plant-specific productivity does not rise in response to the shock, which results in a larger decline in profits and intensity in production. Notice that the recession generates a “cleansing” effect on impact, consistent with Caballero and Hammour (1994), since less efficient products are destroyed at the outset of a recession. However, as the recovery phase starts and the adverse shock dissipates, the plant-specific productivity level required to retain the product’s profitability decreases and therefore even less productive production lines remain in the economy. This mechanism counteracts the initial cleansing effect of recessions and is absent in the model with *exogenous* product destruction.

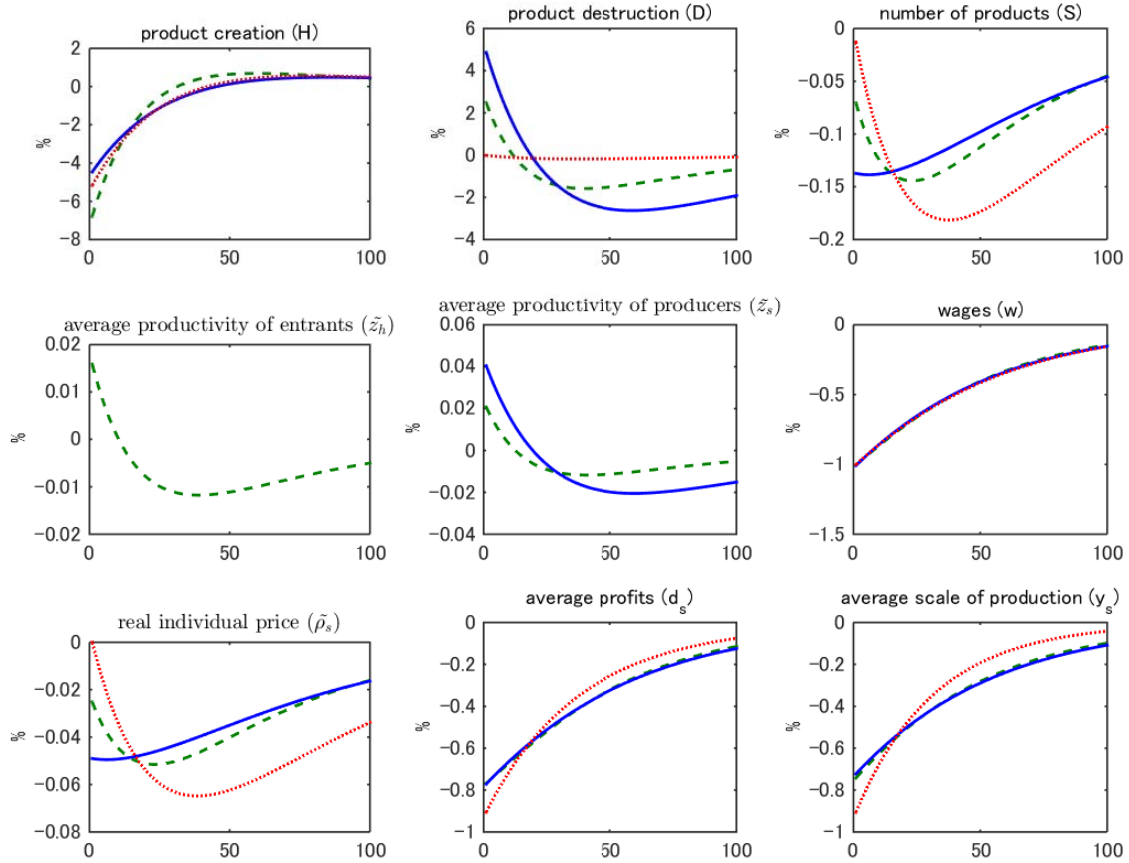
The variables’ responses in the model with selective entry show similar qualitative patterns to the benchmark model. However, the initial cleansing effect of recession and the subsequent fall in the plant-specific productivity level is dampened in the presence of entry selection.<sup>20</sup> In this version of the model, since product creation depends on movements in plant-specific productivity, newly created products must be more productive compared to the benchmark case. Therefore, the drop in product creation is higher and the rise in product destruction is lower, attenuating the cleansing effect and the subsequent fall in plant-specific productivity in recession.

Figure 3 plots cumulative impulse response functions of product creation and destruction associated with a recessionary productivity shock. The cumulative responses compound the effect of the adverse shocks in the contractionary and recovery phases, therefore accounting for the overall effects of the shocks. The findings are striking. The recessionary shock induces the cumulative reaction of product creation to increase but remain negative whereas cumulative product destruction increases on impact but then declines in the aftermath of the shock. The sign reversal in the cumulative response of product

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<sup>20</sup>In line with our analysis, Lee and Mukoyama (2008) report that the relative productivity of entering plants during recessions is about 10-20% higher than during booms. They also find that the relative productivity of exiting plants is of lower magnitude across recessions and booms.

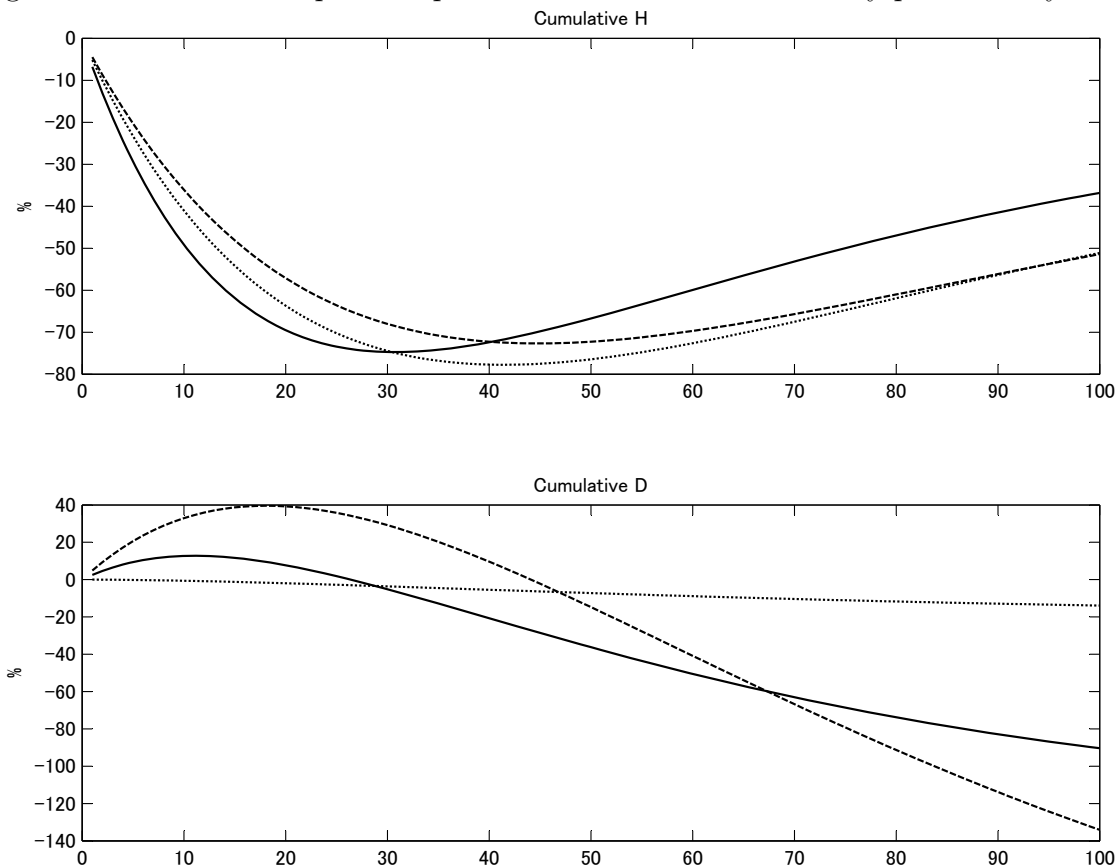
Figure 2: Impulse response functions to a recessionary productivity shock



Notes: Each entry shows the percentage-point response of one of the model's variables to a one-percentage deviation of the shock for the benchmark economy (solid line), the economy with selection entry (dashed line) and the economy with exogenous destruction (dotted line).

destruction is due to the lower plant-specific productivity required for production lines to remain profitable in the recovery phase, which reduces product destruction. Hence, in the presence of endogenous product destruction, recoveries hinge on lower product destruction rather than higher product creation. This conclusion is in line with a related strand of literature that focuses on worker flows (Davis et al. (2006) and Caballero and Hammour (2005)) that finds that a fall in worker separation is the primary channel for recovery.

Figure 3: Cumulative impulse response functions to a recessionary productivity shock



Notes: Each entry shows the cumulative impulses to a percentage-point response of establishment creation and destruction to a one-percentage deviation of the shock for the benchmark economy (solid line), the economy with selection entry (dashed line) and the economy with exogenous destruction (dotted line).

### 3.3.2 Permanent entry deregulation

Figure 4 shows the effect of entry deregulation, proxied by a permanent one-percent reduction in sunk entry costs ( $f_{E,t}$ ). A long-lasting decrease in entry costs induces a permanent rise in the creation of products ( $H_t$ ). The increase in the number of new products raises labor demand and generates a permanent increase in wages ( $w_t$ ). In the presence of endogenous product destruction, higher wages command higher plant-specific productivity to maintain a production line's profitability (i.e.  $\tilde{z}_{s,t}$  rises) and therefore

leaves marginal costs ( $\tilde{\rho}_{s,t}$ ) unchanged, along with a rise in the production scale ( $\tilde{y}_{s,t}$ ) and profits ( $\tilde{d}_{s,t}$ ).

The model with endogenous selection delivers similar responses to a permanent entry deregulation. In this instance, the rise in the number of new products is lower than in the benchmark model. The increase in the expected future fixed costs induced by a rise in wages ( $w_t$ ) triggers an increase in the average productivity level of new entrants ( $\tilde{z}_{h,t}$ ). However, due to pre-selection based on plant-specific productivity, the rise in gross destruction ( $D_t$ ) and the productivity level of producers ( $\tilde{z}_{s,t}$ ) are less pronounced compared to the benchmark model.

It is worth noticing that across the two models with endogenous product destruction, the effect of deregulation is to permanently increase the average plant-specific productivity in the economy. The rise in wages in response to higher firm entrance commands permanently higher plant-specific productivity levels for the production lines to remain profitable.

The responses of the variables are substantially different when product destruction is constant. In this instance, a raise in wages increases marginal costs (since establishment productivity remains constant) and therefore induces a fall in the production line’s scale and profits. This mechanism generates “sclerosis” (i.e. the survival of production units that would not survive in an efficient equilibrium) that echoes the empirical findings on worker flows in Caballero and Hammour (2005).<sup>21</sup>

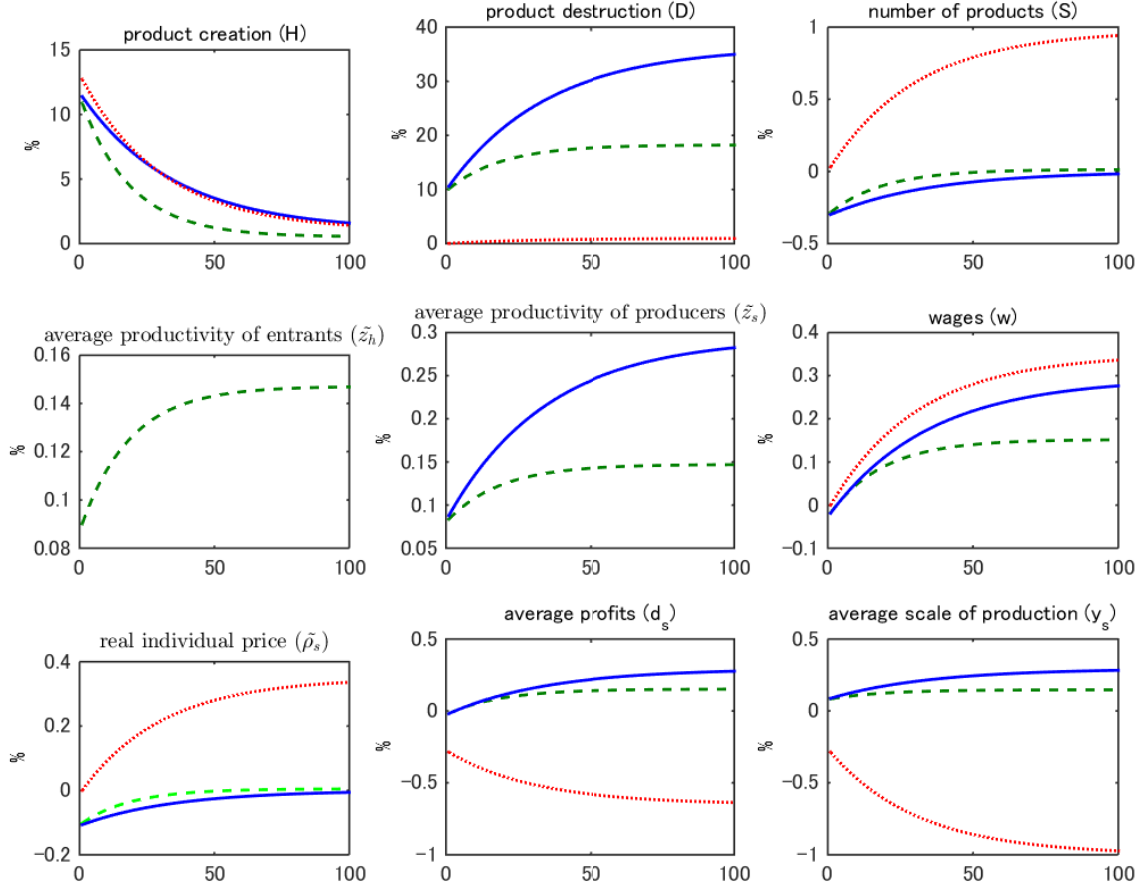
### 3.3.3 Permanent subsidy increase

Figure 5 shows the effect of production subsidies, proxied by a permanent one-percent reduction in fixed operational costs ( $f$ ). Subsidies are irrelevant for the model with constant product destruction since the plant-specific productivity level is constant whereas they play an important role in models with endogenous product destruction, due to their interplay with the profitability of the production line.

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<sup>21</sup>However, in our framework, differently from Caballero and Hammour 2005, there is no “scrambling” effect that reduces the effectiveness of the restructuring process related to financial constraints of firms.

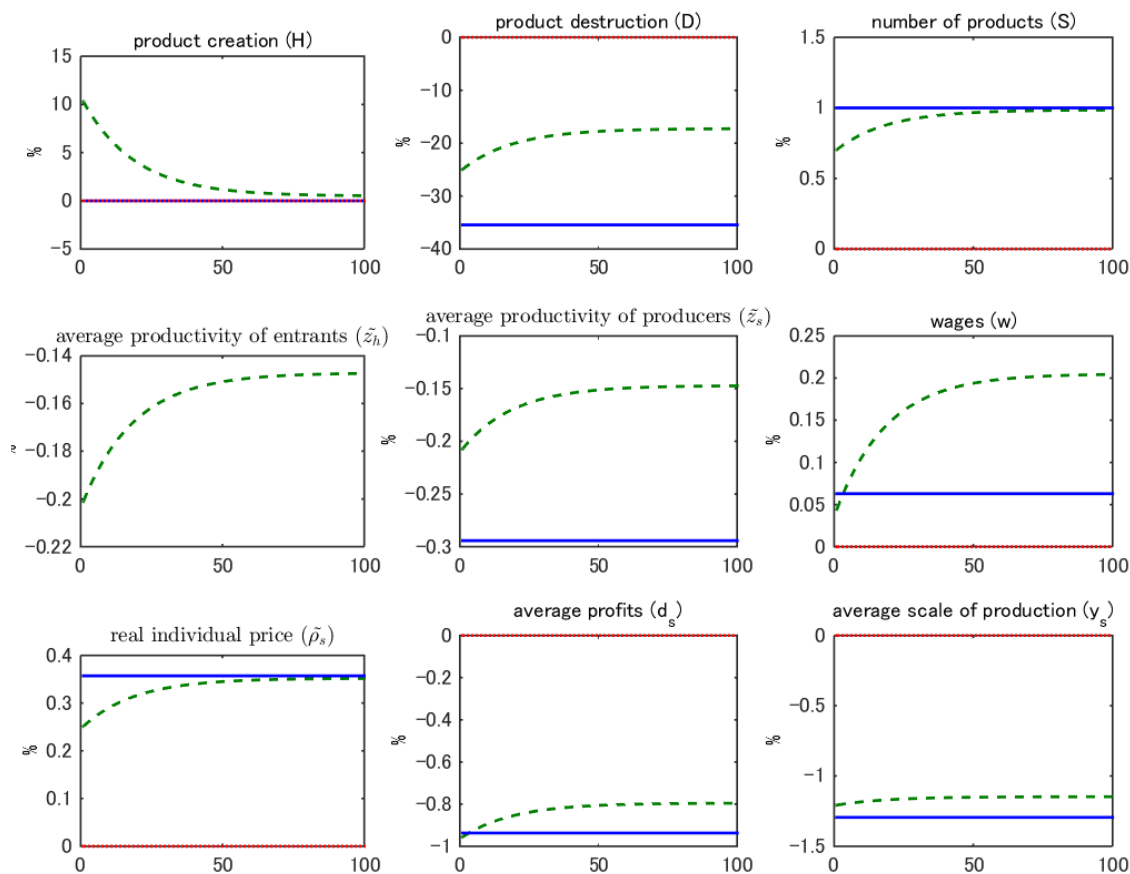
Figure 4: Permanent deregulation shock



Notes: Each entry shows the percentage-point response of one of the model's variables to a permanent deregulation shock for the benchmark economy (solid line), the economy with selection entry (dashed line) and the economy with exogenous destruction (dotted line).

In the benchmark model, a permanent decrease in subsidies leaves new products ( $H_t$ ) unchanged and induces a permanent fall in plant-specific productivity ( $\tilde{z}_{s,t}$ ) that decreases product destruction ( $D_t$ ). As a result, the number of products ( $S_t$ ) rises, which in turn increases the labor demand and raises wages ( $w_t$ ). Consequently, marginal costs ( $\tilde{p}_{s,t}$ ) increase, and the production scale ( $\tilde{y}_{s,t}$ ) and profits ( $\tilde{d}_{s,t}$ ) fall. These dynamics are common across the two models with endogenous product creation. In the entry selection model, however, the same policy induces a higher number of new products ( $H_t$ ) that are less efficient ( $\tilde{z}_{h,t}$  decreases), due to expected subsidies in production. Since produc-

Figure 5: Permanent subsidy shock



Notes: Each entry shows the percentage-point response of one of the model's variables to a permanent subsidy shock for the benchmark economy (solid line), the economy with selection entry (dashed line) and the economy with exogenous destruction (dotted line).

ers are already somewhat inefficient, the decrease in gross destruction ( $D_t$ ) and average productivity levels ( $\tilde{z}_{s,t}$ ) are less pronounced compared to the benchmark model.

This analysis shows that a reduction in fixed operational costs generates a permanent decrease in the average plant-specific productivity in the economy. However, the propagation channel is different from the case of deregulation, and in this case the results are driven by the increase in profitability due to lower operational costs, despite the counteracting effect of increasing wages. These dynamics account for the findings in Caballero et al. (2008), suggesting that the indiscriminate channeling of financial support to firms

depressed the long-run restructuring process of the Japanese economy in the aftermath of the early 1990s crisis.

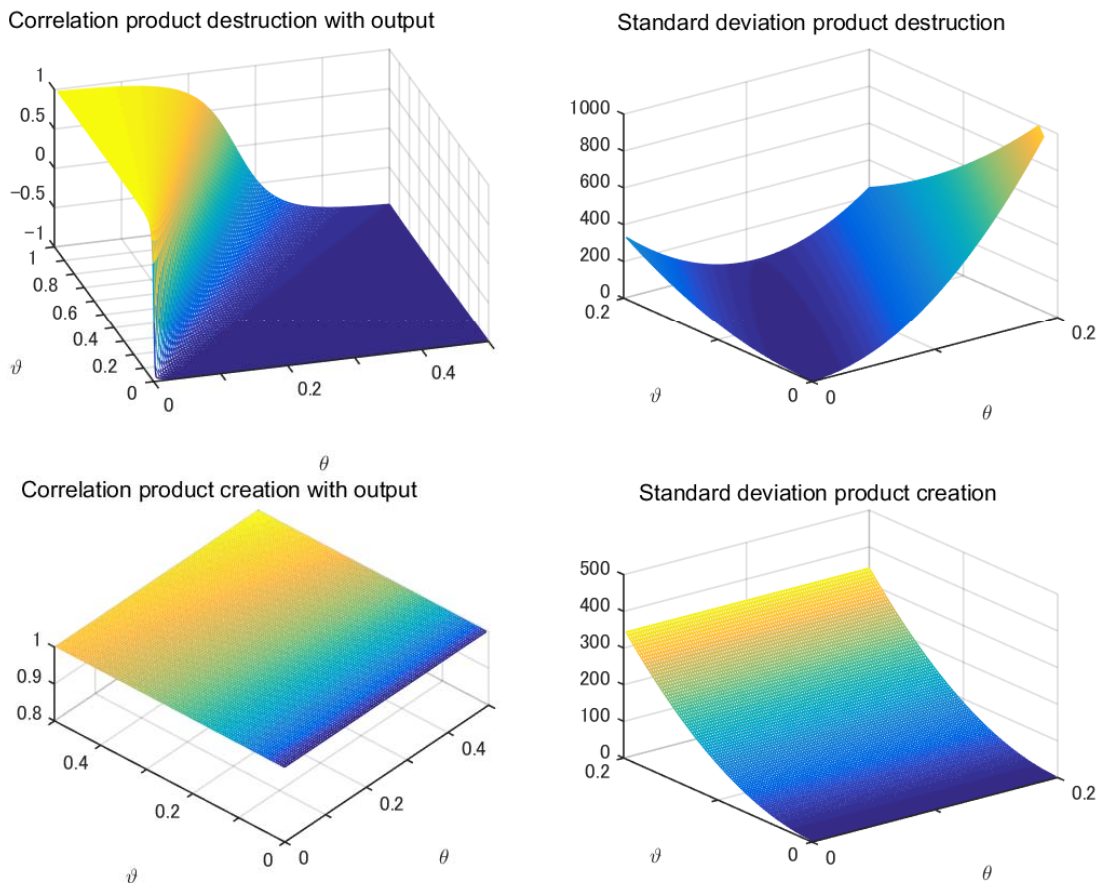
## 4 Sensitivity analysis

In this section, we discuss the sensitivity of the cyclical properties of product creation and destruction to the spillover coefficients of productivity shocks on fixed operational costs ( $\theta$ ) and sunk entry costs ( $\vartheta$ ). The analysis is performed using the same calibration of the benchmark model, except for the parameters  $\theta$  and  $\vartheta$ , which cover the entire range of feasible values.

The top-left entry of Figure 6 shows the contemporaneous correlation of the product destruction rate with output. The correlation between output and product destruction decreases, and it becomes negative for higher values of the parameter related with the spillover of technology shocks on fixed operational costs,  $\theta$ . The reason for the decline in correlation and the sign reversal is straightforward. In the aftermath of a recessionary shock, for any given value of  $\vartheta$ , the response of fixed operational costs,  $w_t f/A_t^\theta$ , is stronger the higher the value of  $\theta$ . If fixed costs are insensitive to productivity ( $\theta = 0$ ), the correlation between output and product destruction is positive since a fall in productivity reduces wages, decreasing fixed operational costs. The plant-specific productivity level required to retain the production line's profitability declines and therefore product destruction falls. By contrast, if fixed operational costs react to productivity ( $\theta > 0$ ), the correlation between output and product destruction decreases and becomes negative for high values of  $\theta$  since the fall in productivity raises fixed operational costs, increasing product destruction. The figure shows that for sufficiently high values of  $\theta$ , a perfect negative correlation exists between product destruction and output. As described above, such a strong correlation is explained by lack of adjustment costs related with product destruction, leaving this margin to perfectly co-move with output in reaction to shocks.

The top-left entry in Figure 6 shows that for any given value of  $\theta$ , higher values of the spillover coefficient of productivity shocks on sunk entry costs,  $\vartheta$ , generate a strong

Figure 6: Correlation and standard deviation of product destruction and creation



Notes: The top- (bottom-)left entry shows the contemporaneous correlation of product destruction (creation) with output. The top- (bottom-)right entry shows the standard deviation (in percent) of the product destruction (creation).

response of fixed entry costs,  $w_t f_E / A_t^\vartheta$ , inducing product destruction to become pro-cyclical. Higher values for the parameter  $\vartheta$  imply higher entry costs in recessions and therefore fewer numbers of products enter the economy. As a result, labor demand falls, leading to a decline in real wages. The fall in real wages decreases fixed operational costs and product destruction. In other words, product destruction is “insulated” from aggregate conditions, similar to the effect estimated in Caballero and Hammour (1994).

These findings reconcile the contrasting results in Lee and Mukoyama (2008) and Samaniego (2008), whose theoretical models generate pro-cyclical and a-cyclical plant

destruction, respectively. In particular, our analysis shows that the cyclical properties of product destruction are related to the degree of propagation of aggregate productivity shock on fixed operational costs ( $\theta$ ) and sunk entry costs ( $\vartheta$ ). The model is able to generate pro-cyclical product destruction for relatively low values of fixed operational costs whereas product destruction becomes a-cyclical for a specific combination of fixed operational costs and sunk entry costs.

The top-right entry of Figure 6 shows the standard deviation (in percent) of the product destruction rate as a function of the spillover coefficients of the fixed operational and entry costs to productivity ( $\theta$ , and  $\vartheta$  respectively). The figure shows that the relation between the standard deviation of product destruction and the parameters  $\theta$  and  $\vartheta$  is non-monotonic. For low (high) values of  $\theta$ , higher  $\vartheta$  increases (decreases) the volatility of product separation. Changes in the standard deviation of product destruction are related with movements in fixed operational costs and with the plant-specific productivity levels that maintain the profitability of the production line. When fixed operational costs rise, product destruction increases because a higher plant-specific productivity is required to retain profitability. Fixed operational costs depend on wages and the spill-over effect of productivity, which is determined by the size of the parameter  $\theta$ , as defined in equation (10). When  $\theta$  is low (i.e. close to zero), fixed operational costs are determined primarily by wages. Hence, in the aftermath of a recessionary productivity shock, an increase in  $\vartheta$  induces fewer new products, decreasing wages and fixed operational costs. However, the decrease in fixed operation costs generates a sharp fall in the plant-specific productivity level that retains production line's profitability and therefore product destruction falls, increasing the standard deviation of product destruction. For sufficiently low values of  $\theta$ , an increase in  $\vartheta$  still generates a decline in wages, which combined with the fall in technology, decreases fixed operational costs. Product destruction falls sharply and therefore the standard deviation of product destruction increases.

By contrast, when  $\theta$  increases (i.e. close to one), a recessionary productivity shock generates two competing effects. On the one hand, the direct effect of the fall in technology raises fixed operation costs, but on the other hand, wages fall for higher values of  $\vartheta$ , due

to the lower number of product creation. Hence, for sufficiently high values of  $\theta$ , increases in  $\vartheta$  generate a dampening effect to the rise in fixed operational costs, which decrease the product destruction and its standard deviation. The sensitivity analysis on the standard deviation of product destruction shows the existence of the insulation effect of product creation on destruction, corroborating the results on the contemporaneous correlation between output and destruction.

The bottom-left panel of Figure 6 shows that product creation is highly pro-cyclical and insensitive to changes in both  $\theta$  and  $\vartheta$ . In the aftermath of a recessionary shock, output falls, diminishing expected future dividends and therefore reducing the benefits for new product to enter the market, irrespective of fixed operational costs ( $\theta$ ) and sunk entry costs ( $\vartheta$ ). The bottom-right panel of Figure 6 shows that the standard deviation of product creation rises steadily with increases in  $\vartheta$  while it is insensitive to changes in  $\theta$ . High values of sunk entry costs ( $\vartheta$ ) induce pronounced fluctuations in fixed entry costs,  $w_t f_E / A_t^\vartheta$ , thereby raising the volatility of product creation. Instead, changes in fixed operational costs ( $\theta$ ) do not affect product creation.

We find substantially similar patterns in the entry selection model. However, the insulation effect is stronger since the plant-specific productivity level to retain the production line's profitability is higher and therefore fewer product are able to enter the market in each period. Labor demand reduces substantially, leading to a decrease in fixed operational costs and consequently product destruction. An appendix that details sensitivity analysis for the heterogenous entry model is available on request.

## 5 Conclusion

The analysis performed in this paper, with the help of a general equilibrium model that features endogenous product creation and destruction, shows that recessions destroy less efficient products on impact, allocating resources towards more efficient products. However, during the recovery phase while aggregate productivity recovers, this process is reversed and less profitable products remain in the market. The analysis establishes that

recoveries are driven by a decrease in the rate of product destruction as opposed to increase in product creation.

The analysis shows that endogenous product destruction is critical to evaluate the effect of permanent policies aimed to stimulate the economy. For instance, the effect of a permanent decrease in sunk entry costs on the profitability of the production line and the scale of production depends on whether product destruction is an additional margin of adjustment. In the presence of endogenous product destruction, a fall in sunk costs raises wages and simultaneously increases the level of plant-specific productivity required to maintain a production line's profitability, which in turn, decreases the marginal costs of production and therefore increases profits and the scale of production. Conversely, if product destruction is constant, a permanent fall in sunk costs leads to an increase in wages that subsequently lead to a rise in the marginal costs of production, therefore decreasing profits and the scale of production.

The theoretical model shows that product destruction is insulated from aggregate conditions when exogenous productivity affects the set up and development costs associated with a production line. In addition, we show that the correlation of product destruction with output may be perfectly positive or negative or any value in between, depending on the spillover effect of technology shocks to operational and entry costs. Therefore, the theoretical framework is able to reconcile contrasting empirical results.

The analysis may be extended across several dimensions. First, by introducing nominal price rigidities, the model may be used to investigate the effect of demand driven recessions and monetary policy shocks on product dynamics. Second, the theoretical framework may be extended to incorporate multi-product firms, as in Bernard et al. (2010), which may shed light on the interplay between the fall in production and product destruction during recessions. Finally, another interesting extension is to consider vertical and horizontal differentiation in production varieties, and investigate interactions between changes in quality and variety of products during recessions.

## A Data

The data on establishment entry and exit are taken from private sector establishment births and deaths, reported by the Bureau of Labor Statistics (BLS).<sup>22</sup> For each variable, the mnemonics and data source are:

Domestic Product, GDP, BEA.

Fixed Private Investment, FPI, BEA.

Personal Consumption Expenditures: Services, PCESV, BEA.

Personal Consumption Expenditures: Nondurable Goods, PCND, BEA.

Gross Domestic Product: Implicit Price Deflator, GDPDEF, BEA.

All Employees: Total nonfarm, PAYEMS, BLS.

Average Weekly Hours of Production and Nonsupervisory Employees: Manufacturing, AWHMAN, BLS.

A detailed discussion on establishment births and deaths is available at:

<http://www.bls.gov/news.release/cewbd.tn.htm>. By definition establishment birth and death do not include re-openings and temporarily shutdown. Births are defined as establishments that appear in the longitudinal database for the first time with positive employment in the third month of a quarter, or showed four consecutive quarters of zero employment in the third month followed by a quarter in which it shows positive employment in the third month. Similarly, deaths are defined as establishments that either drop out of the longitudinal database or an establishment that had positive employment in the third month of a given quarter followed by four consecutive quarters of showing zero employment in the third month. The definition of establishment destruction in the model is consistent with the characterization of the data.

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<sup>22</sup>The dataset is available at the web address: [http://www.bls.gov/web/cewbd/table9\\_1.txt](http://www.bls.gov/web/cewbd/table9_1.txt).

## B Model extensions: entry selection and exogenous destruction

In this section, we describe two extensions to the benchmark model. First, we introduce heterogeneity in newly created firms, and second, we rule out endogenous destruction.

### B.1 Entry selection

In the benchmark model, unprofitable production line whose specific productivity is below a certain threshold exit the market. However, firms are identical at the entrance in the market. As an extension, to study heterogeneity in newly created firms, we introduce pre-selection in entry based on plant-specific productivity.

Upon entry, potential entrants,  $N_{E,t}$ , draw a productivity level from the same Pareto distribution  $G(z)$ . However, only a subset of  $H_t$  firms actually enter the market, and entry costs are financed by households. This assumption rationalizes the fact that only a subset of initial ideas materialize due to the R&D process. Lee and Mukoyama (2008) consider a similar preselection in entry. In equilibrium, the firm's expected value weighted by the probability of successful entry must be equal to sunk entry costs, according to the free entry condition:

$$\frac{H_t}{N_{E,t}}v_t = \frac{w_t f_{E,t}}{A_t^\vartheta}, \quad (22)$$

which prevents the entrance of potential new producers with a productivity level below the profitable threshold. For simplicity, we assume that firms never re-enter the market once they are destroyed in the pre-selection. The firm with the cutoff productivity level,  $z_{h,t}$ , observes  $v(z_{h,t}) = 0$ , implying  $E_t d_{t+1}(z_{h,t}) = 0$ . The term  $E_t d_{t+1}(z_{h,t})$  is derived as

follows:

$$E_t d_{t+1}(z_{h,t}) = E_t \frac{S_{t+1}}{N_{t+1}} d_{s,t+1}(z_{h,t}) \quad (23)$$

$$= E_t \frac{S_{t+1}}{N_{t+1}} \left( \frac{1}{\sigma} S_{t+1}^{\psi(\sigma-1)-1} \rho_{t+1}^{1-\sigma}(z_{h,t}) C_{t+1} - \frac{w_{t+1} f_{t+1}}{A_{t+1}^\theta} \right) \quad (24)$$

$$= E_t \frac{S_{t+1}}{N_{t+1}} \left( \frac{1}{\sigma} \frac{k - (\sigma - 1)}{k} S_{t+1}^{\psi(\sigma-1)-1} \rho_{t+1}^{1-\sigma}(\tilde{z}_{h,t}) C_{t+1} - \frac{w_{t+1} f_{t+1}}{A_{t+1}^\theta} \right) \quad (25)$$

$$= E_t \frac{S_{t+1}}{N_{t+1}} \left[ \frac{1}{\sigma} \frac{k - (\sigma - 1)}{k} \frac{C_{t+1}}{S_{t+1}} \left( \frac{\tilde{z}_{h,t}}{\tilde{z}_{s,t+1}} \right)^{\sigma-1} - \frac{w_{t+1} f_{t+1}}{A_{t+1}^\theta} \right], \quad (26)$$

where to write the third identity (25), we use the equilibrium pricing conditions (16) and (14) and to write the fourth identity (26), we use the definition of the price index and real price, namely,  $\tilde{\rho}_{s,t+1}(\tilde{z}_{s,t+1}) = S_{t+1}^\psi$  and  $\rho_{t+1}(\tilde{z}_{h,t}) = \frac{\sigma}{\sigma-1} \frac{w_{t+1}}{A_{t+1} \tilde{z}_{h,t}}$ . Thus we have the following zero cutoff profit condition for entry (ZCPE)

$$\frac{1}{\sigma} E_t \left[ \frac{S_{t+1}}{N_{t+1}} \frac{C_{t+1}}{S_{t+1}} \left( \frac{\tilde{z}_{h,t}}{\tilde{z}_{s,t+1}} \right)^{\sigma-1} \right] = \frac{k}{k - (\sigma - 1)} E_t \left[ \frac{S_{t+1}}{N_{t+1}} \frac{w_{t+1} f_{t+1}}{A_{t+1}^\theta} \right]. \quad (27)$$

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

$$\frac{H_t}{N_{E,t}} = z_{\min}^k \left[ \frac{k}{k - (\sigma - 1)} \right]^{\frac{k}{\sigma-1}} \tilde{z}_{h,t}^{-k}. \quad (28)$$

Equations (27) and (28) determine  $\tilde{z}_{h,t}$  and  $H_t$ . Since the number of new entrants that enter the market is equal to  $H_t$ , the labor market clearing condition (21) is the same as in the model without entry selection, where the free entry condition is (22). Finally, note that the extended model contains the additional variables,  $N_{E,t}$  and  $\tilde{z}_{h,t}$ , whose dynamics are represented by equations (27) and (28). Therefore, in the entry selection model, the number of destroyed firms at entrance is defined as

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

and the overall number of destroyed firms is

$$D_t \equiv D_t^S + D_t^\delta + D_t^H,$$

where  $D_t^S \equiv N_t - S_t$  and  $D_t^\delta \equiv \delta(N_t + H_t)$ , as in the benchmark model.

## B.2 A model with exogenous destruction

The baseline model nests a model with exogenous product destruction when operational fixed costs are set to zero ( $f_t = 0$ ). In this instance, all firms engage in production ( $N_t = S_t$ ), and the plant-specific productivity level becomes irrelevant for the product profitability. From equation (19), the average productivity level of producers remains at its steady state level:  $\tilde{z}_{s,t} = \tilde{z}_s$ . Therefore, in the model with exogenous product destruction, equations (17) and (18) are removed from the system.

## C Steady state

We start by deriving the steady state of the benchmark model. The Euler equation (7) provides:

$$\frac{1}{\beta} = (1 - \delta) \left( 1 + \frac{\tilde{d}}{v} \right). \quad (29)$$

Using the average profit equation (17), the ZCP equation (18), we can write equation (29) as:

$$\frac{\tilde{d}_s}{w} = \frac{\sigma - 1}{k - (\sigma - 1)}. \quad (30)$$

From the definition of operational profits among producers, equation (20), we have  $\tilde{d} = S\tilde{d}_s/N$ , and the free entry condition (9) implies:  $v = w$ . Using these relations, we can express equation (29) as:

$$\frac{1}{\beta} = (1 - \delta) \left( 1 + \frac{S}{N} \frac{\sigma - 1}{k - (\sigma - 1)} f \right), \quad (31)$$

which provides the steady state endogenous destruction rate,  $S/N$ , given operational fixed costs,  $f$ .

We set the value of  $\chi$  so that the steady state labor supply is equal to one. From the law of motion of producers (6), we derive the number of new entrants,  $H = \delta N / (1 - \delta)$ . Using these relations in the labor market clearing condition (21), it yields:

$$\frac{1}{N} = (\sigma - 1) \frac{S}{N} \frac{\sigma - 1}{k - (\sigma - 1)} f + \sigma \frac{S}{N} f + \frac{\delta}{1 - \delta}, \quad (32)$$

which provides a unique solution for the number of producers, provided the endogenous destruction rate,  $S/N$ . Once the value  $S$  is obtained, the steady state values of other variables is straightforward to derive.

In the model with entry selection, the free steady-state entry condition is  $Hv/N = w$ , and then the steady state can be derived using the same procedure outlined for the benchmark model. In the place of (31) and (32), we have

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

and

$$\frac{1}{N} = (\sigma - 1) \frac{S}{N} \frac{\sigma - 1}{k - (\sigma - 1)} f + \sigma \frac{S}{N} f + \frac{\delta}{1 - \delta} \left( \frac{H}{N_E} \right)^{-1}. \quad (33)$$

Because there is no difference between entry and exit selection, the rate of destruction in entry and exit coincides as  $S/N = H/N_E$ . Provided the value of  $S/N = H/N_E$  and  $f$ , the above equation (33) gives the value of  $N$ , and those of other variables are straightforward to find.

In the model with exogenous job destruction, we assume that  $f = 0$ , which implies  $S/N = 1$ ,  $\tilde{d} = \tilde{d}_s$ . Using these conditions on the Euler equation (7) yields:

$$\frac{1}{\beta} = (1 - \delta) \left( 1 + \frac{\tilde{d}_s}{v} \right). \quad (34)$$

Inserting equation (34) into the free entry condition (9) and the law of motion of producers (6), the labor market clearing condition (21) yields:

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

which determines the value of all producers,  $N$ . It is relatively easy to find the steady state value for other variables.

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