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Endogenous product turnover and macroeconomic dynamics[☆]

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ABSTRACT

This paper introduces endogenous product 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. We find that product heterogeneity and the persistence of technology shocks play a critical role for the cyclicality of product turnover. Endogenous product destruction is important to evaluate the effect of permanent policies of entry deregulation and subsidies aimed to stimulate the economy.

1. Introduction

The importance of product creation and destruction as determinants of market performance is well recognized.[3] 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 modeling assumption.[4] This paper revisits the importance of product destruction for macroeconomic dynamics, and it shows that product destruction is critical to generate realistic fluctuations in product turnover.

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[3] See Broda and Weinstein (2010) and references therein.

[4] See Ghironi and Melitz (2005) and Bilbiie et al. (2012) and references therein for a recent discussion of the issue.

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Our research is motivated by the observation that high product turnover is a robust stylized fact in the data. Broda and Weinstein (2010), using micro-level data collected at the household level for a six-year period (1994 and 1999–2003), show that product creation is strongly pro-cyclical while product destruction is mildly counter-cyclical. As a result, net product creation (i.e. creation less destruction) is pro-cyclical.[5] Our paper shows that endogenous product destruction is critical to replicate these stylized facts.

This paper sets up a 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 product-specific heterogeneity, imposing that unprofitable production lines stay idle until a positive shock makes them profitable. The model is calibrated to replicate the business cycle statistics on product dynamics in Broda and Weinstein (2010). 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.[6] 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 and stay idle until a new technological improvement makes them profitable, 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).[7] 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 the number of products.[8]

Second, we show that product heterogeneity and the degree of persistence of the aggregate productivity shock plays a critical role for the cyclicality of product destruction. In the presence of products with different productivity levels, a substantial adjustment takes place in the cutoff level of productivity, generating a strong counter-cyclical pattern of product destruction. Likewise, in the presence of high productivity persistence, sales decline considerably as a result of consumption-smoothing preferences of households, generating a strong counter-cyclical pattern of product destruction. Therefore, the model generates pro-cyclical product destruction for a relatively low degree of product heterogeneity and persistence in the aggregate productivity shock whereas it generates a-cyclical product destruction for a high degree of product heterogeneity and persistence in the shock. As we discuss below, these mechanisms help reconcile contrasting results on the cyclicality of product destruction in the literature. We show that the degree of product heterogeneity and the persistence of the technology shock are tightly linked to the "insulation effect" of product creation on product destruction, argued in Caballero and Hammour (1994). Specifically, we characterize the dynamic aspects of the insulation effect, which show that a reduction in current product creation insulates future product destruction.

Third, 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 to entry costs 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 product-specific output in the long run.[9] A fall in entry costs stimulates product creation. However, if product destruction is constant, the 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

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[5] The statistics on net product creation, product creation and product destruction are taken from Broda and Weinstein (2010), and they are computed from the ACNielsen Homescan database. According to their estimates, a one percentage point increase in consumption growth is associated with a rise in product creation of 0.299 percentage points and a decrease in product destruction of −0.053 percentage points, respectively. A one percentage point increase in consumption growth is associated with a rise in net creation of 0.351 percentage points. See also Table 3 in section 4.2.

[6] 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.

[7] Hamano and Zanetti (2015) provide an extension of the model that accounts for selective entry by assuming that product creation also depends on plant-specific productivity levels. Newly created products must therefore have sufficiently high productivity levels to remain in the market. This alternative version of the model is able to study the effect of plant-specific characteristics of newly created products on aggregate fluctuations.

[8] Caballero and Hammour (2005) document a similar empirical pattern that they call "reversed liquidationist view."

[9] The term "sclerosis" was coined by Caballero and Hammour (2005).

costs enables less productive products to stay in the market, thereby reducing the long-run, plant-specific productivity and contributing to the creation of "zombie" industry in the economy.

A number of studies investigate the interplay between *firm* flows and business cycle dynamics. Recent research by Chatterjee and Cooper (2014), Bilbiie et al. (2012), Jaimovich and Floetotto (2008), Lewis and Poilly (2012) and Minniti and Turino (2013) show that the interplay between endogenous firm 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 firm creation, they assume constant firm destruction. Other studies consider the effect of entry deregulation and subsidies in the presence of endogenous firm destruction. Melitz (2003) investigates the effect of subsidies to entry and fixed costs of production on the stationary equilibrium of an open economy model. Felbermayr and Prat (2011) develop a search model with heterogeneous, multiple worker firms and investigate the long-run effect of sunk entry costs and fixed costs on unemployment. We extend the analysis of these studies by considering a dynamic model.

We also relate to the literature on the relevance of firm heterogeneity for aggregate fluctuations, as established in Gabaix (2011). 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 the demand and supply side of the economy. The focus of the aforementioned study is, however, on firm heterogeneity and the implication on the propagation mechanism of technology shock. We instead investigate the interplay between entry and exit under different types of policy shocks. Samaniego (2008) investigates the relevance of establishment entry and exit over the business cycle and finds that establishment dynamics play a limited role on aggregate fluctuations. Lee and Mukoyama (2015), Caunedo (2011), Clementi and Palazzo (2016) 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.[10] 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 research that develops general equilibrium models with endogenous firm creation to investigate the effect of policy reforms on aggregate fluctuations (Shao and Silos, 2013; Cacciatore and Fiori, 2016 and Cacciatore et al., 2015) and to study optimal monetary policy (Lewis, 2013 and Cacciatore et al., 2016) and fiscal policy (Chugh and Ghironi, 2015 and Colciago, 2016). 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 discusses the extensions of the model with exogenous product destruction. Section 4 discusses the calibration of the model and reports the results. Section 5 performs sensitivity analysis. Section 6 concludes.

2. The model

The model embeds product creation and product variety diversification 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. There is a large firm that has multiple product lines. Upon release, each product draws a specific productivity level from a given distribution and is subject to sunk entry costs. During each period, fixed operational costs are required to maintain production. Both sunk entry costs and fixed operational costs are paid in terms of effective labor, and products that cannot afford fixed operational costs become unprofitable and stay "idle" until a positive technology shock makes they profitable again. At that point, the product line resumes production.

2.1. Households

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

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

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 φ is the Frisch elasticity of labor supply.[11]

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[10] These latest works extend the analysis of earlier studies by Hopenhayn (1992a, 1992b), Hopenhayn and Rogerson (1993) and Campbell (1998).

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

Consumption is defined over a continuum of goods, Ω, and during each period t, only a subset of goods, $\Omega_t \subset \Omega$, is available. Each produced good has a unique variety indexed by $\omega \in \Omega_t$. The consumption aggregator is

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

where $c_t(\omega)$ is individual demand for variety ω. In particular, $\sigma > 1$ is the elasticity of substitution among varieties. The price index that minimizes the consumption expenditure is

$$P_t = \left(\int\limits_{\omega \in \Omega_t} p_t^{1-\sigma}(\omega)\, d\omega \right)^{\frac{1}{1-\sigma}}, \tag{3}$$

where $p_t(\omega)$ is the individual price of variety ω. Equation (3) is consistent with a welfare-basis index and shows that for a given variety ω, the price index rises (decreases) when the number of available varieties decreases (rises).

The demand for each variety, ω, is

$$c_t(\omega) = \left(\frac{p_t(\omega)}{P_t} \right)^{-\sigma} C_t, \tag{4}$$

where $p_t(\omega)$ denotes the physical unit price of variety ω.

2.2. Production, pricing and producing decision

Products are indexed by their specific productivity, z. Production requires a fixed operational cost of f_t units of labor in each period. During each period t, the labor demand, $l_t(z)$, depends on the scale of effective production, $y_t(z)/A_t z$. Fixed operational costs are defined in terms of effective labor, f_t/A_t, so that the total labor demand is[12]

$$l_t(z) = \frac{y_t(z)}{A_t z} + \frac{f_t}{A_t}. \tag{5}$$

Fixed costs fluctuate with aggregate labor productivity level, A_t, and the exogenous term, f_t, proxies (de)regulation in production.

In each period, a number of new products, H_t, enters the market. Prior to entry, these new products are identical and producers face a sunk entry cost of $f_{E,t}$ effective labor units. Entry cost is therefore equal to $w_t f_{E,t}/A_t$ units of consumption goods, where w_t is the real wage. Upon entry, each product draws a productivity level, z, from a distribution, $G(z)$, with support on $[z_{\min}, \infty)$.[13]

Due to fixed operational costs, only a subset of products with a productivity level, z, that is higher than the cutoff level, $z_{s,t}$, charges sufficiently lower prices and earns profits, despite the existence of fixed operational cost, f_t. Destruction of the production unit is therefore endogenous and depends on the cutoff productivity level. In addition to the endogenous destruction, an exogenous depreciation shock, which takes place with probability $\delta \in (0,1)$, hits producers in each period. The shock is independent from the level of product-specific productivity and materializes at the end of each period. Therefore, $G(z)$ also represents the productivity distribution of all products that have production potential.

Each product faces a residual demand curve with constant elasticity, σ, described by equation (4), which contributes to the determination of the production scale. Profit maximization of the product prices yields the following optimal pricing decision:

$$\rho_t(z) = \frac{\sigma}{\sigma - 1} \frac{w_t}{A_t z}, \tag{6}$$

which states that the real price of production is a markup over marginal costs. Depending on the level of product-specific productivity, z, a product may or may not be produced. Thus, using equation (5) and (6), if production materializes, the real

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[12] To maintain the theoretical framework as close as possible to the benchmark model of Bilbiie et al. (2012), we refrain from embedding physical capital in the model. However, the model accounts for investment decisions in the creation of new products.

[13] Empirical studies by Bloom et al. (2012), Bachmann and Bayer (2013) and Kehrig (2015) show that the distribution of productivity is asymmetric and more spread out in recession. Similarly, Berger and Vavra (2015) and Vavra (2014) show that asymmetries in the responses of economic variables are driven by variations in the dispersion of price changes over the business cycle. Our model is not designed to replicate these important empirical regularities. Instead, it assumes a fixed distribution of productivity, $G(z)$, which allows the cutoff productivity level, z_t, to change, resulting in different shapes of the distribution of products in the market. Extending the model to incorporate a time-varying productivity distribution would certainly be a very useful extension for future research.

profits are[14]:

$$d_t(z) = \frac{1}{\sigma}\rho_t^{1-\sigma}(z)\, C_t - \frac{w_t f_t}{A_t}. \tag{7}$$

Since the elasticity of substitution among varieties is more than unitary ($\sigma > 1$), lower real prices induce a rise in profits.

2.3. Product average

To focus on aggregate dynamics across different products, we derive the average product specific productivity across survivors-producers, $\widetilde{z}_{s,t}$. Given the distribution of productivity level, $G(z)$, the mass of products, N_t, is defined over the productivity levels $[z_{\min}, \infty)$. Among these products, the fraction $S_t = \left[1 - G\left(z_{s,t}\right)\right] N_t$ of product is produced after surviving product destruction, as described below. Following Melitz (2003) and Ghironi and Melitz (2005), we define the average productivity of surviving products, $\widetilde{z}_{s,t}$, as

$$\widetilde{z}_{s,t} \equiv \left[\frac{1}{1 - G(z_{s,t})}\int_{z_{s,t}}^{\infty} z^{\sigma-1} dG(z)\right]^{\frac{1}{\sigma-1}}. \tag{8}$$

The term, $\widetilde{z}_{s,t}$ thus contains all the information about the distribution of productivities. Aggregating across productivity levels and substituting equation (8) into equation (6), the average real price of surviving products is

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

Similarly, average real profits among surviving producers are expressed as follows:

$$\widetilde{d}_{s,t} = \frac{1}{\sigma}\frac{C_t}{S_t} - \frac{w_t f_t}{A_t}. \tag{9}$$

Finally, we define average operational profits among total products as $\widetilde{d}_t = (S_t/N_t)\widetilde{d}_{s,t}$.

2.4. Product entry and exit

We assume that products entered at time t only start producing at time $t+1$. These products are discounted by the stream of their expected profits $\left\{\widetilde{d}_{s,i}\right\}_{i=t+1}^{\infty}$, using the stochastic discount factor of households adjusted by exogenous exit and inducing shock δ. Thus, their expected post entry value is

$$v_t = E_t \sum_{i=t+1}^{\infty} \left[\beta(1-\delta)\right]^{i-t}\left(\frac{C_i}{C_t}\right)^{-1}\widetilde{d}_i, \tag{10}$$

which represents the share price of equities and mutual funds across different products. Product entry occurs until the expected product value (10) is equal to the entry cost, leading to the free entry condition,

$$v_t = \frac{w_t f_{E,t}}{A_t}. \tag{11}$$

The timing of entry and of production implies that the number of products evolves according to the law of motion:

$$N_t = (1-\delta)(N_{t-1} + H_{t-1}). \tag{12}$$

Among N_t number of total product lines, only a subset number of S_t products is produced.

For any given specific productivity level, z, the producer produces if profits are positive, $d_t(z) > 0$. Otherwise it terminates production. Inefficient production lines that have drawn a lower productivity level than the cutoff ($z \le z_{s,t}$) necessary to ensure positive profits are discontinued and stay idle until a positive technological process makes them profitable. Endogenous destruction takes place following a “strict productivity ranking,” as in Caballero and Hammour (1994, 1996, 2005).

Operational profits become zero for the product with the cutoff productivity level, $z_{s,t}$, provided that the following zero profit cutoff condition holds:

$$d_t\left(z_{s,t}\right) = \frac{1}{\sigma}\rho_t\left(z_{s,t}\right)^{1-\sigma} C_t - \frac{w_t f_t}{A_t} = 0. \tag{13}$$

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[14] As in Chugh and Ghironi (2015), under the assumption of a large firm such as ours, it is possible to internalize the setup entry cost of products in the dividends. The resulting equilibrium conditions, however, are similar.

2.5. Parametrization of productivity draw

To solve the model, we must assume a distribution of productivity levels, z. We assume the following Pareto distribution for $G(z)$:

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

where $z_{\min}$ is the minimum productivity level and κ $(> \sigma - 1)$ determines the shape of the distribution. The parameter κ indexes the dispersion of productivity across products. The dispersion decreases as κ increases, and the productivity levels are concentrated towards the lower bound $z_{\min}$. When $\kappa = \infty$, all products are located at $z_{\min}$, and products become homogenous. To ensure that variance of the productivity distribution is finite, we assume that $\kappa > \sigma - 1$. With this parametrization, we can express the average productivity of surviving products, $\widetilde{z}_{s,t}$, in equation (8) as

$$\widetilde{z}_{s,t} = z_{s,t}\left[\frac{\kappa}{\kappa - (\sigma - 1)}\right]^{\frac{1}{\sigma - 1}}, \tag{14}$$

and the fraction of surviving products as

$$\frac{S_t}{N_t} = z_{\min}^{\kappa}\left[\frac{\kappa}{\kappa - (\sigma - 1)}\right]^{\frac{k}{\sigma - 1}} \widetilde{z}_{s,t}^{-\kappa}. \tag{15}$$

As mentioned, the product with cutoff productivity level earns zero profits from production, such that $d_t\left(z_{s,t}\right) = 0$, and productivity levels below the cutoff level $z_{s,t}$ are unprofitable. Substituting equation (14) in the product's real profits (7) yields the equation that determines the cutoff productivity level:

$$\frac{1}{\sigma}\frac{C_t}{S_t} = \frac{\kappa}{\kappa - (\sigma - 1)}\frac{w_t f_t}{A_t}. \tag{16}$$

2.6. Household budget constraint and intertemporal problems

We choose the consumption-based price index, P_t, as numéraire. The household receives income by supplying labor, L_t, at the real wage rate, w_t, by acquiring average dividends income, $\widetilde{d}_t$, and by selling its initial share position, v_t, of share holdings, x_t, of the firm composed of existing products, N_t. The household spends its income on consumption, C_t, buying x_{t+1} shares of the firm composed of existing products, N_t, and new products, H_t, at the share price, v_t. The household budget constraint is thus

$$L_t w_t + x_t N_t\left(v_t + \widetilde{d}_t\right) = C_t + x_{t+1} v_t\left(N_t + H_t\right). \tag{17}$$

During each period t, the representative household chooses consumption, C_t, share holding, x_{t+1}, and the labor supply, L_t, to maximize the expected utility function (1) subject to the budget constraint (17). The first-order conditions with respect to consumption and labor supply yield the standard labor supply equation

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

The first-order condition with respect to share holdings once combined with the products law of motion (12) and the first-order condition for consumption yields

$$v_t = \beta\left(1 - \delta\right) E_t\left(\frac{C_{t+1}}{C_t}\right)^{-1}\left(v_{t+1} + \widetilde{d}_{t+1}\right), \tag{18}$$

which, once iterated forward, shows that share prices are the expected discounted sum of future dividends.

2.7. Model equilibrium and solution

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 products (extensive margins):

$$L_t = S_t l_t\left(\widetilde{z}_{s,t}\right) + H_t\frac{v_t}{w_t},$$

Table 1
Summary of the benchmark model.

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

which can be expressed as[15]

$$L_t = S_t \left[(\sigma-1) \frac{\widetilde{d}_{s,t}}{w_t} + \sigma \frac{f_t}{A_t}\right] + H_t \frac{v_t}{w_t}. \tag{19}$$

Equation (19) is equivalent to the aggregated accounting identity of GDP obtained by aggregating budget constraints among households, $Y_t \equiv C_t + v_t H_t = L_t w_t + S_t \widetilde{d}_{s,t}$, where Y_t is real GDP measured in the welfare basis of expenditures and income. The model consists of 11 equations and 11 endogenous variables among which the number of products, 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 ε_t is a normally distributed innovation with zero mean and variance equal to σ_{υ}^2. Table 1 summarizes the benchmark model.

The equilibrium conditions do not have an analytical solution. Consequently, we approximate the system by loglinearizing its equations around the stationary steady state. In this way, a linear dynamic system describes the path of the endogenous variables' relative deviations from their steady-state value, accounting for the exogenous shock.

3. A model with exogenous destruction

In this section, we describe the extension to the benchmark model and rule out endogenous 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 products engage in production ($N_t = S_t$), and the plant-specific productivity level becomes irrelevant for the product profitability. From equation (15), the average productivity level of producers remains at its steady state level: $\widetilde{z}_{s,t} = \widetilde{z}_s$. Therefore, in the model with exogenous product destruction, equations (15) and (16) are removed from the system.

4. Results

In this section, we describe the calibration of the 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 exogenous product destruction rate. We perform the analysis by studying the variables' responses to recessionary productivity shocks, permanent product entry deregulation and permanent subsidies. We also compare business cycle statistics across the different specifications of the model.

4.1. Calibration

Table 2 provides a summary of the calibration of the benchmark model. We calibrate the model on quarterly frequencies. The value of discount factor, β, and the Frisch elasticity of labor supply, φ, are set to 0.99 and 2, respectively. These values are within the range of those used in the literature. The value of the parameter of the disutility of supplying labor, χ, is set to 0.9884 to deliver a steady-state labor supply equal to one.[16] The elasticity of substitution among varieties, σ, is set to 11.5, within brand elasticity, based on Broda and Weinstein (2010).[17]

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[15] Note that $\widetilde{d}_{s,t} = \frac{\widetilde{\rho}_{s,t}}{\sigma} \widetilde{y}_{s.t} - \frac{w_t f_t}{Z_t^{\theta}}$, where $\widetilde{y}_{s,t}$ represents average intensive margins.

[16] We set χ equal to 0.9873 in the model without endogenous destruction. This choice is a mere normalization, with no effect on the system dynamics, as outlined in Bilbiie et al. (2012).

[17] Ghironi and Melitz (2005) set the elasticity of substitution across variety to 3.8, which also corresponds with the elasticity between local and imported goods. As a robustness check, we have simulated the model with alternative lower values (i.e. setting $\sigma = 7.5$ to match the across brand elasticity in Broda

Table 2
Calibration of the model.

β	Discount factor	0.99
φ	Frisch elasticity of labor supply	2
χ	Disutility of supplying labor	0.9884
σ	Elasticity of substitution among varieties	11.5
κ	Distribution parameter	11.5070
δ	Exogenous destruction rate	0.0588
f	Fixed operational costs	0.0075
A	Steady-state level of aggregate productivity	1
$z_{\min}$	Minimum idiosyncratic productivity level	1
f_E	Fixed entry costs	1
ρ	Persistence of aggregate productivity	0.979
σ_{υ}	Standard deviation of productivity shocks	0.0072

We calibrate the parameter, κ that determines the shape of the distribution of product-specific productivity to replicate the mean relative sales of exiting products to those of the average products, 0.09, and also the mean quarterly endogenous destruction rate, $0.24/4 = 0.06$, as in Broda and Weinstein (2010).[18] To achieve this calibration, we set the steady-state value of subsidies, f, equals to 0.0075. The value of κ is critical for the dynamic properties of the model. Therefore, we conduct a sensitivity analysis on this parameter in the last section of the paper. For the version of the model with exogenous destruction, operational fixed costs are set equal to zero ($f = 0$).

The exogenous rate of product destruction, δ, is set to match the mean annual product creation rate of 0.25 in Broda and Weinstein (2010), consistent with equation (12) at the steady state. Therefore, we set the exogenous destruction rate, δ, to 0.0588, implying that, on average, 5.8 percent of products are exogenously destroyed per quarter. We normalize A, $z_{\min}$ and f_E to be equal to one.[19] Appendix A provides the derivation of the steady state for different versions of the model.

Finally, we set the persistence parameter, ρ, and the standard deviation of innovations, σ_{υ}, equal to 0.979 and 0.0072, respectively, as in King and Rebelo (1999).[20]

4.2. Cyclicality of product turnover

To investigate how product creation and destruction co-move with economic activity, we compare how changes in consumption growth correlate with movements in product creation, destruction and net creation. As outlined in Ghironi and Melitz (2005) and Bilbiie et al. (2012), we define the data consistent variables by deflating each original variable 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: $X_{R,t} \equiv P_t X_t / \widehat{P}_t$.

The measure of consumption that is consistent with observed data is $C_{R,t} = \widetilde{y}_{s,t} S_t$, since it abstracts from the welfare effect imputed to the extensive margin of product variety. Similar to Broda and Weinstein (2010), by combining equations (12) and (15) and loglinearizing the resulting equation around the stationary steady state, we decompose the deviation of the consumption growth rate from its steady state as[21]:

$$\widehat{C}_{R,t} = \underbrace{\widehat{\widetilde{y}}_{s,t} + \widehat{N}_{t-1}}_{\text{Existing products}} - \underbrace{\left(\kappa \widehat{\widetilde{z}}_{s,t} + \delta \widehat{N}_{t-1} + \frac{\delta^2}{1-\delta}\widehat{H}_{t-1}\right)}_{\text{Product destruction}} + \underbrace{\frac{\delta}{1-\delta}\widehat{H}_{t-1}}_{\text{Product creation}}, \tag{20}$$

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and Weinstein, 2010). The impulse response functions are qualitatively similar to those in our benchmark calibration. An appendix that details the findings is available on request to the authors.

[18] The relative sales of exiting products with respect to the average of all products in our theoretical model is:

$$\frac{\frac{1}{G(z_{s,t})}\int_{z_{\min}}^{z_{s,t}} S_t^{\psi(\sigma-1)-1}\rho(z)^{1-\sigma}\,dG(z)}{\int_{z_{\min}}^{\infty} S_t^{\psi(\sigma-1)-1}\rho(z)^{1-\sigma}\,dG(z)} = \frac{1 - z_{s,t}^{-\kappa} z_{s,t}^{\sigma-1}}{1 - z_{s,t}^{-\kappa}}.$$

The corresponding endogenous destruction rate in the theoretical model is $1 - S/N$.

[19] To calibrate the product 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 product destruction rate in the data. Ghironi and Melitz (2005) use a similar calibration strategy. Hence, $z_{\min}$ plays no role on the level of product destruction whereas f is the parameter that determines the rate of product destruction.

[20] The calibration of the model is aimed to capture the dynamics of the product turnover in Broda and Weinstein (2010), which covers the six-year period 1994 and 1999–2003. The short time span makes the estimation of the innovation parameters (ρ and σ_{υ}) unreliable. We therefore resort to standard values in the literature. However, in section 5, we perform extensive robustness analysis on the parameter ρ and show that it plays an important role for product turnover.

[21] Using equation (12), the number of products manufactured in time period t is partitioned into two parts as: $N_t = (N_{t-1} + H_{t-1}) - \delta (N_{t-1} + H_{t-1})$. The first term, $(N_{t-1} + H_{t-1})$, is the number of existing products and new products from the previous period whereas the second term, $\delta (N_{t-1} + H_{t-1})$, is the number of existing and entrants that are destructed exogenously. By loglinearizing the first and second term, we obtain equation (20).

Table 3
Regression slopes.

	Net creation	Creation	Destruction
U.S. data	0.351	0.299	−0.053
Benchmark	0.402	0.312	−0.090
Exogenous destruction	0.264	0.315	0.051

Notes: The observed statistics on net product creation, product creation and product destruction are from Broda and Weinstein (2010), which are computed from the ACNielsen Homescan database. Each entry shows the elasticity of a variable with respect to consumption growth.

where each variable is expressed in deviation from its steady-state level. The first two terms ($\widehat{\widetilde{y}}_{s,t} + \widehat{N}_{t-1}$) on the right side of equation (20) show that consumption growth depends on changes in average real value of the existing products. The terms in the brackets represent the part of consumption growth that depends on endogenous ($\kappa\widehat{\widetilde{z}}_{s,t}$) and exogenous ($\delta\widehat{N}_{t-1} + \delta^2/(1-\delta)\widehat{H}_{t-1}$) product destruction, in which $\delta^2/(1-\delta)\widehat{H}_{t-1}$ captures exogenous destruction of new products. The last term ($[\delta/(1-\delta)]\widehat{H}_{t-1}$) describes the part of consumption growth related with product creation.

Similar to Broda and Weinstein (2010), in order to quantify the cyclicality of product creation and destruction, we present the patterns of net-product creation (i.e. creation less destruction) as well as product creation and destruction separately. Broda and Weinstein (2010) describe the co-movements of each of these variables by regressing consumption growth on net product creation, product creation and product destruction, respectively. They establish that product creation and *net* product creation is pro-cyclical whereas product destruction is counter-cyclical in U.S. data. To evaluate the performance of the different models, we produce the regression slope between net product creation, product creation and product destruction and consumption growth for the benchmark model with endogenous product destruction as well as for the alternative version of the model with exogenous product destruction. We then compare them against the same statistics in the data.[22] Table 3 reports the results.

The benchmark model that embodies endogenous product destruction and the model with exogenous destruction generate pro-cyclical patterns of net product creation with consumption growth (a one percentage point increase in consumption is associated with increase in net creation of 0.402 and 0.264 percentage points, respectively) that are close to the value of 0.351 percentage points in the data. All two models generate pro-cyclical patterns of product creation and consumption growth with the regression slope equal to 0.312 and 0.315, respectively, which are larger than the value of 0.299 in the data. Only the benchmark model successfully reproduces the counter-cyclical movements in product destruction, generating a regression slope equal to −0.090, similar to the value in the data.[23] Instead, the model with exogenous destruction generates pro-cyclical movements in product destruction (i.e., the regression slope equal to 0.051). This latest finding further outlines that the presence of endogenous product destruction is critical to replicate the counter-cyclicality of product destruction. To gain an intuition on the findings, equation (20) shows that, in the absence of endogenous product destruction (i.e., $\widehat{\widetilde{z}}_{s,t} = 0$), a fall in newly-introduced and existing products leads to a strong positive co-movement between product destruction and consumption growth. On the contrary, in the presence of endogenous product destruction, the average level of productivity rises, leading to a negative correlation between product destruction and consumption growth, as in the data.

To evaluate the overall performance of the model, we compare the second moments of key macroeconomic variables and their correlation with output.[24] The data are taken from King and Rebelo (1999), and results are reported in Appendix B. The benchmark model and the alternative version of the model show similar performance in reproducing the observed standard deviations of the aggregate macroeconomic variables of output, consumption and investment. Overall, the analysis shows that the theoretical models replicate relatively well movements in aggregate data. As we have discussed above, however, the model with endogenous product destruction is able to capture the negative correlation between consumption and product destruction whereas the model with exogenous product destruction fails to replicate this important stylized facts.[25]

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[22] 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. Specifically, the regression slope between a variable x and y, $b_{y,x}$ is computed as

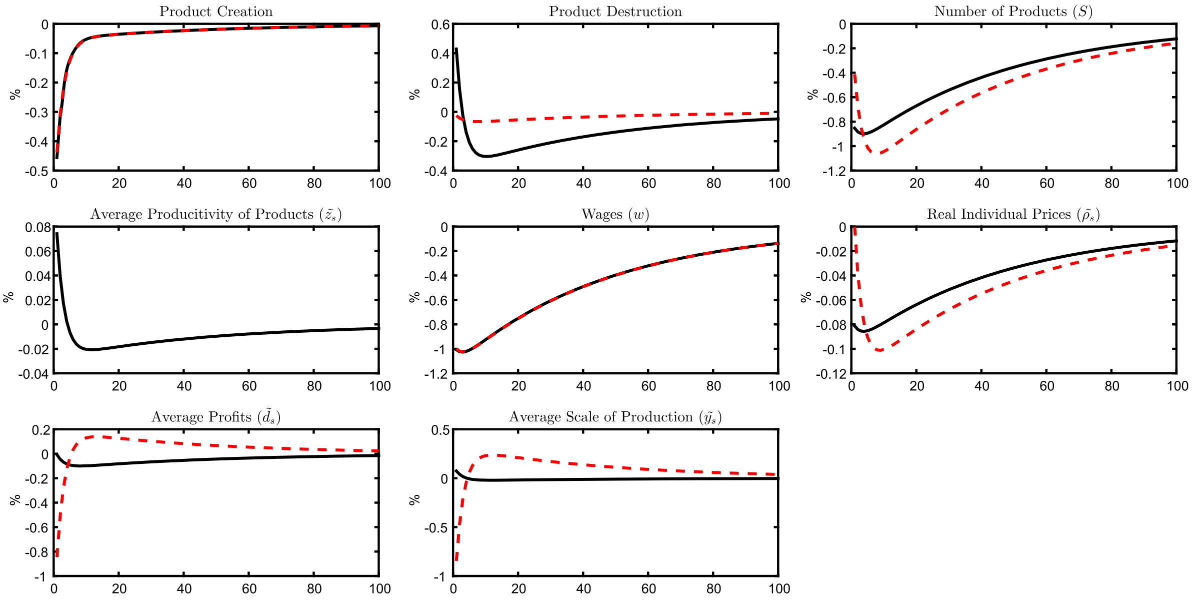
$$b_{y,x} = \rho_{xy}\frac{Std(y)}{Std(x)},$$

where ρ_{xy} denotes unconditional correlation between x and y.

[23] Note that Lee and Mukoyama (2015) report a similar pattern for *establishment* creation but they detect pro-cyclical establishment destruction using U.S. manufacturing data. We impute the difference to the specific data set used.

[24] It would be interesting to extend the model to include additional shocks (i.e., demand shocks) to investigate whether they have non-trivial implications for the dynamic properties of product creation and product destruction. We leave this extension open to future research. However, it is worth noting that although the model does not include demand shocks explicitly, product turnover acts as an *endogenous* demand shock since the agents have preferences for variety. Therefore the model indirectly accounts for movements in demands.

[25] Hamano and Zanetti (2015) show that results are robust to alternative calibrations of the elasticity of labor supply, φ, within a model that accounts for different preferences for variety. An appendix that details robustness analysis is available on request.



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) and the economy with exogenous destruction (dashed line).

Fig. 1. Impulse response functions to a recessionary productivity shock.

4.3. *Impulse response functions*

Figs. 1–4 present impulse response functions to a one percent recessionary productivity shock, A_t, a one percent permanent reduction in entry costs, $f_{E,t}$, and a one percent permanent reduction in operational costs, f_t, respectively. Each entry reports responses for the benchmark economy (solid line) and the economy with exogenous destruction (dashed line).

4.3.1. *Recessionary productivity shock*

Fig. 1 shows the response of key variables to a negative productivity shock. On impact, a recessionary technology shock raises fixed operational costs requiring higher product-specific productivity level for the product to survive destruction, increasing the average productivity level of products ($\widetilde{z}_{s,t}$). This process generates an increase in the destruction of less efficient products. As a result, surviving products charge lower prices ($\widetilde{\rho}_{s,t}$), which dampen the decrease in profits ($\widetilde{d}_{s,t}$) and the scale of production ($\widetilde{y}_{s,t}$) due to a recessionary shock. The figure shows that when the product destruction is constant, the on-impact fall in prices is contained since product-specific productivity fails to rise in response to the shock, which results in a larger decline both in profits and intensity in production on impact of the shock. 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 product-specific productivity level required to retain the product's profitability decreases. As a result, even less productive production lines remain in the economy. Accordingly, destruction is lower compared to the initial steady state along the recovery phase in the benchmark model. This mechanism counteracts the initial cleansing effect of recessions and is absent in the model with *exogenous* product destruction.

Fig. 2 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 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 destruction is due to the lower product-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 "reversed-liquidationist" (Caballero and Hammour, 2005) pattern 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.[26]

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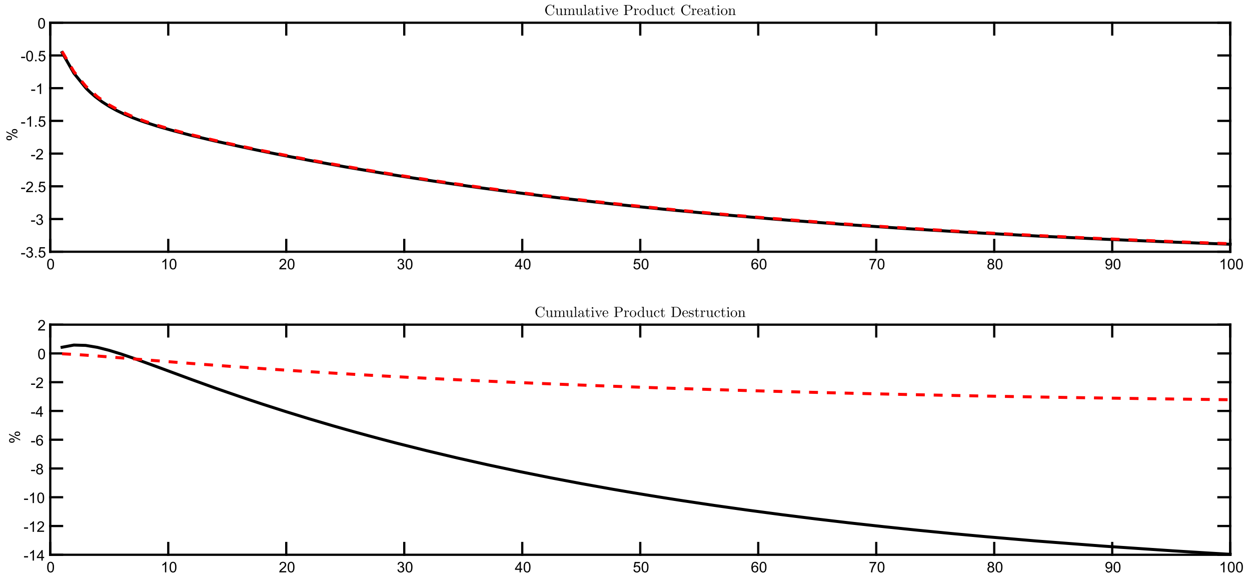
[26] To investigate the extent to which higher product destruction is relevant for welfare, it is critical to consider product-quality upgrading, which Aghion and Howitt (1992) establish as a distinguishing feature of newly-created products. Since our model abstracts from quality upgrading, it fails to account for



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) and the economy with exogenous destruction (dashed line).

Fig. 2. Cumulative impulse response functions to a recessionary productivity shock.

4.3.2. Permanent entry deregulation

Fig. 3 shows the effect of product 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. 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 product-specific productivity to maintain a production line's profitability (i.e. $\widetilde{z}_{s,t}$ rises) and therefore leaves marginal costs $(\widetilde{\rho}_{s,t})$ unchanged, along with a rise in the production scale $(\widetilde{y}_{s,t})$ and profits $(\widetilde{d}_{s,t})$.

It is worth noticing that with endogenous product destruction, the effect of deregulation is to permanently increase the average product-specific productivity in the economy. The rise in wages in response to higher product entrance commands permanently higher product-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 product productivity remains constant) and therefore induces a fall in each incumbents' 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 findings on worker flows in Caballero and Hammour (2005).[27]

4.3.3. Permanent subsidy increase

Fig. 4 shows the effect of product subsidies, proxied by a permanent one-percent reduction in fixed operational costs (f_t). By assumption, subsidies are irrelevant for the model with exogenous product destruction (i.e., $f_t = 0$) whereas they play an important role in the model with endogenous product destruction, due to their interplay with the profitability of the production line.

In the benchmark model, a permanent increase in subsidies leaves product creation almost unchanged and induces a permanent fall in product-specific productivity $(\widetilde{z}_{s,t})$ that decreases product destruction. As a result, net creation and the number of products (S_t) rises, which in turn increases the labor demand and raises wages (w_t). Consequently, marginal costs $(\widetilde{\rho}_{s,t})$ increase, and the production scale $(\widetilde{y}_{s,t})$ and profits $(\widetilde{d}_{s,t})$ fall.

This analysis shows that a reduction in fixed operational costs generates a permanent decrease in the average product-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

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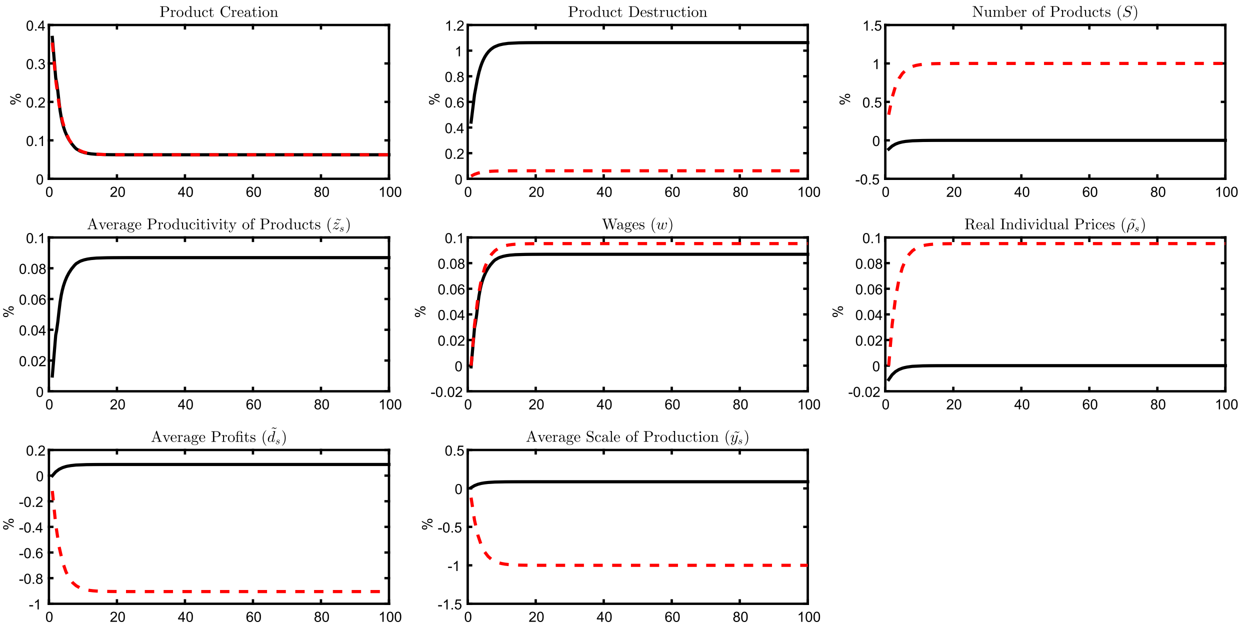
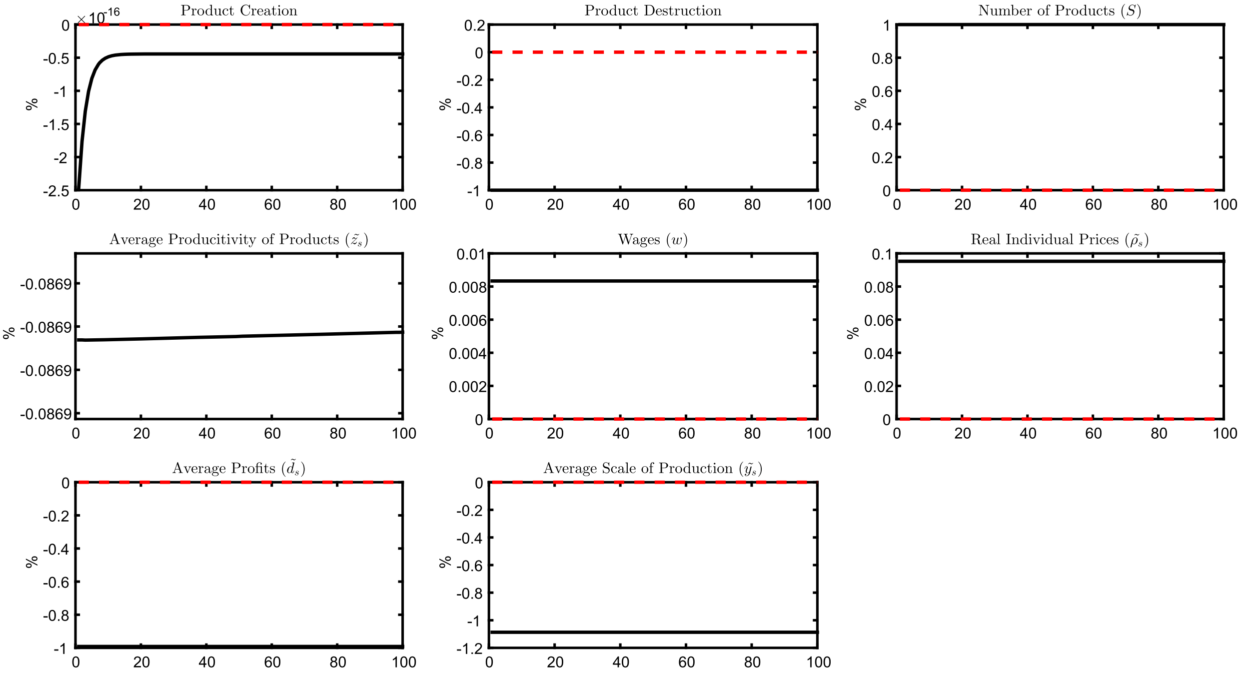
this important channel that surely entails relevant welfare effects. In a recent paper, Hamano and Zanetti (2017) develop a model with quality upgrading and endogenous entry and exit of firms that can be extended to study the welfare effect of a fall in product destruction in the presence of quality upgrading. The investigation of this issue is certainly an interesting extension for future research.

[27] However, in our framework, different from Caballero and Hammour (2005), there is no "scrambling" effect that reduces the effectiveness of the restructuring process related to financial constraints in product creation.



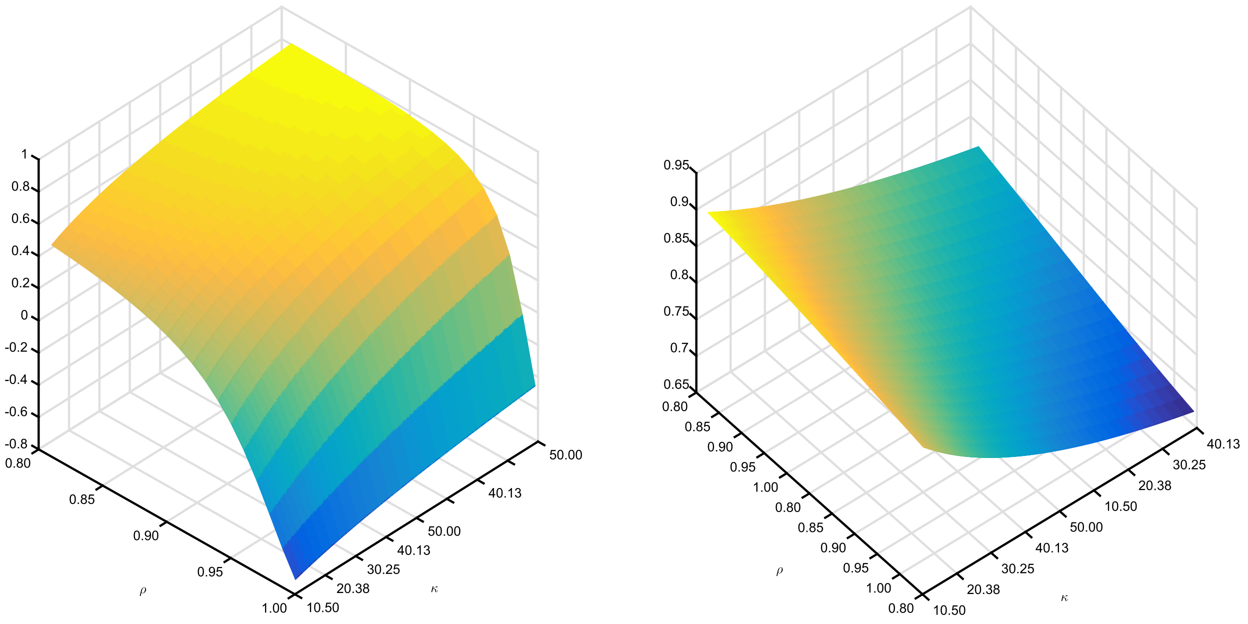
Notes: Each entry shows the percentage-point response of one of the model's variables to a permanent deregulaton shock for the benchmark economy (solid line) and the economy with exogenous destruction (dashed line).

Fig. 3. Permanent deregulation 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) and the economy with exogenous destruction (dashed line).

Fig. 4. Permanent subsidy shock.



Notes: The left (right) entry shows the contemporaneous correlation of product destruction (creation) with output.

Fig. 5. Correlation of product destruction and creation with output.

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.[28]

5. Sensitivity analysis

In this section, we discuss the sensitivity of the cyclical properties of product destruction and creation to the parameter κ that determines the degree of product heterogeneity by controlling the shape of the distribution of product-specific productivity, and the technological parameter ρ that determines the degree of persistence of technology shocks.[29] The analysis is performed using the same calibration of the benchmark model, with the exception of parameter κ and ρ.[30]

5.1. Product destruction and creation

The left entry of Fig. 5 shows the contemporaneous correlation of product destruction with output for different values of parameters κ and ρ. High values of κ lead to a more positive correlation between output and product destruction, for any given value of ρ.

The intuition for this finding is straightforward. Equation (20) shows that consumption growth falls for high values of κ, generating a negative correlation between product destruction and output. However, as explained in Section 2, high values of κ lead to more homogenous products whose productivity levels are clustered at the lower end of the productivity distribution ($z_{\min}$). The change in the distribution of productivity dampens the movements in the cutoff level of productivity, $\widehat{\widetilde{z}}_{s,t}$, and therefore reduces the negative effect of the cutoff level of productivity on the correlation between consumption growth and product destruction. At the limit, when $\kappa = \infty$, all products are located at the lowest end of the product distribution (i.e. $z = z_{\min} = 1$) and products are perfectly homogenous so that no adjustment takes place in the cutoff level

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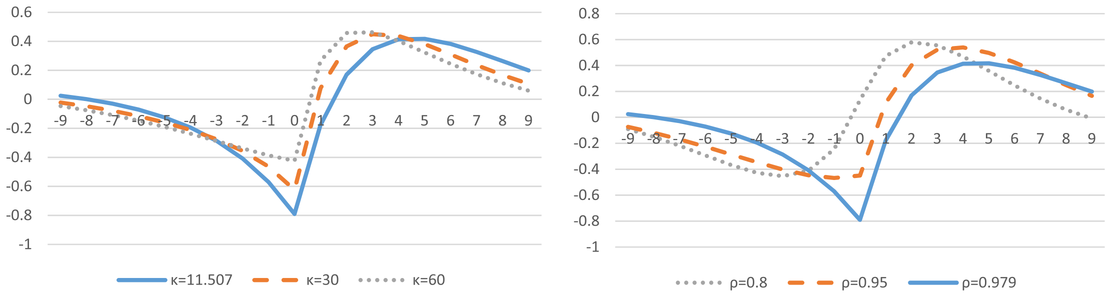
[28] Our results of the entry deregulation and production subsidies are related to the literature on product market reforms and unemployment (see Blanchard and Giavazzi, 2003; Zanetti, 2009 and the references therein). Felbermayr and Prat (2011), Cacciatore (2014) and Cacciatore et al. (2016) present a novel channel based on firm heterogeneity: entry deregulation or subsidies for incumbents change the cutoff-productivity level and unemployment decreases in the steady state since highly productive firms employ a large number of workers. Our findings are consistent with this result despite the model abstracts from unemployment.

[29] Poschke (2014) and Bonfiglioli et al. (2016) and Bonfiglioli et al. (2017) show that the degree of heterogeneity is an important dimension to consider in the analysis since it varies across countries, sectors and time.

[30] We report the cyclical properties of product creation and destruction with an empirically-consistent measure of output. We performed the same robustness analysis using an empirically-consistent measure of consumption for the benchmark model, and we established that results continue to hold. An appendix that details these results is available on request to the authors.



Notes: The left (right) panel shows the correlation of current product creation with leads and lags of product destruction for different values of κ (ρ).

Fig. 6. Correlation of product creation with leads and lags of product destruction.

of productivity, $\widehat{\widetilde{z}}_{s,t}$. In this instance, the cutoff level of productivity has no effect on consumption growth, and the correlation between consumption growth and product destruction becomes positive, as shown in equation (20). On the other hand, for small values of κ, product heterogeneity is large and the cutoff level of productivity, $\widehat{\widetilde{z}}_{s,t}$, adjusts sharply to changes in the economy, leading to strong counter-cyclical movements in product destruction.

The persistence parameter of the technological process, ρ, plays an important role for the cyclicality of product destruction. The left entry of Fig. 5 shows that when the value of ρ increases, the counter-cyclicality of product destruction rises. When the persistence of the technological process is high, a recessionary shock generates a prolonged fall in wage income as productivity takes longer to return to the original steady-state level in the aftermath of the shock. Since the household prefers smooth consumption over time, current consumption declines substantially in the prospect of a long period of low wage income, generating a sharp rise in product destruction and a reduction in output. The higher the persistence parameter, the stronger the reduction in output and the counter-cyclicality of product destruction with output.

These findings help to reconcile the contrasting results in Lee and Mukoyama (2015) 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 tightly linked to the degree of product heterogeneity (κ) and the shock persistence (ρ). The model is able to generate pro-cyclical product destruction for a low degree of heterogeneity or a low degree of persistence in the technological process whereas product destruction becomes a-cyclical for specific combinations of product heterogeneity and shock persistence.

The right entry of Fig. 5 shows the contemporaneous correlation of product creation with output for different values of parameters κ and ρ. The contemporaneous correlation of product creation with output is increasing with κ, for any given level of ρ. Following a recessionary shock, the sunk entry cost exceeds the value of new product and prevents the creation of new products in equilibrium. Unlike product destruction, product creation remains pro-cyclical, with the correlation ranging between 0.6–0.8 for a wide range of parameter values. Pro-cyclical product creation is generated by the large amount of investments for new product creation at the time of an expansionary productivity shock and is broadly insensitive to different values of parameters κ and ρ.

To summarize, the sensitivity analysis shows that product heterogeneity plays an important role in the cyclical properties of product creation and destruction, consistent with the realm of research initiated by Gabaix (2011). The analysis also outlines important interactions between product heterogeneity and the persistence of technology shocks: a high shock persistence amplifies the adjustments in product destruction for a given degree of product heterogeneity.

5.2. The insulation effect

In this section, we show that changes in κ and ρ enable us to revisit the “insulation effect” in Caballero and Hammour (1994), who find that reduced product creation during recessions hampers the adjustment in product destruction. The entries in Fig. 6 show the correlation between current product creation and product destruction at nine leads and lags for different values of κ (left panel) and ρ (right panel).

The panels show a “s-shaped” pattern of cross-correlations, which is generated by the dynamics of product turnover in the model. In the aftermath of a recessionary shock, product creation falls and product destruction rises, generating a negative correlation between current product creation and destruction on impact.[31] Movements in product creation have two opposing effects on the leads and lags of product destruction. On the one hand, a current fall in product creation is positively correlated with *future* product destruction. A fall in current product creation results in a lower number of

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[31] As shown in the right panel in Fig. 6, the current correlation between product creation and product destruction may become positive for sufficiently low value of the persistence of the shock (ρ). When the technological process is less persistent, the effect of the shock becomes intra-temporal and it is characterized by quick reversal. As explained in the previous section, since output and product creation are highly correlated, the insulation effect of creation on destruction is stronger for sufficiently low values of the persistence parameter of the technological process.

products and therefore a lower degree of competition among surviving products in the future, leading to lower product destruction in the future. On the other hand, a current fall in product creation is *negatively* correlated with *past* product destruction. To understand this finding, consider that it is equivalent to the case with current product destruction that is correlated negatively with future product creation. An anticipated fall in product creation that results from weak expected economic condition in the future, reduces current production, leading to a high degree of product destruction in the present period. Thus, the negative correlation of current product creation with past product destruction is generated by the forward looking nature of investment dynamics related to the creation of new products. The insulation effect originated by a fall in current product creation retains a stronger effect on future product destruction than current product destruction and therefore recessions exercise strong insulation effects on future product destruction.

6. 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 an increase in product creation.

The analysis shows that endogenous product destruction is critical to evaluate the effect of permanent polices 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 raises marginal costs, therefore decreasing profits and the scale of production.

The theoretical model shows that the insulation effect is important and that a decline in current product creation sharply decreases future product destruction. We show that the correlation between product destruction and output may be positive or negative, depending on the degree of product heterogeneity and the persistence of the aggregate labor productivity shock. Therefore, the theoretical framework is able to accommodate contrasting empirical results.

The findings of the analysis outline important intertemporal tradeoffs for economic policies aimed at stimulating the economy. For instance, in the presence of endogenous product destruction, permanent entry deregulation stimulates the economy, but it fosters the survival of inefficient production units during the recovery phase. Similarly, subsidies to operational costs stimulate the economy but at the cost of a decrease in average product-specific productivity. These tradeoffs make the evaluation of economic policies complex and call for further investigation on the welfare implications of economic policies.

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) and Minniti and Turino (2013), which may shed light on the interplay between the fall in output and product destruction during recessions. Finally, another interesting extension is to consider vertical and horizontal differentiation in production varieties and to investigate interactions between changes in the quality and variety of products during recessions.

Appendix A. Steady state

We start by deriving the steady state of the benchmark model. The Euler equation (18) provides:

$$\frac{1}{\beta} = (1-\delta)\left(1+\frac{\widetilde{d}}{v}\right). \tag{21}$$

Using the average profit equation (9), the ZCP equation (16), we can write equation (21) as:

$$\frac{\widetilde{d}_s}{w} = \frac{\sigma-1}{\kappa-(\sigma-1)}. \tag{22}$$

From the definition of operational profits among products, we have $\widetilde{d} = S\widetilde{d}_s/N$, and the free entry condition (11) implies: $v = w$. Using these relations, we can express equation (21) as:

$$\frac{1}{\beta} = (1-\delta)\left(1+\frac{S}{N}\frac{\sigma-1}{\kappa-(\sigma-1)}f\right), \tag{23}$$

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

Table 4
Second moments.

		Y_R	C_R	I_R	L
St. dev. (%)	U.S. data	1.81	1.35	5.30	1.79
	Benchmark	1.06	0.82	5.69	0.24
	Exogenous destruction	1.18	0.85	5.57	0.25
Relative st. dev. to Y_{Rt}	U.S. data	1.00	0.74	2.93	0.93
	Benchmark	1.00	0.78	5.38	0.22
	Exogenous destruction	1.00	0.72	4.72	0.21
Corr(Y_{Rt}, X_t)	U.S. data	1.00	0.88	0.80	0.88
	Benchmark	1.00	0.97	0.85	0.79
	Exogenous destruction	1.00	0.99	0.82	0.75

We set the value of χ so that the steady state labor supply is equal to one. From the law of motion of products (12), we derive the number of new products, $H = \delta N/(1-\delta)$. Using these relations in the labor market clearing condition (19), it yields:

$$\frac{1}{N} = (\sigma - 1)\frac{S}{N}\frac{\sigma - 1}{\kappa - (\sigma - 1)} f + \sigma \frac{S}{N} f + \frac{\delta}{1-\delta}, \tag{24}$$

which provides a unique solution for the number of products, 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 exogenous product destruction, we assume that $f = 0$, which implies $S/N = 1$, $\widetilde{d} = \widetilde{d}_s$. Using these conditions on the Euler equation (18) yields:

$$\frac{1}{\beta} = (1-\delta)\left(1 + \frac{\widetilde{d}_s}{v}\right). \tag{25}$$

Inserting equation (25) into the free entry condition (11) and the law of motion of products (12), the labor market clearing condition (19) yields:

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

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

Appendix B. Business cycles moments

Table 4 reports second moments of key variables for the U.S. data against those for the benchmark model and the model with exogenous destruction. U.S. Data comes from King and Rebelo (1999). The performance of the three models to reproduce the standard deviation of empirically-consistent measure of aggregate output (Y_R), consumption (C_R) and investment fluctuations (I_R) is similar. Overall, the analysis shows that the theoretical model replicates relatively well movements in output, consumption and investment in the data.

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