Oil Price Shocks, Firm Entry and Exit in a Heterogeneous Firm Model

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December 2021

Abstract

Oil price shocks are considered to be one of the important factors behind U.S. recessions, yet little is known about the transmission channels of oil price shocks. What complicates the matter further is the small share of oil in production. To address the issue the literature has incorporated amplifying channels such as endogenous depreciation or variable markups. We build a DSGE model with heterogeneous firms and show that inclusion of firm entry and exit amplifies the effect of oil price shocks. Using U.S. firm level data we see that oil shocks are negatively correlated with firm entry and positively correlated with firm exit as predicted by the model. Further, the DSGE model suggests it is the bigger and more productive firms which survive after an oil price shock.

1 Introduction

There is a long tradition of associating oil price increases to U.S. recessions as documented by Hamilton (1983, 1996, 2008), Burbidge and Harrison (1984), Gisser and Goodwin (1986). Oil price shocks are also thought to be an important driving force for terms of trade fluctuations (Backus and Crucini, 2000, Bodenstein et al, 2011). Given the small share of energy in GDP, standard real business cycle (henceforth RBC) models do not attribute an important role to oil price shocks (Kim and

[1] I am indebted to Nathan Balke for all his suggestions and continuous encouragement. I would also like to thank Thomas Fomby, Anna Kormilitsina, for their comments and suggestions.

Lougani 1992; Rotemberg and Woodford 1996, Finn 2000). Leduc and Sill (2004) build on Finn's framework and explore the role of monetary policy in exacerbating the effect of oil price shocks. Rotemberg and Woodford emphasize the role of imperfect competition and implicit collusion to explain the contractionary effects of energy price shocks. Finn (2000) demonstrates that models with perfect competition can produce similar results if there is endogenous depreciation. In both these approaches, channels such as variable mark-ups or capital utilization amplify the effects of energy price shocks.

Our paper proposes that the extensive margin or the number of producing firms is an important channel for propagation of oil price shocks. Standard RBC or DSGE models treat the number of producers as constant; hence all adjustment must happen through the intensive margin or firm level production. However, as mentioned before, the small share of energy in U.S. GDP implies that standard models which rely on the intensive margin cannot explain the sizeable effects of energy price shocks observed in empirical studies. The extensive margin varies with respect to exogenous shocks, due to the entry and exit decisions of firms. An increase in energy prices lowers profit expectations and may deter firm entry or cause higher firm exit. Both these effects would lower the number of producing firms when energy prices increase. Further, firm level production for existing firms also drops due to higher costs. This results in a bigger drop in output operating through both the extensive and intensive margins in our model. The amplification mechanism here does not depend on variable markups though there is some similarity to Finn's approach. In her model, energy affects capital accumulation through endogenous depreciation which is akin to the effect on the exit rate in our model. Moreover, both the approaches of Rotemberg and Woodford (1996) and Finn (2000) rely on a nonstandard definition of oil price shock which makes comparison with other models difficult[2]. Our model assumes a standard AR (1) process for the real oil price shock. Our parameters are also estimated using data for a longer time horizon.

[2] A bivariate VAR is used in their model, where oil price shocks are identified as innovations in nominal oil prices and the real price of oil is affected by both nominal and real oil prices. This leads to a complex dynamic relationship between the shock and real energy prices.

The paper contributes to a growing body of literature that emphasizes the role of firm entry and exit as an important propagation and amplification mechanism for business cycle fluctuations. This includes work of Bilbiie, Ghironi and Melitz (2012), Bergin and Corsetti (2008) and Bilbiie, Ghironi and Melitz (2007), Lewis (2009). Patra (2020) considers oil price shocks and the amplification generated due to endogenous entry. However in all these models, firms are homogeneous and the exit decision is exogenous. This paper uses a Melitz (2003) style model to incorporate firm heterogeneity under imperfect competition to endogenize both the entry and exit decision of firms. The closest papers in this stream of literature are Casares and Poutineau (2014), Hamano and Zanetti (2017) and Totzek (2009). Oil price shocks lower expected profits and cause the firms with poor productivity to exit the market. The exit rate depends on the productivity cut-off which is a forward looking variable depending on future costs (both marginal and fixed) and future aggregate demand. Depending on the interaction between entry and exit in these models, oil price shocks can raise firm level productivity. While in traditional models, oil prices imply a drop in aggregate and firm level productivity (there is no distinction between the two in standard representative firm models) our model suggests oil prices lower aggregate productivity through its effect on the mass of firms which dominates the increase in firm level productivity. In this respect, our work also closely engages with the literature on firm creation and destruction and the cleansing effects of recessions. This includes the work of Caballero and Hammour (1994) who develop a business cycle model which specifies the conditions under which recessions can be cleansing or productivity enhancing. Whether recessions are cleansing or sullying in these set ups depends on the effect on creation versus destruction, if a drop in aggregate demand causes a big drop in creation, the less productive firms may be insulated and recessions may not be productivity enhancing. We demonstrate similar effects in our model for oil price shocks[3]. In the baseline model we generate both lower entry and higher exit in response to oil price shocks. However the drop in entry is not high

[3] There is very limited literature on the effects of oil prices on firm entry and exit. We surmise that oil prices would affect smaller less productive firms disproportionately but more work needs to be done to establish this empirically.

enough for the insulation effect to dominate and firm level productivity increases.

Further, endogenizing the exit rate has a number of other advantages. Firstly, the amplification mechanism depends crucially on the specification of entry cost in Patra (2020). In particular the model generates sufficient amplification only when entry costs have an energy component. Making entry more labor intensive relative to production implies less amplification, in the extreme case when entry costs are specified in terms of only labor[4] the model generates no amplification (this is true for technology shocks in Bilbiie et al. as well, as shown in Patra, 2021). Endogenizing exit makes the model more robust to changes in specification of entry costs. Introducing energy in entry costs does not change the impulse responses significantly vis-a-vis the baseline model as shown in this paper. Another implication of the constant exit rate in Patra (2020) or Bilbiie et.al (2012) is that it implies procyclical exit. As a result the model would predict higher firm exits due to a technology shock and lower firm exits due to an oil shock. This is at odds with the empirics (we document that oil price shocks and firm entry are negatively correlated while firm exits are positively correlated). Endogenizing the exit rate as in this paper allows us to get mildly counter cyclical exit which is more in line with recent evidence (see Hamano and Zanetti, 2017).

The rest of the paper is structured as follows. In section 2, we briefly discuss the empirics on the response of firm entry and exit to oil price shocks. Section 3 introduces the benchmark model. Section 4 presents sensitivity analysis where the baseline model is compared with model without entry and models with exogenous exit. Section 5 concludes.

[4]Recent evidence by Bollard, Klenow and Li (2016) shows that entry costs must increase with technological improvements or must be labor intensive to match the empirical patterns observed in their data set comprising of U.S., Indian and Chinese firms. However the specification of entry costs in BGM et al. (2012) or Patra (2020) imply that marginal costs of entry and production are the same and does not increase in response to a technology shock.

2 Firm Entry, Exit and Oil Prices Empirics

There exists a lot of literature which link oil price shocks to the onset of U.S. recessions (Hamilton 1996, 2008, Kilian 2008, 2017, Engemann et al. 2011 to name a few). We propose in this paper, a role for oil price shocks in the entry and exit decision of firms which amplify the effects of oil price shocks. We expect that oil price shocks would lead to a decline in firm entry and increase in firm exit. This is because rising oil prices would lower future profit expectations through both higher production costs and lower product demand. The high comovement of[5] entry with respect to GDP has already been noted in many studies, while the evidence on exit is mixed. Studies such as Devereux et al. (1996) report exit to be strongly counter-cyclical while recent studies such as Hamano and Zanetti (2015) find exit to be mildly counter-cyclical (-0.15). Note that entry and job creation are positively correlated (0.39[6]). Exit and job destruction also show a strong positive correlation (0.73[7]) and while there exists a body of literature on the effects of oil prices on job creation and destruction[8] very little is known about the impact of oil prices on firm entry and exit. Our paper tries to fill this gap.

A number of different measures of entry and exit have been used in the literature. Patra (2020) documents the negative impact of oil price shocks on Net Business Formation. It also shows that Net Business Formation is positively correlated (0.73) with GDP and negatively correlated (-0.35) with oil price increases as seen in Fig 1 [9]. In this paper we revisit the question and expand our analysis to include firm exits as well. Two measures of Entry (New Incorporations or Establishment births) and two

[5] VAR models with entry show a significant response of entry to real oil prices, see Patra (2020).

[6] Source: Hamano and Zanetti, 2015.

[7] Source: Hamano and Zanetti, 2015.

[8] Davis and Haltiwanger (2001) find both job creation and job destruction rise in response to an oil price shock. Herrera, Karaki and Rangaraju (2017) show increase in job destruction and lower job creation in particular sectors such as oil and gas extraction and support activities for mining. Our work suggests that for firm creation and destruction aggregate channels dominate. Recent work by Herrera and Karaki (2015) also finds similar evidence for job flows with the aggregate channels being more important.

[9] All the series are logged and HP filtered. The reported correlations are the correlations between the deviations from trend for the two series. Source Patra (2020)

measures of exit (Industrial and Commercial Failures or Establishment Deaths) are used. The New Incorporations and Industrial and Commercial Failures data are obtained from Survey of Current Business, the timeline for this data set is 1954: I-1981: IV[10]. The Establishment Births and Deaths data is from Bureau of Labor Statistics. We use data from 1993: I-2019: II for these variables. The correlation of entry with respect to GDP is 0.48 for New Incorporations and 0.57 for Establishment Births. The correlation of exit w.r.t. GDP for Industrial and Commercial Failures is -0.54 and is -0.08 for Establishment deaths. Thus, our evidence supports procyclical entry and countercyclical exit though the last coefficient is not statistically significant. In Figures 2 and 3, we present the cross-correlations of entry and exit with respect to real oil prices at various lags. We calculate the cross-correlations using the HP filter as is common in the entry/exit literature[11].

It can be seen that for both the measures of firm exit the cross- correlations are positive and significant of exit suggesting that oil price shocks may result in more firm exits in the future. More specifically, for the purpose of our analysis the relevant correlations here are the lead correlations which imply how oil prices today impact firm exit in future. The corresponding correlations for industrial and commercial failures vary between 0.3-0.46, for establishment deaths the correlations are a bit weaker with the biggest correlation being 0.28 though still statistically significant. The cross-correlations with respect to firm entry are mixed. In the first sample we find that firm entry as measured by New Incorporations is negatively related to oil price increases as expected (the correlations at different leads are around -0.3). In the second sample however the correlation coefficients are positive though most after the first lag are insignificant[12]. For further investigation on the effect of oil prices on firm entry and exit we utilize VAR models.

Previous work by Patra (2020) documents that there is a negative impact of

[10] The monthly data is converted to quarterly by summing over three months.

[11] Given the recent criticisms of the HP filter we also calculate the correlations using the Hamilton filter. Our results are broadly consistent across the two methods though somewhat weaker for the Hamilton filter.

[12] The correlations using the Hamilton filter are still negative in this case though they are all statistically insignificant.

higher oil prices on Net Business Formation using VAR analysis. In this paper we include measures of both firm entry and exit in our VAR models. We expect oil prices to decrease firm entry and increase firm exit in the aggregate. The results from the VAR models confirm our predictions. We use the following variables in our VAR model: real oil prices, interest rate, measure of entry, measure of exit, real GDP and the inflation rate[13]. Following, Lewis (2009) we run a VAR in levels[14]. Nevertheless, to assess the robustness of our results we run alternative VARs in the log growth rate of real oil prices, entry, exit and GDP[15]. Two measures of Entry (New Incorporations or Establishment births) and two measures of exit (Industrial and Commercial Failures or Establishment Deaths) are used. All the data sources, transformations are mentioned in Table 1.

The first VAR is estimated on real oil prices, 3 month Treasury bill rate, real GDP, New Incorporations, Industrial and Commercial Failures and the inflation rate. Real oil prices, real GDP, New Incorporations, Industrial and Commercial Failures are logged and multiplied with 100, the T-bill rate is not transformed. The lag length for the model is selected to be five consistent with the recommendations of FPE and AIC criterion. Figure 4.1 presents the impulse responses. The results show that firm exits increase when oil prices increase though the results are marginally significant. Oil prices also have a significant negative effect on real GDP and increase the inflation rate. Entry seems to slow down approximately five quarters after the shock and picks up later as oil prices start falling.

Our results are even stronger for the alternative VAR with the log growths of the respective variables, apart from the Treasury bill rate and the inflation rate which are the same as before. Impulse responses are given in figure 4.2. We see that after an increase in oil prices there is drop in the GDP growth rate, the exit rate and inflation

[13]Entry/exit data sources have been mentioned before. The other variables are available from FRED. The implicit GDP deflator is used to convert the nominal oil prices (WTI) to real oil prices. I use log growth of the implicit price deflator as the measure of inflation.

[14]The Cholesky ordering is as given as follows: Oil price, Tbill rate, measure of entry, measure of exit, real GDP, log growth of the GDP deflator.

[15]Using the DF-GLS test the assumption of unit root in the series cannot be rejected, hence we run this alternative VAR for checking the consistency of our results. The ordering of the variables is the same as before.

rate increases approximately five quarters later. There is a drop in the entry rate as well. The accumulated responses are similar to the responses from the levels VAR (significant response of exit and GDP).

We now report the results from the VAR with establishment births and establishment deaths as a measure of entry and exit respectively. The other variables are the same as the first VAR. We run this VAR with two lags consistent with FPE and AIC criterion[16]. The impulse responses (in figure 5.1) show that rising oil prices lead to lower firm entry about six quarters later. There seems to be an increase in firm exits and a decrease in real GDP though the responses are not significant. The inflation rate response is similar to the oil price response.

When running the VAR in log growth, we do not get a significant response of either entry/exit or GDP[17]. The impulse responses are presented (in figure 5.2). Our results are not as strong for the second sample; this is consistent with the view that the effect of oil price shocks on the U.S. macro economy has changed post the Great Moderation period (Herrera and Pesavento, 2009, Blanchard and Gali, 2010). The literature points to factors such as declining oil share in GDP, lower wage rigidity, better monetary policy, changes in sectoral composition of GDP along with different sources behind the oil price increases for this structural break (Fouquet and Ven, 2017).

We think some of these explanations might be true for the lower effect on entry and exit as well. In particular, the surge in U.S. domestic production[18] and a rebounding world economy[19] could imply weaker effect of oil prices on aggregate entry/ exit. However, this is difficult to ascertain as the effect on sectoral entry and exit depends on a number of factors such as energy intensity and substitutability

[16]Running a VAR in levels with more lags leads to marginally diiferent results; the responses of the variables are more pronounced (particularly for GDP where the drop is statistically significant).

[17]The impulse responses are very similar when more lags are included.

[18]Growth of domestic production would imply that the energy sector would gain when oil prices increase while other sectors which use energy as an input would lose so the effect on aggregate would not be as strong as in an economy which is entirely dependent on imports as in this paper.

[19]If the oil price increases are due to increase demand for commodities (fueled by strong economic conditions), we would expect the effects on entry and exit to be not as pronounced as supply driven oil price increases. The net effect might be higher entry and lower exit in such a case as the strong demand channel could dominate.

across inputs. Further the industrial composition of the economy also has a role in determining how these sectoral effects would translate to entry and exit in aggregate. A detailed analysis of these channels is beyond the scope of the current paper. The next section introduces our benchmark model where we show oil prices can affect the entry exit decision of firms in a DSGE framework.

3 Benchmark Model

In this section we build a framework where energy prices impact the extensive margin through firm entry and exit. To the best of our knowledge, this paper is one of the first attempts to analyze how changes in imported input prices (exogenously determined) are transmitted in the economy through firm entry/ exit. As such the implications of the theoretical model can be much broader. We are not aware of any previous work in the macro-literature which addresses this question in models of both entry and exit. Most of the papers in the trade literature which use a similar framework focus on selection and entry/ exit into the export market. Since the entry and exit decision depends on expected profits, it is crucial that firm profits respond to oil price shocks in our model setup. To achieve this goal, we use a lag to build and sunk cost of entry as in Bilbiie, Ghironi and Melitz (2012) to generate procyclical profits. There is no capital in the model; hence all investment is geared towards the extensive margin. Firms are heterogeneous with respect to firm specific productivity. There is a fixed cost of production and firms may optimally decide to exit the market if the expected stream of future revenue is less than the stream of fixed costs. Models without a fixed cost (BGM, 2012, Patra, 2020) imply all firms keep producing until hit by an exogenous exit shock, while the fixed cost implies only a subset of firms produce every period. Another important difference is the specification of entry costs in terms of labor only[20]. In models of exogenous exit (without a fixed cost) this

[20] To generate effect on entry in a model of exogenous exit without fixed costs; we have to use a different specification of entry costs like in Patra (2020), BGM (2012). However, recent evidence is more supportive of the specification used in this paper. Additionally, using the entry specification in Patra (2020) leads to only marginally different impulse responses as shown later in the paper. Thus the responses are more robust to changes in entry cost specifications when we endogenize

specification of entry costs leads to no effect on entry or the extensive margin due to exogenous shocks (Patra, 2021 demonstrates this using the BGM, 2012 framework). Introduction of fixed costs in such a set up can generate an effect on entry but the model would still fail to capture the expected response of firm exit. This is discussed in more detail in section 6 below.

3.1 Firms

There is a continuum of firms each specializing in the production of a specific variety of the intermediate good in each period. There are two factors used in production of each variety, labor and energy. Production entails both fixed and marginal costs. Firms differ in their productivity level z but share the same fixed cost $f > 0$. A firm with higher productivity can produce at a lower marginal cost. Since we abstain from modeling multi-product firms, each firm with a particular productivity level produces a particular variety of the intermediate good. Therefore there is a one to one correspondence between the productivity level, the firm and the intermediate good it produces. This allows us to use z as an index for the intermediate goods as well. The intermediate goods are aggregated to final goods using a CES aggregator to be defined in the aggregation section below.

Output of each variety is given as

$$y_t^c(z) = z l_t^c(z)^{\alpha} m_t^c(z)^{1-\alpha} - zf,$$

where z is firm specific productivity, $l_t^c(z)$ and $m_t(z)$ stand for labor and energy used for production of variety z and α and $1-\alpha$ are the shares of labor and energy payments in output. The cost function in terms of the consumption good can be written as $C(y_t^c(z)) = \left(\frac{y_t^c(z)}{z} + f\right) b w_t^{\alpha} p_{mt}^{1-\alpha}$, where $b = \alpha^{-\alpha}(1-\alpha)^{\alpha-1}$, w_t is the real wage rate and p_{mt} is the real price of energy. The marginal cost of production is given as $\lambda_t^p(z) = \frac{b w_t^{\alpha} p_{mt}^{1-\alpha}}{z}$. Demand for each variety is $y_t^c(z) = \left(\frac{p_t(z)}{P_t}\right)^{-\theta} Y_t^c$, where $p_t(z)$ is the price of each variety, P_t is the aggregate price index of the consumption good and Y_t^c is the final consumption good, θ is the elasticity of substitution.

both entry and exit. This is another advantage over Patra (2020).

The firm's problem can be formulated as a two stage problem where the first step involves cost minimization and the second step is the price setting problem. In the first stage the firms cost minimization problem can be written as

$$min \quad w_t l_t^c(z) + p_{mt} m_t^c(z)$$

$$s.t.$$

$$y_t^c(z) = z l_t^c(z)^{\alpha} m_t^c(z)^{1-\alpha} - zf$$

which gives us the first order conditions given below:

$$w_t = \frac{\alpha \lambda_t^p(z)(y_t^c(z) + zf)}{l_t^c(z)} \ , \tag{1}$$

$$p_{mt} = \frac{(1-\alpha)\, \lambda_t^p(z)(y_t^c(z) + zf)}{m_t^c(z)} \tag{2}$$

In the second stage the firm acts as a price setter and solves the following problem

$$max \ \rho_t(z) y_t^c(z) - \left(\frac{y_t^c(z)}{z} + f \right) b w_t^{\alpha} p_{mt}^{1-\alpha}$$

$$s.t.$$

$$y_t^c(z) = \left(\frac{p_t(z)}{P_t} \right)^{-\theta} Y_t^c$$

We define $\rho_t(z)$, the relative price of the intermediate good with respect to the aggregate consumption good as given below:

$$\rho_t(z) = \frac{p_t(z)}{P_t}$$

Each firm set prices as a constant markup (μ) over marginal cost, where

$$\mu = \frac{\theta}{\theta - 1}. \tag{3}$$

The first order condition for this problem is

$$\rho_t(z) = \mu \frac{b w_t^{\alpha} p_{mt}^{1-\alpha}}{z}, \tag{4}$$

Real operating profits (not including entry costs) can be expressed as

$$d_t(z) = \rho_t(z) y_t^c(z)[1 - 1/\mu] - f b w_t^{\alpha} p_{mt}^{1-\alpha}. \tag{5}$$

Real revenue for each firm is

$$r_t(z) = [\rho_t(z)]^{1-\theta} Y_t^c, \tag{6}$$

which implies that the ratio of the revenue for two firms will depend only on their respective productivities.

$$\frac{r_t(z_1)}{r_t(z_2)} = \left(\frac{z_1}{z_2}\right)^{\theta-1}. \tag{7}$$

3.2 Aggregation

For solving the model, we use the aggregation technique as described in Melitz (2003). Average productivity of producing firms given the timing of exit assumed in this paper is as follows:

$$\widetilde{z}_t = \left[\int_{z_{t-1}^*}^{\infty} z^{\theta-1} g(z) dz\right]^{\frac{1}{\theta-1}} = K z_{t-1}^* \tag{8}$$

where $K = \left(\frac{\kappa}{\kappa-(\theta-1)}\right)^{\frac{1}{\theta-1}}$ under a Pareto distribution. κ is the shape parameter for the Pareto distribution, z_t^* is the cut-off productivity level whose determination is explained in more detail later in the paper.

We can now express aggregate variables in terms of N_t (the total number of producing firms) and the firm with average productivity $\widetilde{z}_t$. The aggregate price level (P_t) , aggregate revenue (R_t), aggregate manufacturing output (Y_t^c), aggregate profits (Π_t) can be expressed in the following way:

$$P_t = N_t^{1-\mu} p_t(\widetilde{z}_t), \tag{9}$$

$$Y_t^c = N_t^{\frac{\theta}{\theta-1}} y_t^c(\widetilde{z}_t), \tag{10}$$

$$R_t = P_t.Y_t^c = N_t r_t(\widetilde{z}_t), \tag{11}$$

$$\Pi_t = N_t d_t(\widetilde{z}_t). \tag{12}$$

Profits for the average firm or the firm with the average productivity can be written as:

$$d_t(\widetilde{z}_t) = [1 - 1/\mu]\frac{Y_t^c}{N_t} - fbw_t^{\alpha} pm_t^{1-\alpha}, \tag{13}$$

Rewriting the wage equation from the firms' first order conditions:

$$w_t = \alpha \left[\frac{Y_t^c - N_t d_t(\widetilde{z}_t)}{L_t^c}\right], \tag{14}$$

Similarly the energy price equation can also be re-written in the following manner:

$$p_{mt} = (1-\alpha) \left[\frac{Y_t^c - N_t d_t(\widetilde{z}_t)}{M_t}\right], \tag{15}$$

where L_t^c and M_t refer to the total labor and energy usage in the production sector.

3.3 Firm Entry and Exit

Entry and exit take place at the intermediate good level. In each period there is a mass N_t of producing firms in the economy and an unbounded mass of prospective entrants. Entering firms compare the returns from entry, the present discounted value of expected profits to the cost of entry when making the decision to enter. We assume for simplicity that entry costs[21] are in terms of labor only in the baseline model[22]. Namely, each firm pays a sunk entry cost $f_{e,t}$ in units of labor, the cost of entering is then $C_{e,t} = f_{e,t}w_t$.

The production technology for entry (with $N_{e,t}$ entering firms every period) can be written as $f_{e,t}N_{e,t} = L_t^e$ where L_t^e refers to the labor used in building $N_{e,t}$ firms. The expected post entry value of the firm in period t is determined by the present discounted value of expected future stream of profits from period $t+1$ onwards : $v_t(\widetilde{z}_t) = E_t \sum_{s=t+1}^{\infty} Q_{t,s} d_s(\widetilde{z}_t)$, where $Q_{t,s}$ is the stochastic discount factor determined in equilibrium by the optimal investment behavior of households. The free entry condition given below implies that entry occurs until the average firm value equals the entry cost (in real units)

$$v_t(\widetilde{z}_t) = C_{e,t} = f_{e,t}w_t. \tag{16}$$

A positive mass of entrants ensure that this condition holds every period.

After the entry costs are paid, the new firms draw their productivity z, from a common distribution $g(z)$. This productivity level is thereafter fixed for the entire lifetime of the firm. As is common in the literature, we take $g(z)$ to be a Pareto distribution with support over $[z_{\min}, \infty)$.The entrants entering in period t start producing in period $t+1$. This lag to build assumption implies that the stock of producing firms is fixed in the short run and responds slowly to macroeconomic shocks.

[21] Entry costs refer to setup/ developmental costs or capital investment costs. Sometimes they have been interpreted as research and development, hiring costs, market research or even advertising or legal fees.

[22] We also consider a modification where energy along with labor is used for entry. The results are qualitatively unaffected under this alternative assumption.

The exit decision takes place at the end of the period. Both incumbent and entering firms make a decision to exit at the end of the period if their productivity level is too low compared to the productivity threshold. The productivity threshold, z_t^* is the level of productivity when the expected value of future profits is zero. The cut-off productivity level is determined by the following equation:

$$E_t(\sum_{j=1}^{\infty} Q_{t,t+j} d_{t+j}^*) = 0 \tag{17}$$

where d_{t+j}^* is the real profit for the firm with the threshold productivity level and $Q_{t,t+j}$ is the stochastic discount factor to be defined later. For any firm with productivity value $z < z_t^*$, it is optimal to exit as it is not expected to break even. However, a firm may make negative profits in some periods and choose to stay on if future profits are expected to be high. The value of z_t^* fluctuates from period to period depending on the state of the economy.

We can formalize the law of motion for firms in the following way. In the beginning of period t, there are N_t producing firms. After production, each firm decides on whether to produce in the next period or not by comparing its productivity with the threshold productivity z_t^*. Entrants also face a similar problem and may optimally decide to exit without producing if their productivity is lower than z_t^*.

The number of producing firms can be interpreted as the stock of capital of an economy and is an endogenous state variable that behaves like physical capital in the standard RBC model. δ_t here is the exit rate. Given the assumption of Pareto distribution δ_t , depends on the productivity threshold z_t^* as follows

$$\delta_t = 1 - \left(\frac{z_{\min}}{z_t^*}\right)^{\kappa}, \tag{18}$$

where κ is the shape parameter and $z_{\min}$ the lower bound of the Pareto distribution.

The timing of entry and production imply the number of producing firms during period $t+1$ is given by:

$$N_{t+1} = (1 - \delta_t)(N_t + N_{e,t}). \tag{19}$$

The total number of exiting firms (including incumbents and entrants) denoted by N_t^X, is

$$N_t^X = \delta_t(N_t + N_{e,t}) \tag{20}$$

When energy prices increase we would expect lower entry as firm profits fall, we would also expect higher exit as δ_t increases (this is due to an increase in the cut-off productivity level z_t^*).

3.4 Consumers Problem

The representative household maximizes expected lifetime utility,

$$E_t[\sum_{i=0}^{\infty} \beta^i U(C_{t+i}, L_{t+i})],$$

where β is the subjective discount factor, C_t refers to aggregate consumption and L_t is labor supply. The period utility function is given as $U(C_t, L_t) = \ln C_t - \frac{\chi L_t^{1+1/\varphi}}{1+1/\varphi}$ where $\chi > 0$ is the weight of disutility of labor and $\varphi > 0$ represents the Frisch elasticity of labor supply to wages and the intertemporal elasticity of substitution in labor supply. We can write aggregate consumption and price level in terms of varieties in the following way: $C_t = \left[\int_{\omega \in \Omega} c_t(\omega)^{\frac{\theta-1}{\theta}} d\omega\right]^{\frac{\theta}{1-\theta}}$, where $\theta > 1$ is the elasticity of substitution between goods, $P_t = \left[\int_{\omega \in \Omega} p_t(\omega)^{\frac{\theta-1}{\theta}} d\omega\right]^{\frac{\theta}{1-\theta}}$ is the consumption based price index with $p_t(\omega)$ being the nominal price of variety ω. The Demand Function for each variety is given as: $c_t(\omega) = \rho_t(\omega)^{-\theta} C_t$.

As mentioned before, each intermediate variety is produced by a particular firm with a certain productivity level. We can therefore re-write the households' optimality conditions in terms of the firm with productivity level $\widetilde{z}$ as shown in the following section.

3.4.1 Household Budget Constraint and Optimality Conditions

The household budget constraint is given as:

$$\widetilde{v}_t(N_t + N_{e,t})x_{t+1} + C_t = (\widetilde{d}_t + \widetilde{v}_t)N_t x_t + w_t L_t, \tag{21}$$

where x_t is the share in the mutual fund held by the representative household in period t. $\widetilde{v}_t, \widetilde{d}_t$ refer to value and profits for the average firm, we suppress the $\widetilde{z}_t$ notation for brevity. The left hand side represents household expenditure on future share holdings in a mutual fund of existing firms and entering firms and consumption. The household does not know which firms will exit so finances all entering firms. The right hand side represents income from dividends, income from selling current share holdings and labor income.

The households first order conditions are given below:

$$C_t : \qquad \frac{1}{C_t} = \lambda_t \tag{22}$$

where λ_t is the Lagrange multiplier associated with the household's budget constraint.

$$x_{t+1} : \widetilde{v}_t = \beta(1-\delta_t)E_t[\frac{C_t}{C_{t+1}}(\widetilde{d_{t+1}} + \widetilde{v_{t+1}})], \tag{23}$$

$$L_t : \chi\left(L_t\right)^{\frac{1}{\varphi}} = \frac{w_t}{C_t}, \tag{24}$$

Iteration of the Euler equation and elimination of speculative bubbles allow us to solve for the stochastic discount factor $Q_{t,s}$:

$$Q_{t,s} = \beta^s[\frac{C_t}{C_{t+s}}]\prod_{i=0}^{s}\left(1-\delta_{t+i}\right). \tag{25}$$

3.5 Derivation of the Productivity Threshold

The firm level profits can be expressed as a function of the markup (μ), aggregate consumption output (Y_t^c), the number of firms (N_t), fixed cost (f),real wages

(w_t) and the price of energy (p_{mt}). Rewriting the cut-off productivity condition as, $\sum_{j=1}^{\infty} Q_{t,t+j} d^*_{t+j}(z^*_t) = \sum_{j=1}^{\infty} Q_{t,t+j} \left(\rho_{t+j}(z^*_t) y^c_{t+j}(z^*_t)[1-1/\mu] - fbw^{\alpha}_{t+j} p^{1-\alpha}_{mt+j}\right) = 0.$

Given the demand function for each variety, we can replace $y^c_{t+j}(z^*_t)$ in the following way

$$\sum_{j=1}^{\infty} Q_{t,t+j} \left(\rho_{t+j}(z^*_t)^{1-\theta} Y^c_{t+j}[1-1/\mu] - fbw^{\alpha}_{t+j} p^{1-\alpha}_{mt+j}\right) = 0.$$

We use the pricing condition to write the equation in terms of marginal costs,

$$\sum_{j=1}^{\infty} Q_{t,t+j} \left[\left(\mu \lambda^p_{t+j}(z^*_t)\right)^{1-\theta} Y^c_{t+j}[1-1/\mu] - fbw^{\alpha}_{t+j} p^{1-\alpha}_{mt+j}\right] = 0.$$

Log-linearizing around the steady state we get the following equation governing the dynamic behavior of z^*_t;

$$\widehat{z^*_t} = \overline{\beta}\widehat{z^*_{t+1}} + \mu(1-\overline{\beta})\widehat{B_{t+1}} + (1-\theta)^{-1}(1-\overline{\beta})\widehat{Y^c_{t+1}},$$

where $B_{t+1} = bw^{\alpha}_{t+1} p^{1-\alpha}_{mt+1}$, $\widehat{B_{t+1}} = \alpha \widehat{w_{t+1}} + (1-\alpha)\widehat{p_{mt+1}}$ and $\overline{\beta} = \beta(1-\delta)$.

Substituting for B_{t+1},we can see that the productivity cut-off goes up with an increase in oil prices:

$$\widehat{z^*_t} = \overline{\beta}\widehat{z^*_{t+1}} + \mu(1-\overline{\beta})\alpha\widehat{w_{t+1}} + \mu(1-\overline{\beta})(1-\alpha)\widehat{p_{mt+1}} + (1-\theta)^{-1}(1-\overline{\beta})\widehat{Y^c_{t+1}}, \quad (26)$$

Thus we observe that the cut-off threshold level depends positively on the costs of production $(\theta > 1)$ and negatively on aggregate demand. As higher energy prices drive up production costs the cut-off productivity increases. Thus both supply and demand side factors influence the distribution of firms. Higher costs and lower demand make it harder for firms with low productivity to survive and consequently, the productivity threshold goes up.

An important issue that arises here is what would be the effect of oil price increases due to higher demand from a flourishing world economy. Indeed, a recent stream of literature led by Kilian (2009, 2010) emphasize that the economic effects of oil price increases differ based on whether the increase is due to lower supply or higher demand. In particular, oil price increases due to higher demand are not seen to have a strong negative effect on the economy. Our model results are consistent with this approach. We can see if there strong product demand the last term can outweigh the effect of higher input prices and it is possible that the productivity cut-off might go down. In that case, we might see higher entry and lower exit along with higher oil prices. This is not to imply that the effects in the paper are not operating, but the strong demand channel which would dominate the effects of higher input costs. As we do not model the energy sector, a detailed discussion of this literature is beyond the scope of the current paper. However, this is something we would like to explore in future as it is imperative to study the factors behind the oil price shock to better understand the transmission channels.

3.6 Market Clearing Conditions

3.6.1 Labor Market Equilibrium

Total labor supplied (L_t) must equal labor demand from the production and entry sector

$$L_t = L_t^c + L_t^e. \tag{27}$$

Aggregate labor demand for the production sector (L_t^c) is sum of firm level labor demand (l_t^c), $L_t^c = N_t l_t^c(\widetilde{z}_t)$. Similarly, aggregate labor demand for entry is

$$L_t^e = N_{e,t} l_t^e(\widetilde{z}_t) = \frac{\alpha \widetilde{z}_t \lambda_t^p(\widetilde{z}_t)(N_{e,t} f_{e,t})}{w_t}. \tag{28}$$

3.6.2 Energy Market Equilibrium

Total energy usage is sum of energy usage in production for all firms, $M_t = N_t m_t^c(\widetilde{z}_t)$.

3.6.3 Trade Balance Condition

We impose a balanced trade condition every period, the consumption good is exported to pay for energy imports[23]. In terms of aggregate variables, the balance trade condition implies

$$Y_t^c = C_t + p_{mt} M_t. \tag{29}$$

3.6.4 Aggregate Resource Constraint

Summing over all households, imposing $x_{t+1} = x_t = 1$, gives us the aggregate resource constraint ;

$$GDP_t = C_t + \widetilde{v}_t N_{e,t} = N_t \widetilde{d}_t + w_t L_t. \tag{30}$$

Total expenditure on consumption and investment in new firms must equal total income from profits and labor. Note that $\widetilde{v}_t N_{e,t}$ represents investment in new firms. Investment on the intensive margin can be included by adding capital in the model. However inclusion of capital may allow for another intertemporal reallocation channel and dampen the impact of shocks on entry and exit.

Total consumption output Y_t^c is given as,

$$Y_t^c = \rho_t(\widetilde{z}_t)\widetilde{z}_t \left(L_t^c\right)^{\alpha} \left(M_t^c\right)^{1-\alpha} - N_t \widetilde{z}_t f. \tag{31}$$

4 Baseline Results

4.1 Calibration

This section presents the parameter values used for calibration in the baseline model. The benchmark calibration values and interpretations are summarized in Table 2.

[23] There are a number of papers which study the impact of oil price shocks on trade balances such as Backus and Crucini (1998), Bodenstein et al (2011).

The share of energy in value added is given as

$$\frac{p_m M}{C_t + \widetilde{v}_t N_{e,t}} = \frac{(1-S)(1-\alpha)}{1+\gamma-(1-S)(1-\alpha)} \tag{32}$$

where $S = (1-\frac{1}{\mu})(\frac{\theta-1}{\kappa})$ and $\gamma = \frac{1}{\theta}\frac{\delta}{r+\delta}$. We calibrate $\alpha = 0.9437$, such that the share of energy in GDP is 4 percent. This is close to the value used in Finn (2000) and Rotemberg and Woodford (1996). The steady state value for energy price, p_{mt} is taken to be 1. The fixed cost of entry parameter f_e is taken to be 1 following Bilbiie et al. Since periods are interpreted as quarters, β is set to be 0.99 which implies a 4 percent annual interest rate. The value of θ is fixed at 3.8 following Bernard et al. (2003). The parameter for disutility of labor χ, is set to be 0.924271 as in Bilbiie et al. (2012). The elasticity of labor supply ϕ is set to 4 which is consistent with King and Rebelo (1999). $z_{\min}$ is normalized to 1. We set $\delta = 0.029$, $\kappa = 4$ following Casares et al. (2014). The steady state fixed cost, f is determined through the Euler equation , $\widetilde{v} = \beta(1-\delta)(\widetilde{v}+\widetilde{d})$. δ refers to the exit rate $\frac{N^X}{N}$ in the steady state. From the free entry condition, $\widetilde{v} = wf_e$. In addition, the sum of profits for all periods must be zero for the cut-off productivity firm by definition. This implies that the cut-off firm must be making zero profits every period. Therefore, $d^* = 0$, or $r^* = fbw^{\alpha}p_m^{1-\alpha}$. Given that the ratio of revenues depend only on the productivity levels of the firms, we know that $r(\widetilde{z}) = \left(\frac{\widetilde{z}}{z^*}\right)^{\theta-1} r^*$. We can use this relation, to express the average profit or profit of the firm with the average productivity level in terms of z^* and r^*. Therefore, $\widetilde{d} = d(\widetilde{z}) = \left[\left(\frac{\widetilde{z}}{z^*}\right)^{\theta-1} - 1\right] fbw_t^{\alpha}p_{mt}^{1-\alpha}$. Substituting for $\widetilde{d}$ and $\widetilde{v}$ in the Euler equation we get the following equation which gives us the value of f in the steady state.

$$f = \frac{(1-\beta(1-\delta))\, w^{1-\alpha} f_e}{b\beta(1-\delta)\left(\frac{\kappa-(\theta-1)}{\theta-1}\right)} \tag{33}$$

The exogenous variable p_{mt} is assumed to follow an AR (1) process[24] in logs as in Blanchard and Gali (2007). The exogenous process for p_{mt} is given below:

$$log(p_{mt}) = \phi_m \log(p_{mt-1}) + \varepsilon_{m,t} \qquad \varepsilon_{m,t} \sim N(0, \sigma^2_{mZ}).$$

We estimate the exogenous process for real oil prices using U.S. data from 1947: II-2019: IV. The persistence of the energy price process ϕ_m and the standard deviation σ_{mz} are estimated to be 0.9919 and 0.12 respectively. For checking the robustness of our results we also use an ARMA specification for oil price shock. The results are very similar to the baseline results though the ARMA specification does give us a higher impact on GDP[25].

There is some debate regarding whether oil prices can be exogenously determined relative to the U.S economy[26]. Moreover, as we do not model the energy sector we cannot distinguish between oil price increases due to high demand or low supply; it is well known that the economic effects of oil price increases differ in the two cases (Kilian, 2009). Indeed, oil price increases caused by high demand due to higher economic activity do not seem to have significant effects on the economy while price increases due to higher speculative demand or lower supply have a contractionary effect (Baumeister and Hamilton, 2019). While it is possible the effect on entry and exit may differ along these lines as well; disentangling the effects of different sources of oil shocks on entry and exit is beyond the scope of this paper.

[24] For this estimation, we fit an AR(1) model to the logged real oil price data (WTI). In the empirical section, we see that the possibility of a unit root in the real oil price series cannot be rejected. However, most theoretical models assume a stationary process for oil prices. We follow this tradition; we think this is reasonable as the primary focus of the paper is to study the effect of oil prices on firm entry and exit.

[25] These results are included in appendix A3.

[26] Kilian and Vega(2011) test whether energy prices are predetermined with respect to U.S. macroeconomic aggregates. They find no evidence of feedback from U.S. macroeconomic aggregates to innovations in energy prices using monthly and daily data. However, extending this assumption to quarterly data is problematic and the possibility oil prices responding contemporaneously to U.S. economic activity remains. Addressing this issue, unfortunately is beyond the scope of this paper.

4.2 Results

We solve the model and obtain impulse responses using first order linear approximations.[27] Figure 6.1 and figure 6.2 present the impulse responses from the DSGE model with respect to an energy price shock. The impulse responses are scaled to a 10 percent increase in energy prices for comparison with the other papers in the literature and presented as percentage deviations from steady state values.

The energy price shock reduces GDP as can be seen from the impulse responses. The maximum fall in GDP on impact is about 1.2 percent due to a 10 percent increase in energy prices. This relationship has been extensively studied in the literature and the estimates vary from (0.25 percent to 2.5 percent). Fall in investment along the extensive margin is around 9.5 percent while drop in consumption on impact is about 0.4 percent. Edelstein and Kilian, 2009 estimate an elasticity of -0.15 (1.5 percent decline in consumption for a 10% increase in oil prices). Other papers such as Baumeister and Kilian (2016) estimate a 1.2 percent cumulative increase in consumption and a 2.2 percent cumulative increase in private nonresidential investment (excluding the oil sector) from a 66 percent decrease in oil prices (over 7 quarters, July 2014-March 2016). In a follow up paper, Baumeister, Kilian and Zhou (2018) estimate a 0.84 percent cumulative increase in consumption during 1986 Q1-1987 Q3. Lee, Kang and Ratti (2011) also find a negative response of firm level investment to oil price shocks. Thus the literature predicts fairly modest responses of consumption and investment, though investment seems more responsive to energy price shocks.

The model predicts a 9 percent decline in entry and a 4.4 percent increase in the exit rate on impact (total exits fall by around 4.2 percent). As households accommodate shocks thorough lower entry, the response of consumption is not proportional to the shock on impact. We get hump-shaped impulse responses for consumption and the maximum drop in consumption (0.7 percent) comes a bit later when oil prices start going down, entry picks up and households cut back on consumption further to finance entry. Average firm output ($\widetilde{y}_t$) and profits ($\widetilde{d}_t$) fall on impact. The produc-

[27] For the impulse response labeling we skip the tilde notation. All firm level variables refer to the average firm. The horizontal axis represents time in quarters.

tivity cut-off z_t^* increases on impact as profits fall and firms face lower demand for their output. This causes a higher exit and firms from the lower end of the distribution fail to survive. As the number of firms N_t is predetermined, it is not affected by shocks on impact but falls over time as entry falls and exit increases. Relative prices $\widetilde{\rho}_t$ also follow a similar pattern (see equation 9). Given constant markups in this model, marginal cost of production $\widetilde{\lambda_t^p}$must be constant on impact, this follows from the firms pricing equation (equation 4). As a result, a rise in energy prices is accompanied by a fall in real wages. Households labor supply (L_t) falls due to drop in real wages. We assume the marginal cost of entry consists only of labor so the entry cost must fall. However, as profits fall, the returns to entry ($\widetilde{re}_{t+1} = \frac{\widetilde{v_{t+1}}+\widetilde{d_{t+1}}}{\widetilde{v_t}}$) are also lower. Entry falls to equate the cost of entering to average firm value[28] . In the next section, we highlight the amplification mechanism by contrasting our results with models without entry/exit and models with exogenous exit.

5 Sensitivity Analysis

5.1 Model without Entry or Exit

The no entry case helps us identify the amplification solely due to inclusion of entry and exit. We assume $N_{e,t} = 0, N_t = 1, \delta = 0$.The productivity level is set at $\widetilde{z}$ and $\mu = 1.35$ as in the baseline model. Since there is no entry or exit in this model and the number of firms is equal to 1. There is no investment in the extensive margin here; therefore GDP is equal to consumption. Figure 7 shows the impulse responses from the imperfect competition model with the same markups as in our baseline model[29]. One can see that GDP falls by around 0.5 percent on impact which is about half the impact as compared to the baseline model. The number of firms (N_t) is fixed at one, so does not respond to shocks. There is drop in consumption (C_t), firm profit (d_t), wages (w_t), energy imports (M_t) and firm value (v_t) on impact. These findings are

[28] If the cost to entering was held constant, the impact on entry would be higher as we show in the case where entry costs are modeled in the same way as production costs with energy in entry costs as well (these results are shown in Appendix A2).

[29] Appendix A1 presents the model summary.

intuitive and consistent with findings in the literature.

Since there is no entry/exit channel in this model the dynamics is also simpler, all these variables increase over time and go back to the old steady state as oil prices starts falling. In terms of magnitude, consumption falls by about 0.5 percent which is higher than the drop in the baseline model on impact. As entry is used as a reallocation channel in the baseline model, entry falls and limits the drop in consumption on impact. However, over time the drop in consumption continues and is much more protracted in the baseline model. Similarly for wages, the impact is bigger in the baseline model as both the entry and consumption sector contract. This model does predict a bigger and more pronounced drop in firm profits (as there is no entry/exit so the impact of the shock is on firm profits entirely). The response of energy imports is similar across the models.

5.2 Comparison with Exogenous Exit Models

In this section, we compare models with endogenous and exogenous exits. This is important as we believe endogenizing exit is key for replicating some of the empirical facts shown in this paper (and elsewhere). Firstly, the symmetric firm exogenous exit model cannot match the evidence of countercyclical exit. In fact, models with exogenous exit rate as in Bilbiie, Melitz and Ghironi (2012), Patra (2020) imply lower exit in response to negative shocks (as exit rate is constant, fewer producing firms imply fewer exits). The model in this paper is also able to generate a bigger amplification effect on output. Further due to firm heterogeneity we are able to address the issue of firm selection due to negative shocks[30]. Since the models of exogenous and endogenous exit differ in multiple dimensions, we discuss two separate cases.

In the first case we contrast our results in this paper with the model in Patra (2020) where entry costs are specified only in terms of wages without fixed costs in production[31] . We show that the exogenous exit models as in Patra (2020) are

[30] This is well documented in the literature as the "cleansing effect of recessions", Caballero and Hammour (1994).

[31] Most exogenous exit models do not have fixed costs of production (Patra, 2020 and other papers

unable to generate any effect on the extensive margin under this specification of entry costs. Consequently the effect on GDP is very similar to the no entry/exit model. In the second case, we build an exogenous exit model with fixed costs in production. Here we see that there is an effect on the extensive margin though the amplification mechanism is weaker than our baseline model. As in the baseline model, we assume wages and prices are completely flexible and entry costs are specified in terms of labor costs only. For comparison across the models, we assume the same average productivity for firms i.e. the firm level productivity z is taken to be the same as $\widetilde{z}$ in the heterogeneous firm model for steady state calculations.

The impulse responses are given in Figure 8.1 and 8.2. One can see that the endogenous exit model generates a bigger impact on GDP compared to the exogenous exit models. The endogenous exit model also generates hump-shaped responses for consumption, real wages and firm value with the impact over time being much bigger and protracted. The number of firms also shows a much bigger and protracted drop in the endogenous exit model due to the response of both entry and exit. The exogenous exit model with fixed costs in production does capture the negative impact on entry but cannot capture the exit response by design. The impact on GDP is also smaller compared to the baseline model.

Comparing the two different exogenous exit models, when there are fixed costs in production, higher energy prices would lower profits further. This leads to a negative response of entry when oil prices increase in the second model[32]. Entry goes down in response to an oil price shock which limits the response of firm profits. Due to the effect on entry, we get a bigger drop in GDP as investment ($v_t N_{e,t}$) goes down (the response of consumption and firm value is almost same on impact in the two models).

Analyzing the two models with fixed costs (exogenous exit and the baseline model) we see that the response of entry is lower in the baseline model as firm exit also responds to oil price shocks. Due the response in both entry and exit,

based on BGM 2012, do not consider fixed costs in production).

[32] Alternatively, a model with fixed costs in production will give analogous results to a model without fixed costs but higher entry costs (with appropriate scaling as shown in Melitz and Redding, 2015).

the drop in consumption is smaller on impact. Firm profits fall less in the baseline model as average firm productivity $\widetilde{z}$ increases post an energy price shock (this effect is absent in the exogenous exit model). The response of energy imports is the same across the three models.

Thus when entry costs are specified in terms of labor costs, we need endogenous exits to capture the effects of oil price shocks on the extensive margin when there are no fixed costs of production. The exogenous exit model with fixed costs does capture the negative response of entry though the effect on GDP is weaker relative to the baseline model. Both the exogenous exit models cannot match the empirics on exit.

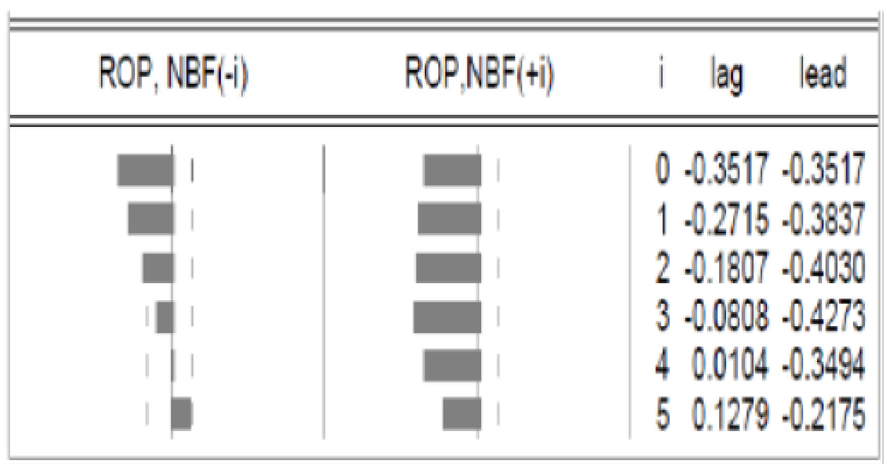
The endogenous exit model successfully captures the response of oil price shocks on both entry and exit (as seen in the VAR models). Firm entry, exit are also seen to be more sensitive in the data (relative to GDP) which is true in our DSGE model as well. In terms of correlations presented in Table 3, the model captures the negative correlation of entry with respect to oil prices and positive response of exit. Additionally we show that oil price shocks cause reallocation towards more productive firms due to increase in the productivity cut-off required for survival. From this perspective, oil price shocks can be productivity enhancing at the firm level which is in contrast to the standard approach of treating oil price shocks as negative productivity shocks (Finn, 1995; Hall 1988). Thus, comparing the impulse responses across the models, one can see that the extensive margin can be an important channel for propagation of oil price shocks. This has been an over looked aspect in the literature. Our paper tries to fill this gap. Given the recent developments in the energy sector we think introduction of domestic oil production and studying firm entry exit at a sectoral level might be promising avenues of future research.

6 Conclusion

This paper builds a framework to incorporate energy price shocks in a DSGE model with endogenous firm entry and exit. We show that the extensive margin is an important channel for propagation of shocks and magnifies the effect of energy price increases. This is in contrast to typical RBC models that imply only small effects of oil price changes. Our approach shows that even without the standard channels, amplification is possible by endogenizing the extensive margin. Our model also successfully captures the correlation pattern of firm entry and exit observed in U.S. data. Additionally, due to firm heterogeneity, the model can explain selection over the business cycle. Depending on the interaction between entry and exit in these models, oil price shocks can raise firm level productivity. In the baseline model we generate both lower entry and higher exit in response to oil price shocks. However the drop in entry is not high enough to insulate existing firms and firm level productivity increases. This is consistent with the literature on creative destruction and the productivity enhancing effects of recessions. Thus the evidence presented in this paper highlights an important channel of transmission for oil price shocks which can potentially amplify the effects of oil price shocks that has been somewhat over looked in the macro literature.

Figure 1

Cross-Correlation of Real Oil Prices and Net Business Formation (HP Filter)



ROP, NBF(-i)	ROP,NBF(+i)	i	lag	lead
		0	-0.3517	-0.3517
		1	-0.2715	-0.3837
		2	-0.1807	-0.4030
		3	-0.0808	-0.4273
		4	0.0104	-0.3494
		5	0.1279	-0.2175

Source: Patra (2020)

Figure 2

Cross-Correlation of Real Oil Prices and New Firm Incorporations (HP Filter)

OILHP,NIHP(-i)	OILHP,NIHP(+i)	i	lag	lead
		0	-0.3292	-0.3292
		1	-0.3278	-0.3266
		2	-0.2845	-0.3162
		3	-0.1822	-0.2609
		4	-0.0678	-0.1311
		5	0.0012	0.0103

Cross-Correlation of Real Oil Prices and New Firm Incorporations (Hamilton Filter)

OILHA,NIHA(-i)	OILHA,NIHA(+i)	i	lag	lead
		0	-0.3644	-0.3644
		1	-0.3486	-0.3574
		2	-0.2980	-0.3314
		3	-0.2008	-0.2674
		4	-0.0721	-0.1647
		5	0.0320	-0.0424

Cross-Correlation of Real Oil Prices and Industrial and Commercial Failures (HP Filter)

OILHP,ICFHP(-i)	OILHP,ICFHP(+i)	i	lag	lead
		0	0.2877	0.2877
		1	0.1716	0.3670
		2	0.0829	0.4262
		3	0.0570	0.4671
		4	-0.0078	0.4338
		5	-0.1093	0.2694

Cross-Correlation of Real Oil Prices and Industrial and Commercial Failures (Hamilton Filter)

OILHA,ICFHA(-i)	OILHA,ICFHA(+i)	i	lag	lead
		0	0.1134	0.1134
		1	0.0637	0.1725
		2	0.0140	0.1913
		3	-0.0660	0.1651
		4	-0.1667	0.1033
		5	-0.2547	-0.0086

Figure 3

Cross-Correlation of Real Oil Prices and Establishment Births (HP Filter)

OILHP,EBHP(-i)	OILHP,EBHP(+i)	i	lag	lead
		0	0.2670	0.2670
		1	0.2284	0.1943
		2	0.0877	0.1368
		3	0.0330	0.0861
		4	-0.0344	0.0431
		5	-0.0913	0.0669

Cross-Correlation of Real Oil Prices and Establishment Births (Hamilton Filter)

OILHA,EBHA(-i)	OILHA,EBHA(+i)	i	lag	lead
		0	0.0140	0.0140
		1	-0.0073	-0.0131
		2	-0.0870	-0.0485
		3	-0.0989	-0.1169
		4	-0.0958	-0.1689
		5	-0.1244	-0.1876

Cross-Correlation of Real Oil Prices and Establishment Deaths (HP Filter)

OILHP,EDHP(-i)	OILHP,EDHP(+i)	i	lag	lead
		0	-0.0968	-0.0968
		1	-0.1908	0.0201
		2	-0.2639	0.1473
		3	-0.3003	0.2074
		4	-0.2255	0.2898
		5	-0.1759	0.2325

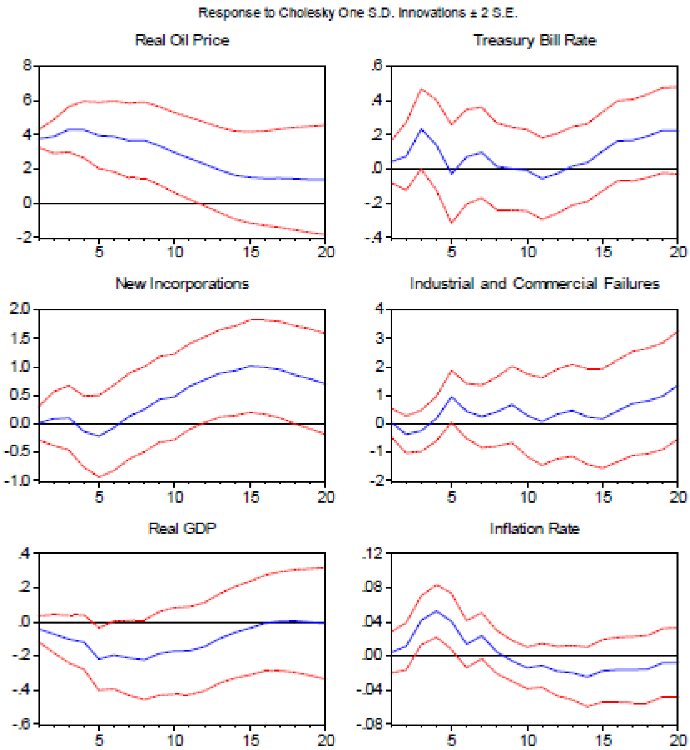
Cross-Correlation of Real Oil Prices and Establishment Deaths (Hamilton Filter)

OILHA,EDHA(-i)	OILHA,EDHA(+i)	i	lag	lead
		0	0.0204	0.0204
		1	-0.0118	0.1094
		2	-0.0668	0.1703
		3	-0.1065	0.1681
		4	-0.0932	0.1687
		5	-0.0728	0.1387

Table 1

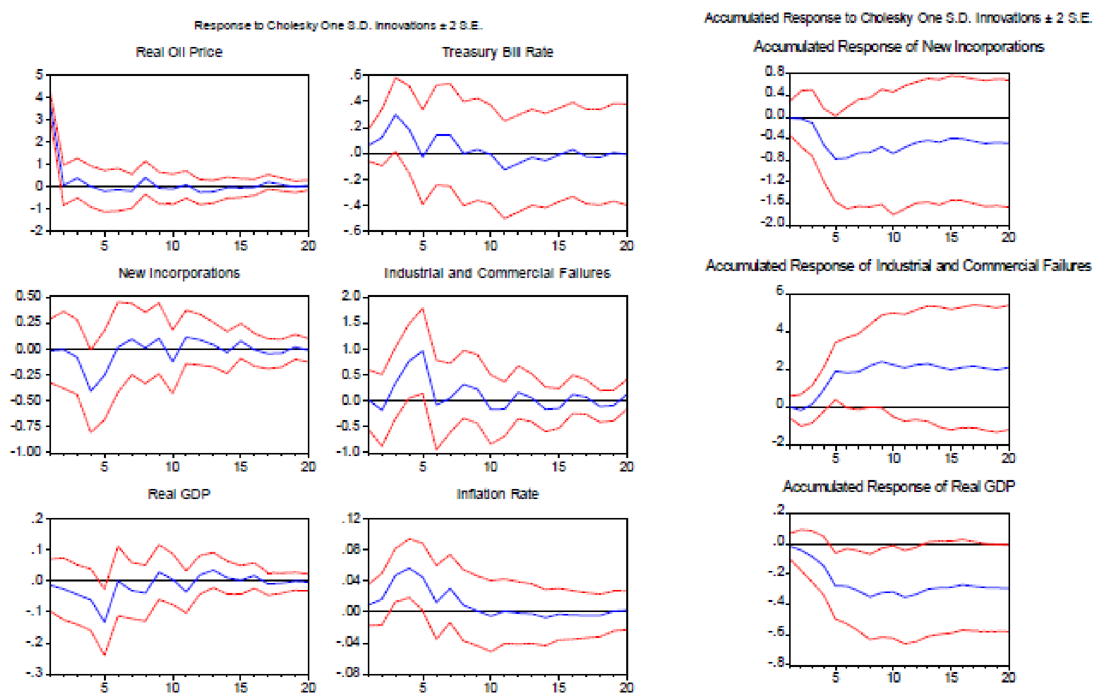
Variable	Data Source/Series	VAR variables (log level or log growth)
Oil Price	FRED, WTISPLC	$OIL = 100 * \log ROP_t \ or \ 100 * \log(ROP_t / ROP_{t-1})$
Entry (NI/ EB)	SCB/BLS	$Entry$=$100 * \log Entry_t \ or \ 100 * \log(Entry_t / Entry_{t-1})$
Exit (ICF/ ED)	SCB/BLS	$Exit$=$100 * \log Exit_t \ or \ 100 * \log(Exit_t / Exit_{t-1})$
Real GDP	FRED, GDPC1	$\mathrm{Re}\,al\ GDP = 100 * \log GDP_t \ or \ 100 * \log(GDP_t / GDP_{t-1})$
Inflation Rate	FRED, GDPDEF	$Inflation\ Rate = 100 * \log(DEF_t / DEF_{t-1})$
Treasury Bill Rate	FRED, DTB3	$3 - Month\ Treasury\ Bill\ Rate$

Figure 4.1: VAR 1 (Levels)



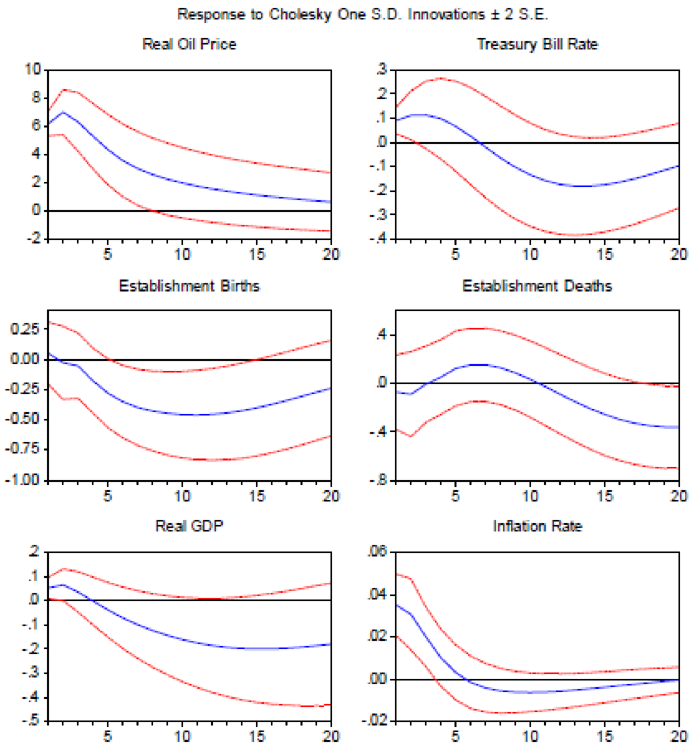
Note: Impulse responses to a one standard deviation shock in real oil prices for key variables are shown. The horizontal axis shows time in quarters. The error bands represent 95 percent confidence intervals.

Figure 4.2: VAR 2 (Growth Rates)



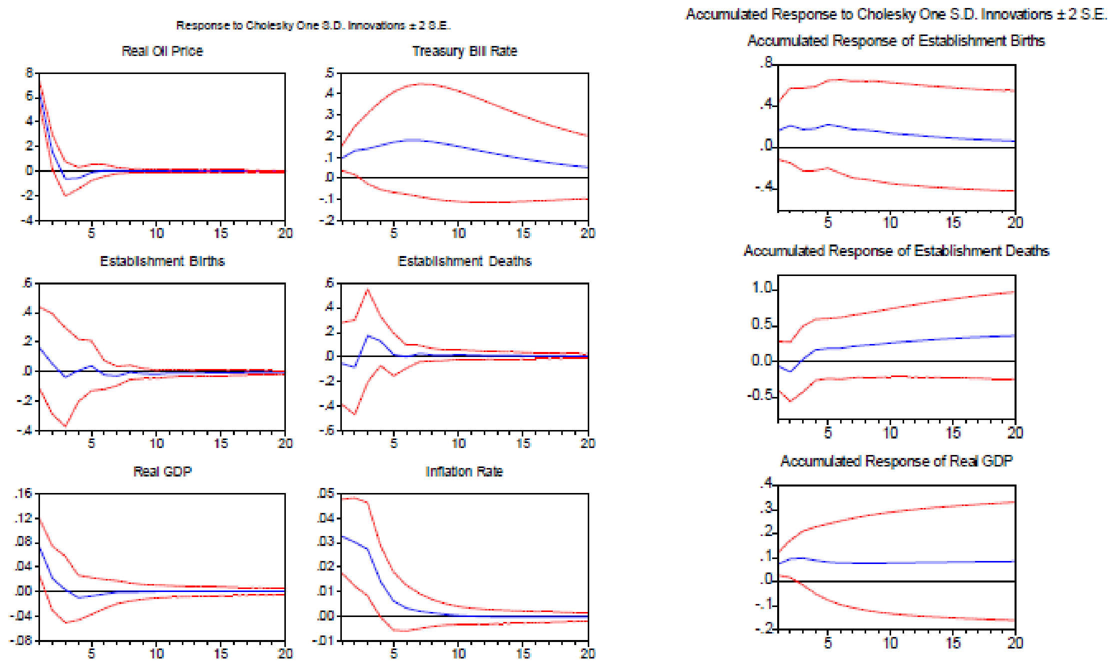
Note: Impulse responses to a one standard deviation shock in real oil prices for key variables are shown. The horizontal axis shows time in quarters. The error bands represent 95 percent confidence intervals.

Figure 5.1: VAR 3 (Levels)



Note: See notes to Figure 4.

Figure 5.2: VAR 4 (Levels)



Note: See notes to Figure 4.

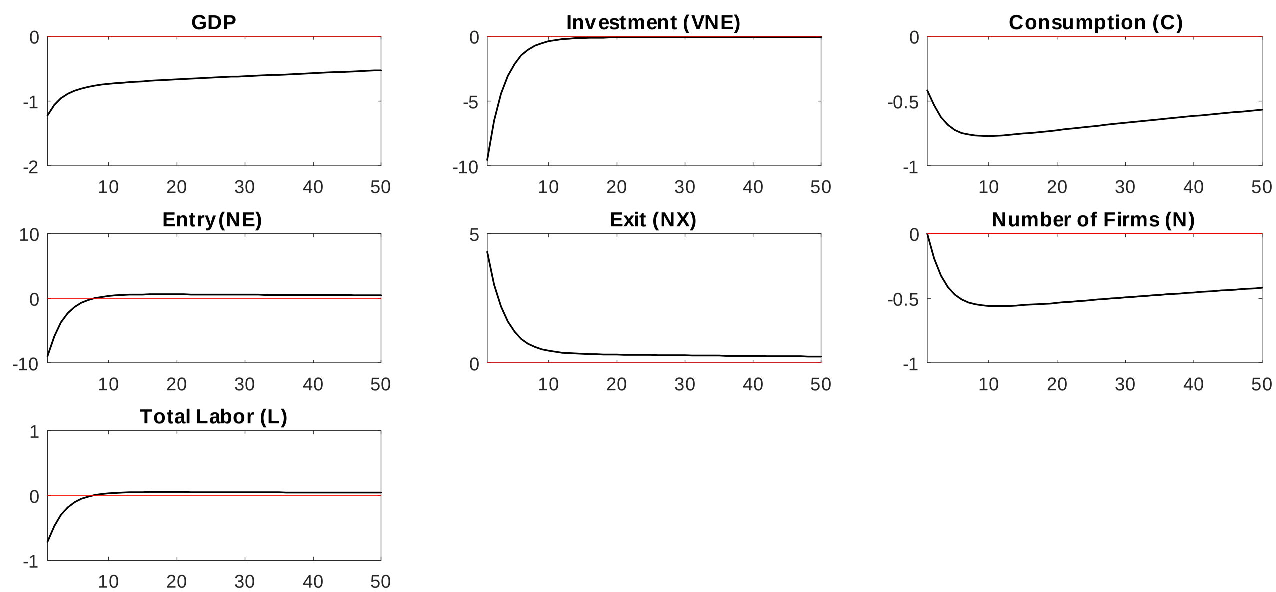
Table 2: Calibrated Parameters

Parameter	Value	Description
β	0.99	Discount factor
θ	3.8	Elasticity of substitution
φ	4	Frisch elasticity
χ	0.924271	Disutility of labor
f_e	1	Entry cost
α	0.9437	Share of labor
δ	0.029	Exit in the steady state
$z_{\min}$	1	Lower bound of Pareto Distribution
κ	4	Shape parameter of Pareto Distribution
σ_{m_Z}	0.12	Standard deviation of energy price shock
ϕ_m	0.9919	Persistence of Energy Price Shock

Table 3

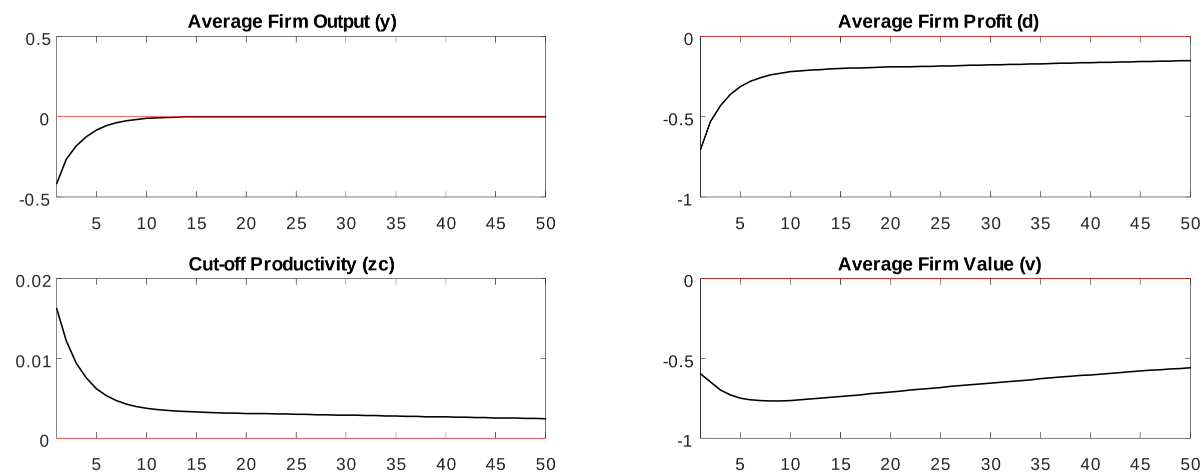
Correlations	Data (HP Filter)	Baseline DSGE
Net Business Formation, Oil	-0.35 (Patra, 2020)	-0.70
Net Business Formation, GDP	0.73 (Patra, 2020)	0.84
New Incorporations, Oil	-0.32	-0.70
New Incorporations, GDP	0.48	0.84
Establishment Births, Oil	0.26	-0.70
Establishment Births, GDP	0.57	0.84
Industrial and Commercial Failures, Oil	0.28	0.78
Industrial and Commercial Failures, GDP	-0.54	-0.91
Establishment Deaths, Oil	-0.09	0.78
Establishment Deaths, GDP	-0.08	-0.91

Figure 6. 1: Impulse Responses to a 10% p_m shock Baseline Model, $\alpha = 0.9437$



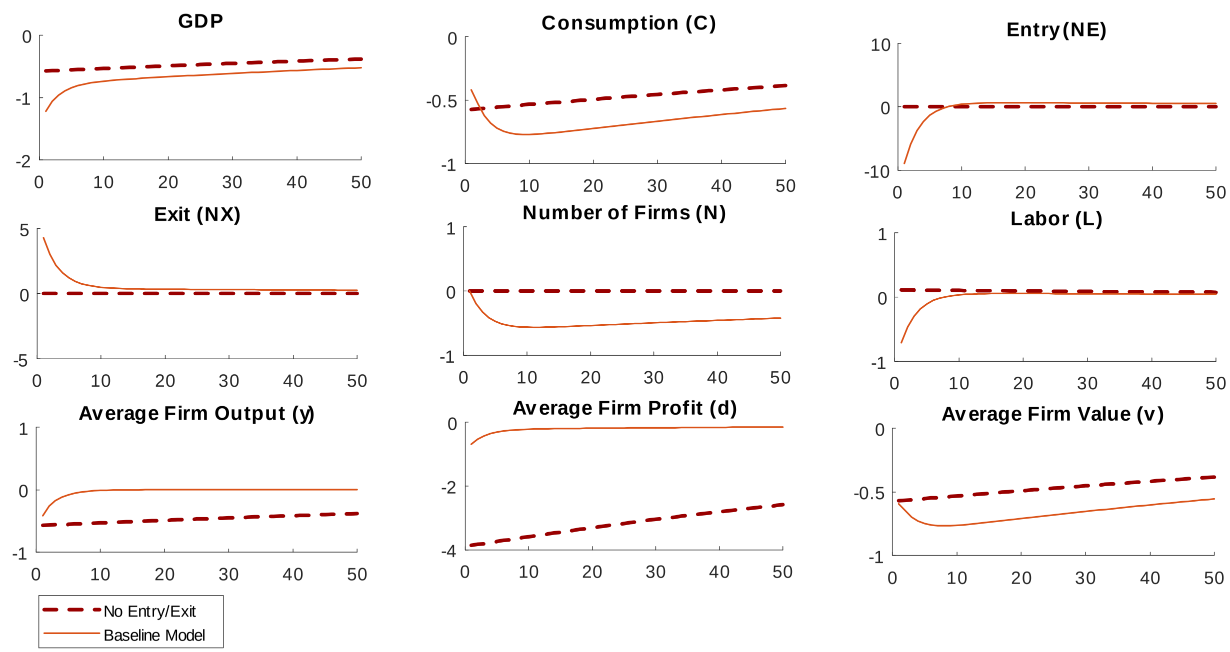
Note: All impulse responses are scaled to a 10 percent increase in energy prices. The horizontal axis represents time in quarters. The vertical axis shows percent deviations of variables from the steady state.

Figure 6. 2: Impulse Responses to a 10% p_m shock Baseline Model, $\alpha = 0.9437$



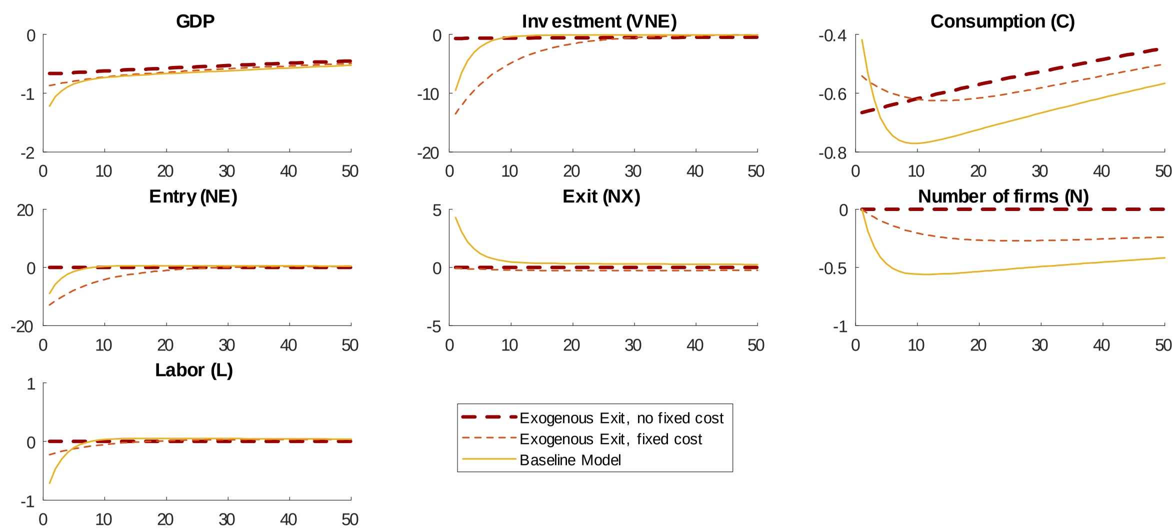
Note: All impulse responses are scaled to a 10 percent increase in energy prices. The horizontal axis represents time in quarters. The vertical axis shows percent deviations of variables from the steady state.

Figure 7: Impulse Responses to a 10% p_m shock Baseline Model versus No Entry/Exit Model



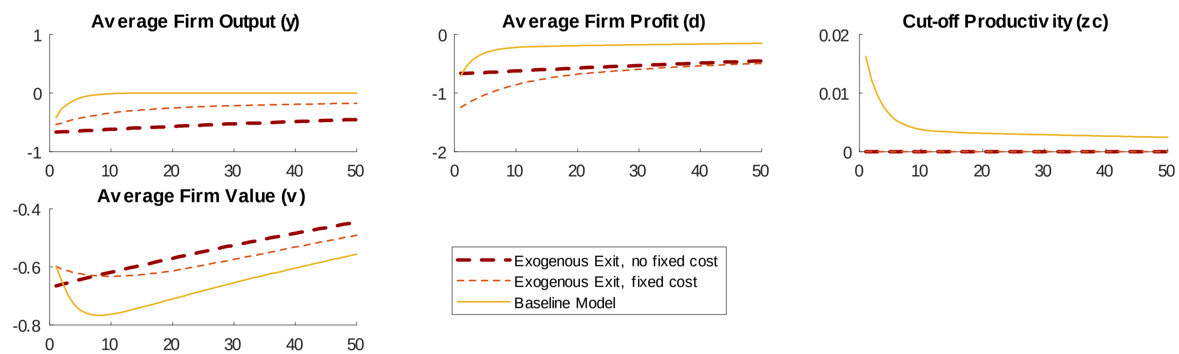
Note: All impulse responses are scaled to a 10 percent increase in energy prices. The horizontal axis represents time in quarters. The vertical axis shows percent deviations of variables from the steadystate.

Figure 8.1: Impulse Response to a 10% p_m shock, Baseline model vs Exogenous Exit Models



Note: See notes to Figure 6.

Figure 8.2: Impulse Response to a 10% p_m shock, Baseline model vs Exogenous Exit Models



Note: See notes for figure 6.

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