Energy in a Model of Firm Entry

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Abstract

Nine out of the last ten recessions in the U.S. have been preceded by an increase in the price of oil as noted by Hamilton (2008). Given the small share of energy in GDP this phenomenon is difficult to explain using standard models. In this paper, I show that firm entry can be an important transmission and amplifying channel for energy price shocks. The results from the baseline DSGE model predict a drop in output which is two times the impact in a model without entry. The model also predicts an increase in energy prices would lead to a decline in real wages, investment, consumption and return on investment. Additionally, using U.S. firm level data I demonstrate that a rise in energy prices has a negative impact on firm entry as predicted by the DSGE model. This lends further support towards endogenizing firm entry when analyzing the effects of energy price shocks.

Keywords: Oil Prices, Firm Entry, DSGE, VAR

1 Introduction

The literature linking oil prices to macroeconomic activity is extensive. Many authors observe that oil price shocks appear to be an important driving force for business cycles and terms of trade fluctuations (Mork 1989; Hamilton 1983, 1996; Carruth et al. 1998; Backus and Crucini, 2000 among many others). Furthermore, a substantial amount of evidence points to a direct link between oil price increases and the onset of recessions (Hamilton 1983, 1996, 2008; Engemann et al. 2011). Other studies such as Balke, Brown and Yucel (2002), Kilian and Vigfusson (2011), Hamilton (2011), Herrera, Lagalo and Wada (2011), Rahman and Serletis (2011) focus on the asymmetric effects of oil price shocks on output. Given the small share of energy in production, standard real business cycle (henceforth RBC) models with energy as an added factor of production cannot explain the sizable effects of energy price shocks (Kim and Lougani 1992; Rotemberg and Woodford 1996). This has led to alternative approaches of modeling the energy sector. For example, Rotemberg and Woodford emphasize the role of imperfect competition and implicit collusion to explain the contractionary effects of energy price shocks. Finn (2000) shows that even with perfect competition one can get contractionary effects in line with the estimates of Rotemberg and Woodford, by incorporating endogenous depreciation. In both these approaches another extra channel such as variable mark-ups or capital utilization amplify the effects of energy price shocks.

This paper demonstrates that firm entry is an additional channel by which energy price shocks are transmitted. The economic intuition behind this proposition is that increasing energy prices lower profit expectations and should therefore deter entry. Thus energy price shocks affect not only the scale of production but also the profitability of new ventures. In the standard literature, the number of producers or the extensive margin is exogenously fixed which implies all adjustment must occur through the intensive margin or firm level production. In contrast, this paper provides a framework where energy prices affect the extensive margin through entry as well as the intensive margin. The objective of this paper is not to challenge the existing theories of modeling energy but to provide another dimension of adjustment through the impact of energy prices on the extensive margin. The paper adds 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 paper to the best of my knowledge is the first attempt to incorporate energy price shocks and investigate the implication of energy price shocks for the extensive margin. The paper contributes to the existing literature in two ways i) inclusion of firm entry which is an important channel through which energy prices may effect economic activity ii) entry also serves as an amplifying mechanism for energy price shocks.

In the paper, I first briefly document the empirical relationship between firm entry and energy price shocks using a few VAR models. For the VAR models, I use new firm incorporations and net business formation as a measure of firm entry. I use real oil prices to identify oil price shocks. The VAR models predict that there is a negative effect of energy price shocks on firm entry though the response is significant for only one measure of Entry (Net Business Formation). Entry is also much more sensitive to energy price shocks compared to real GDP. Second, I build a

DSGE model that endogenizes firm entry with respect to energy price shocks. When energy prices increase, profits fall and the returns to entry falls. There is a sunk cost of entry[1], therefore households choose to re-allocate resources from financing new firms. Investment along the extensive margin falls along with consumption and generates a bigger impact on output. Inclusion of firm entry serves to amplify the impact of rising energy prices, the baseline DSGE model with firm entry predicts a drop in output which is two times the drop in a similarly calibrated model without entry. The model also predicts an increase in energy prices would lead to a decline in real wages, investment, consumption and return on investment.

All of these results are consistent with theoretical and empirical findings in the literature. Moreover, the model provides an alternative way of linking firm value (stock prices) and energy prices and produces results in line with the findings of Wei (2003). The model also predicts that when energy price increases are persistent, the effect on the extensive margin is much more persistent compared to the intensive margin. This suggests that the primary effect of persistent energy price increases work through the extensive margin and not the intensive margin. Furthermore, the model is consistent with the fact that oil price shocks act as negative productivity shocks since the impulse responses to an oil price shock are qualitatively similar to the impulse responses from a negative productivity shock.

The rest of the paper is structured as follows. In section 2, I briefly discuss some of the related literature. Section 3 obtains the empirical results on the response of firm entry to energy price shocks. Section 4 introduces the benchmark model. Section 5 presents sensitivity analysis with respect key model parameters and the model without entry. Section 6 concludes.

2 Related Literature

This paper is related to several different strands of literature linking energy prices to macroeconomic activity. The aggregate theoretical models such as Rotemberg and Woodford, Finn (2000) rely on other channels along with production to explain the significant effects of energy price shocks on the economy. Rotemberg and Woodford (1996) emphasize the role of imperfect competition. They show that inclusion of implicit collusion where producers can increase markups in response to energy price increases can lead to a substantial decline in output in line with their empirical estimates (a 2.5 percent reduction in output with a 10 percent increase in energy prices 5 to 6 quarters later versus a 0.5 percent decline in a perfectly competitive model). Finn (2000) shows that energy can play a significant role even in perfectly competitive models if it affects capital utilization. In her model energy impacts aggregate output through two different channels i) energy enters the production function indirectly through capital utilization ii) energy affects the capital accumulation through variable depreciation. However, Kormilitsina (2013) shows that the amplification in Finn's model is due to specific calibration strategy and functional form used in modeling the energy sector. My model takes a similar approach by introducing firm entry as an extra channel of transmission along with production. Rising energy prices lower firm entry and deplete the stock of producing firms in the future. As in Bilbiie, Ghironi and Melitz (2012) the stock of firms can be thought of as a representation of the capital stock in an economy. From that perspective the model is close to Finn's specification. However in her model, energy affects capital accumulation through endogenous depreciation while in this model the depreciation rate of firms or the exit shock is constant. The returns to entry vary endogenously with respect to energy price shocks and is the primary channel of transmission.

Other approaches include Atkeson and Kehoe (1999) who model energy as complementary to capital in a putty-putty and putty clay model to explain difference of energy use elasticity in the short run and the long run. Wei (2003) develops a putty clay model with capital obsolescence to provide a link with energy prices and stock prices. I provide an alternative method of linking the two, in addition my model generates a bigger impact on output. In Wei (2003), a 10 percent increase in energy prices leads to a 0.5 percent decline in output, the impact on real wages and consumption is similar across the two models. Blanchard and Gali (2007, BG henceforth) model energy in a New Keynesian framework with nominal rigidities. In contrast to their model, wages are completely flexible in my baseline model. Herrera (2016) models inventory behavior of firms to explain the delayed response of GDP to oil price shocks. Firms use inventories to smooth production declines in her model. Thus, investment falls to accommodate a sharp decline in output. In my model, entry plays a similar role, entry falls due to energy price shocks and produces a muted hump shaped response in consumption. Lee, Kang and Ratti (2011) also find that oil price shocks depress firm investment decisions consistent with findings of this model. Elder and Serletis (2010, 2011) focus on the effect of oil price volatility on aggregate investment. They find that increase in oil price volatility causes a decline in nonresidential investment and GDP. The effect is even stronger on the manufacturing sector, especially when monthly data is used and is seen to be persistent even in recent years post 2008.

There are a number of studies at the sectoral level that document the effects of energy price shocks. Davis and Haltiwagner (2001) use plant level census data (1972-1988) to quantify the effect of oil price shocks on job creation and job destruction in the U.S. manufacturing sector. They estimate the 1973:3-1974:4 oil shock to cause reallocation of about 11 percent of employment over the next 15 quarters and more than 80 percent of this reallocation happened within manufacturing. Davis, Loungani and Mahidhara (1997) find oil shocks to be a major driving force behind regional employment and unemployment fluctuations in the U.S. post 1972. Keane and Prasad (1996) use micro panel data to examine the effect of oil price shocks on employment and real wages at the aggregate and industry level. They find that oil price increases decrease real wages for all workers but raise the relative wage of skilled workers. They also find that oil shocks cause substantial changes in employment shares and relative wages across industries. Lee and Ni (2002) analyze the effects of oil price shocks in various industries. The impulse responses from their VAR models imply that oil shocks act as supply shock for industries with a large cost share of oil like petroleum refineries and industrial chemicals, whereas other industries such as automobile industries perceive them as demand shocks. More recently, Herrera and Karaki (2015) revisit this question using more recent time series data. They find no evidence of asymmetry in the response of U.S. manufacturing job flows to positive and negative oil price shocks. In addition, their results suggest that the allocative channel is not the dominant channel for transmission of oil price shocks and aggregate channels may be more important. They also document that even though oil prices have been more volatile in recent years the effect on job creation and destruction has been smaller. Further work by Herrera, Karaki and Rangaraju (2016) shows that the effect of oil price shocks extend beyond the manufacturing sector with sectors such as services and mining playing an important role. In particular, unexpected decline in oil prices lead to a decline in job creation and increase in job destruction in the oil and gas extraction and support activities for mining. Other industries such as construction, manufacturing and services exhibit a rise in the net employment change.

While my model is an aggregate model, it does capture some reallocation in the form of reallocation from the entry sector to the productions sector. Also given the significant contribution of new firms to job openings (about 20 percent as estimated by Jaimovich and Floetotto, 2008) the model can partly explain lower employment growth rates and job creation rates post an oil price increase (as noted in Davis and Haltiwagner, 2001).

3 Firm Entry and Oil Prices

As an empirical motivation for my analysis, I consider two different facts. First is the high comovement of entry and GDP as noted in Bergin and Corsetti (2008), Jaimovich and Floetotto (2008), Bilbiie, Ghironi and Melitz (2012), Chatterjee and Cooper (1993). Second is the link between oil price shocks and U.S. recessions.

Given that rising energy prices reduce profit expectations, we should see a fall in entry as well which would be consistent with both facts. I use two different measures of entry, New Incorporations and Net Business formation. The data runs from 1959: II-2013: IV for New Incorporations[2] and from 1954: III-1994: IV for Net Business Formation. The correlations[3] of entry with respect to GDP are 0.73 for Net Business Formation and 0.56 for New Incorporations. The correlations of GDP and real oil price are -0.02 and -0.26 in the two data sets[4]. The correlations of entry with real oil prices are -0.07[5] and -0.35 for New Incorporations and Net Business Formation respectively. In Figure 1, I present the cross-correlations of entry with respect to real oil prices. It can be seen that for both the measures of firm entry, the cross-correlations between oil and lead values of entry are negative and significant. This implies that oil price increases deter entry in the future periods as fewer firms enter the market in anticipation of lower profits.

To formally investigate the impact of oil prices on firm entry, I use vector autoregressions estimated on U.S. data. Using the DF-GLS test the null hypothesis of the series having a unit root cannot be rejected, therefore I estimate a VAR (3) in the log growth[6] of real GDP, Federal funds rate[7], the log growth of entry (measured as Net Business Formation, NBF or New Incorporations, NI), the log growth of the GDP deflator and the log growth of the real oil prices[8]. The source of data and transformations are given in Table 1. The lag length for model is the determined according to Akaike information criteria[9].

Figure 2 shows the impulse responses with respect to an oil price shock with the horizontal axis representing time in quarters[10]. The dashed lines represent 2 standard error confidence intervals. One can see that an increase in oil prices causes a sharp drop in Net Business Formation 4 quarters later. GDP also falls at around 5 quarters though the response is marginally significant. Net Business Formation is also much more sensitive to oil prices compared to GDP, the magnitude of the effect on Net Business Formation is 0.5 percent compared to a 0.1 percent drop in GDP. The accumulated impulse responses show that Entry and GDP both fall post an energy price shock. The drop in Net Business Formation is 0.89 percent compared to a 0.45 percent drop in GDP after about 5 quarters.

The impulse responses with New Incorporations as a measure of entry (refer to Figure 3) show a similar pattern[11]. Entry measured as New Incorporations falls by 0.4 percent vs. a 0.1 percent drop in GDP, though the responses are not significant in this case. Both the federal funds rate and GDP deflator increase post an oil price shock.

A number of conclusions can be drawn from the VAR impulse responses. Firstly, energy prices do impact the entry decision of firms and entry is much more sensitive to energy price shocks compared to GDP. While these results seem intuitively plausible, this is the first paper to document this finding. Secondly, there is a delay in the response of entry, which suggests lags in setting up new firms. The VAR models also understate the response of the extensive margin, because the measure of entry only includes new firm incorporations or net business formation. In particular, it does not capture the introduction of new product lines in existing firms which the theoretical model captures. However due to lack of aggregate data on product development in existing firms, I limit the analysis to the impact of energy prices on new firms.

The main implication from this brief exercise is that entry responds to energy prices shocks and should therefore be included as a transmission channel in theoretical models.

4 Benchmark Model

The empirical evidence suggests that increasing oil prices act as a deterrent to firm entry. I therefore build a framework where energy prices impact the extensive margin through firm entry. The model is based on the Bilbiie, Ghironi and Melitz (2012) paper with primary focus on the transmission of energy price shocks. Since there is no capital in the model, investment is solely along the extensive margin. Other salient features of the model are entry subject to sunk costs and a time to build lag.

4.1 Firms

There is a continuum of monopolistically competitive firms each specializing in the production of a specific variety of the consumption good[12]. Output of each variety is given as $y_t^c(\omega) = Z_t l_t^c(\omega)^{\alpha} m_t^c(\omega)^{1-\alpha}$, where Z_t is a aggregate productivity shock, $l_t^c(\omega)$ and $m_t(\omega)$ stand for labor and energy used for production of variety ω. The Cost Function can be written as $C(y_t^c(\omega)) = \frac{y_t^c(\omega)}{Z_t} b w_t^{\alpha} p_{mt}^{1-\alpha}$, where $b = \alpha^{-\alpha}(1-\alpha)^{1-\alpha}$, w_t is the real wage rate and p_{mt} is the real price of energy. The marginal cost of production is given as $MC = AC = \frac{b w_t^{\alpha} p_{mt}^{1-\alpha}}{Z_t} = \lambda_t^p$. The firms first order conditions are given below. Equations (1) and (2) result from the firm's cost minimization strategy. Equation (3) is derived from the firm's price setting problem. In the first stage the firms cost minimization problem can be written as

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

s.t.

$y_t^c(\omega) = Z_t l_t^c(\omega)^\alpha m_t^c(\omega)^{1-\alpha}$

which gives us the first order conditions given below:

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

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

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

max $\rho_t(\omega) y_t^c(\omega) - \frac{y_t^c(\omega)}{Z_t} b w_t^\alpha p_{mt}^{1-\alpha}$

s.t.

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

where Y_t^c refers to aggregate consumption output.

The first order condition for this problem is

$$\rho_t(\omega) = \mu \frac{b w_t^\alpha p_{mt}^{1-\alpha}}{Z_t} \tag{3}$$

Each firm sets prices as a constant markup (μ) over marginal cost. Given the CES aggregation method used in this paper μ can be written as a function of θ, the elasticity of substitution, in the following way:

$$\mu = \frac{\theta}{\theta - 1}. \tag{4}$$

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

$$d_t(\omega) = \rho_t(\omega) y_t(\omega)[1 - 1/\mu].$$

4.2 Firm Entry and Exit

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. The entrants entering in period t only 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. It may be interpreted as time required to set up distribution network or establish clientele base before the firms start selling. This assumption is important and along with sunk cost of entry generates pro-cyclical profits and entry, which cannot be explained with frictionless entry as in Chatterjee and Cooper (1993), Devereux (1996) and Jaimovich and Floetotto, (2008). These other approaches to entry impose a period by period fixed cost to solve for number of firms with free entry driving profits to zero every period. Thus in these models, the number of firms adjusts instantaneously and profits do not respond to shocks.

Each firm pays a sunk entry cost fe_t in terms of effective input bundles, the cost of entering is $C_{e_t} = \frac{fe_t}{Z_t} b w_t^{\alpha} p_{mt}^{1-\alpha}$. The aggregate production function for entry is $fe_t N_{e,t} = Z_t (L_t^e)^{\alpha} (M_t^e)^{1-\alpha}$ where L_t^e and M_t^e represent the total labor and energy used in entry. Both producing and entering firms face a constant exit shock δ at the end of the period. Namely, a fraction δ of entering firms will never produce[13]. The exit shock keeps the number of firms finite and ensures that the system is stable[14]. The 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: $v_t(\omega) = E_t \sum_{s=t+1}^{\infty} Q_{t,s} d_s(\omega)$. v_t also represents the average value of incumbent firms after production, $Q_{t,s}$ is the stochastic discount factor determined in equilibrium by the optimal investment behavior of households to be defined below. Entry occurs until value of firm equals the entry cost (in real units) i.e.

$$v_t(\omega) = C_{e_t} = fe_t \lambda_t^p. \tag{5}$$

A positive mass of entrants ensures that this condition holds every period. The timing of entry and production imply the number of producing firms during period t is given by:

$$N_t = (1-\delta)(N_{t-1} + N_{e,t-1}). \tag{6}$$

The number of producing firms represents the stock of capital of an economy and is an endogenous state variable that behaves like physical capital in the standard RBC model. I assume a symmetric equilibrium i.e. each variety has the same marginal cost of production: $p_t(\omega) = p_t, \rho_t(\omega) = \rho_t, l_t^c(\omega) = l_t^c, m_t^c(\omega) = m_t^c, y_t^c(\omega) =$

$y_t^c, d_t(\omega) = d_t, v_t(\omega) = v_t, m_t^e(\omega) = m_t^e$. Symmetry also implies that the aggregate variables such as aggregate price level (P_t) , aggregate revenue (R_t) , aggregate manufacturing output (Y_t^c) , aggregate profits (Π_t) can be expressed in terms of N_t and the corresponding firm level variables p_t , r_t , y_t^c , d_t in the following way:

$$P_t = N_t^{1-\mu} p_t, \tag{7}$$

$$R_t = P_t.Y_t^c = N_t r_t, Y_t^c = N_t^{\mu} y_t^c, \Pi_t = N_t d_t.$$

Aggregate consumption output production function can be written as:

$$Y_t^c = N_t^{\mu} y_t^c = \rho_t Z_t \left(L_t^c\right)^{\alpha} \left(M_t^c\right)^{1-\alpha} \tag{8}$$

Firm level revenue can be written as:

$$r_t(\omega) = r_t = R_t / N_t = P_t Y_t^c / N_t$$

Firm profits are given as:

$$d_t = [1 - 1/\mu] \frac{Y_t^c}{N_t}, \tag{9}$$

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

$$w_t = (\alpha/\mu) \frac{Y_t^c}{L_t^c}. \tag{10}$$

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

$$p_{mt} = \left(\frac{1-\alpha}{\mu}\right)\frac{Y_t^c}{M_t^c}, \tag{11}$$

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

4.3 Consumers Problem

The 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 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 $\varphi \geqslant 0$ represents the Frisch elasticity of labor supply to wages and the intertemporal elasticity of substitution in labor supply. The aggregate consumption basket of goods C_t is defined over a continuum of goods Ω. Only a subset of goods $\Omega_t \in \Omega$ is available in a given time period t. Aggregate consumption and price level are given by the (standard) Dixit Stiglitz aggregator: $C_t = \left[\int\limits_{\omega\in\Omega} c_t(\omega)^{\frac{\theta-1}{\theta}} d\omega\right]^{\frac{\theta}{1-\theta}}$,where $\theta > 1$ is the elasticity of substitution between goods, $P_t = \left[\int\limits_{\omega\in\Omega} p_t(\omega)^{\frac{\theta-1}{\theta}} d\omega\right]^{\frac{\theta}{1-\theta}}$ 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: $c_t(\omega) = \rho_t(\omega)^{-\theta} C_t$ where $\rho_t(\omega) = \frac{p_t(\omega)}{P_t}$ is the relative price.

4.3.1 Household Budget Constraint and Optimality Conditions

The household budget constraint is given as:

$$v_t(N_t + N_{e,t})x_{t+1} + C_t = (d_t + v_t)N_t x_t + w_t L_t,$$

where x_t is the share in the mutual fund held by the representative household in period t. The left hand side represents household expenditure on future share holdings in a mutual fund of existing firms and entering firms and consumption. Since the household cannot identify which firms will exit it 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:

$$C_t : \quad \frac{1}{C_t} = \lambda_t,$$

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

$$x_{t+1} : v_t = \beta(1-\delta)E_t[\frac{C_t}{C_{t+1}}(d_{t+1} + v_{t+1})], \tag{12}$$

$$L_t : \chi\left(L_t\right)^{\frac{1}{\varphi}} = \frac{w_t}{C_t}, \tag{13}$$

Iteration of the Euler equation and elimination of speculative bubbles allow us to solve for the stochastic discount factor:

$$Q_{t,s} = \beta^s(1-\delta)^s[\frac{C_t}{C_{t+s}}].$$

4.4 Market Clearing Conditions

4.4.1 Labor Market

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

$$L_t = L_t^c + L_t^e. \tag{14}$$

Aggregate labor demand for consumption(L_t^c) is the sum of firm level labor demand (l_t^c) for the production sector, $L_t^c = N_t l_t^c$. Similarly aggregate labor demand for entry is

$$L_t^e = N_{e,t} l_t^e = \frac{\alpha \lambda_t^p N_{et} f_{et}}{w_t}. \tag{15}$$

4.4.2 Energy Market

Similarly for energy, total energy usage is the sum of energy usage in production and entry.

$$M_t = M_t^c + M_t^e. \tag{16}$$

Aggregate energy usage in production and entry can be obtained by summing over producing and entering firms, $M_t^c = N_t m_t^c$,

$$M_t^e = N_{e,t} m_t^e = \frac{(1-\alpha) \lambda_t^p N_{et} f_{et}}{p_{mt}}. \tag{17}$$

4.4.3 Balanced Trade Condition

I impose a balanced trade condition every period, the consumption good is exported to pay for energy imports. I assume foreign demand for the home country's consumption good is symmetric and do not explicitly model the foreign economy .i.e. $\int_{\omega\in\Omega} p_t(\omega)c_t^*(\omega)d\omega = P_{mt}M_t$ where P_{mt} is the nominal price of energy and $y_t(\omega) = c_t(\omega) + c_t^*(\omega)$. This assumption can be interpreted in the following way; since there are no barriers to trade the domestic firm cannot distinguish between home and consumers when selling their product and are only concerned with total demand for their product. Therefore foreign demand acts a demand shifter here[15]. In aggregate terms this implies that aggregate manufacturing output (Y_t^c) is used for consumption and as payment for consumption imports:

$$Y_t^c = C_t + p_{mt}M_t \tag{18}$$

4.4.4 Aggregate Resource Constraint

Summing over all households, firms, imposing $x_{t+1} = x_t = 1$, and adding the energy expenditure results in the following aggregate resource constraint;

$$Y_t \equiv C_t + p_{mt}M_t + v_t N_{e,t} = N_t d_t + w_t L_t + p_{mt}M_t. \tag{19}$$

Total expenditure on consumption and investment in new firms equal total income from profits and labor. Note that $vN_{e,t}$ represents investment in new firms. Therefore all investment in the model is in the creation of new firms or the extensive margin [16] .

4.5 Model Equilibrium

The model is summarized by equations (3) through (19). There are fifteen endogenous variables: $N_t, \rho_t, \mu, d_t, w_t, Y_t^c, C_t,\ L_t, L_t^c, L_t^e, M_t, M_t^c, M_t^e, N_{e,t}, v_t,$ one of which (N_t) is predetermined at time t and two exogenous variables $Z_t,\ p_{mt}$. The labor market equilibrium condition (equation (14)) and the energy market condition (equation (17)) are redundant. The remaining system of fifteen equations can be used to solve for the fifteen endogenous variables.

4.5.1 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. The share of energy in value added is given as $\frac{p_m M}{Y - p_m M} = (\frac{1}{\mu} + \gamma)(1-\alpha)\frac{1}{[(1+\gamma)-S]}$ where $S = (\frac{1}{\mu} + \gamma)(1-\alpha)$. I calibrate α, so that the share of energy in value added is 4 percent which is close to the value used in Finn (2000), Rotemberg and Woodford (1996). I set the steady state values for productivity and energy price to be 1 i.e. $Z_t = 1$, $p_{mt} = 1$. The other parameters are calibrated following BGM (2012). The exogenous variables Z_t and p_{mt} are assumed to follow an AR (1) process in logs.

There is a substantial literature on the stationarity of oil prices. Real oil prices have been found to be stationary in many studies (Pindyck (1999), Lee et.al (2006), Li and Thompson (2010)) while nominal oil prices have often been modeled as non-stationary. Macroeconomic models of oil prices such as Rotemberg and Woodford (1996) , Finn (2000), Kilian (2009), Pieschacon (2012) assume stationarity of real oil prices. This paper assumes stationarity following this approach, in addition the values used for the oil price process are very close to the ones used in Blanchard and Gali (2007)[17].The exogenous process for Z_t , and p_{mt} and the sources are as follows:

$$log(Z_t) = \phi_z \log(Z_{t-1}) + \varepsilon_{z,t} \qquad \varepsilon_{z,t} \sim N(0, \sigma^2_{\varepsilon_Z}),$$

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

I estimate the exogenous process for real oil prices[18] using U.S. data from 1959: II-2013: IV. The persistence of the energy price process ϕ_m and the standard deviation σ_{ε_m} are estimated to be 0.99 and 0.127 respectively.

4.6 Model Dynamics

I solve the model using first order linear approximation.[19] Figure 4 presents the impulse responses for key variables from the DSGE model with respect to an energy price shock and highlights the amplification due to endogenous entry[20]. The horizontal axis represents number of quarters. The impulse responses are scaled to a 10 percent increase in energy prices for comparison with the other papers in the literature. I study the impulse responses by separating the effects on the variables on impact and over time.

4.6.1 Energy Price Shock

I consider the effects of the shocks on impact first. The number of firms N_t is predetermined and therefore not affected by shocks on impact. The variables which are a function of N_t will also behave similarly. Relative prices ρ_t would therefore remain constant on impact (see equation 7). Given constant markups in this model, marginal cost of production λ_t^p must be constant on impact (follows from equation 3). If energy prices increase real wages must fall to keep λ_t^p constant. Since I assume the marginal cost of production and entry to be same, the entry cost must also be predetermined w.r.t shocks on impact (f_e is constant here). From the free entry condition, entry adjusts to keep the value of the firm v_t same on impact[21] . If there was no entry, firm value would fall on impact due to an energy price increase. Note that the response of consumption is not proportional to the shock on impact. This is because households choose to accommodate shocks thorough entry decisions.

Energy imports (M_t), firm level output (y_t) and profits (d_t) fall on impact. The return to entry ($re_{t+1} = \frac{v_{t+1}+d_{t+1}}{v_t}$) falls due to lower profit expectations. Entry falls on impact and households optimally choose to reallocate resources from financing new firms to consumption. Consumption therefore falls less than proportionally on impact. Lower firm production and less entry imply energy usage in both the production sector (M_t^c) and entry sector (M_t^e) goes down. As the entry sector contracts L_t^e falls on impact, households choose to reallocate labor from entry to production. However since all firms are producing less, labor demand is low in production and entry and it leads to a drop in real wages. Households supply less labor due to fall in real wages. $GDP_t = C_t + v_t N_{e,t}$, falls as both consumption and investment fall. The maximum fall in GDP is about 0.9 percent on impact due to a 10 percent increase in energy prices. Most of the drop in GDP is due to fall in investment in the extensive margin (around 3.5 percent) while response of consumption on impact is about 0.4

percent. N_t, v_t, ρ_t are predetermined with respect to the shock as discussed before.

Over time the fall in entry leads to fewer firms N_t falls. As the number of varieties fall during transition, demand for each variety increases which leads to higher firm level output along the transition period. Relative prices ρ_t falls as there are fewer varieties. This is also reflected in lower firm value. Profit per variety increases which offsets the decrease in v_t so that re_{t+1} increases above its steady state value over the transition period. Labor is reallocated back to the entry sector, entry increases over time. Consumption response is hump -shaped and drops further to about 0.6 percent as households cut back on consumption to finance entry. Wages drop further as even though firm level production is higher, there are fewer firms than before so labor demand is lower. As entry recovers, N_t starts increasing till the number of varieties is back to its old steady state value. As N_t increases, y_t and d_t fall till they reach the old steady state. Investment ($v_t N_{e,t}$) keeps increasing along with consumption and GDP goes back to its old steady state value.

5 Sensitivity Analysis

5.1 No Entry Model

I assume $N_{e,t} = 0, N_t = 1, \delta = 0, \mu = 1.35$. Since there is no entry, I assume away the exit inducing shock. There is no investment in the extensive margin here, therefore GDP is equal to consumption. Figure 4 presents the impulse responses from the imperfect competition model with markups the same as in our baseline model. As the parameter values are the same across the two models, the no entry case helps us identify the amplification solely due to inclusion of entry. One can see that consumption falls by around 0.5 percent on impact which is about half the impact as compared to the baseline model. Energy imports, wages, profits and firm value fall. In this case as there is no entry, the value of the firm adjusts on impact. In the benchmark model, entry doubles the responsiveness of the economy to oil price shocks.

5.2 Different Energy Intensities in Entry and Production

In this section, I make the input bundles in Production versus Entry different which implies that the marginal cost of entry is now different from the marginal cost of production. The consumers' problem is the same as in the baseline model. In this case, α^e denotes the labor share in entry and α is the labor share in production as before. The corresponding entry cost is therefore $C_{e_t} = fe_t\lambda_t^e$, where $\lambda_t^e = \frac{bw_t^{\alpha^e} p_{mt}^{1-\alpha^e}}{Z_t}$. I pick values of α^e and α so that the share of energy expenditure in value added is 4 percent as in the baseline model. Figure 5 shows the impulse responses.

5.2.1 Entry more energy intensive than production

Given $\alpha^e < \alpha$, I pick $\alpha^e = 0.9$ which implies the share of energy in entry costs equals 10 percent. Since Entry is now more energy intensive, an increase in energy prices decreases entry more than the baseline model. N_t, ρ_t, λ_t^p are predetermined w.r.t the shock on impact. The fall in wages on impact is smaller than in the baseline model (this also follows from the fact that λ_t^p does not react to the shock on impact, since share of energy in production is lower, wages need to fall less vis-a-vis the baseline model to keep λ_t^p same). Since entry is more energy intensive and wages fall less the marginal cost of entry, λ_t^e, increases on impact. The bigger fall in entry implies fewer firms in future and firm level profits rise above the steady state along the transition path, v_t accordingly increases on impact. Investment falls as entry ($N_{e,t}$) falls. Consumption falls very little on impact as households cut down on investment. GDP falls by about 1.1 percent on impact.

Over time the adjustment mechanisms are the same as in the baseline model. The impulse responses for the productivity shock are the same as the baseline model as the productivity shock impacts entry and production symmetrically.

5.2.2 Entry less energy intensive than production

Now, $\alpha^e > \alpha$, I pick $\alpha^e = 0.99$ so that the share of energy in entry costs is 1 percent. Since entry is less energy intensive now, entry responds less to an energy price shock on impact. N_t, ρ_t, λ_t^p are predetermined w.r.t the shock on impact. Wages fall more than in the baseline case to keep λ_t^p constant on impact. Thus entry costs fall along with a fall in firm value. Investment decreases on impact due to fall in both v_t and $N_{e,t}$. GDP falls by around 0.7 percent on impact as both consumption and investment is lower.

5.3 Persistence of energy shock

In this section, I change the persistence of the energy price shock[22]. Since the extensive margin or number of firms is slow to adjust to shocks while firm level output adjusts fairly quickly in the model a more persistent shock lets us identify the contribution of the extensive and intensive margin.

Figure 6 presents the impulse responses. When energy price increase is less persistent ($\phi_m = 0.7$), entry is more sensitive to energy price increases. This is because it is the only channel for households for intertemporal substitution. Households choose to invest less in entry to smooth out consumption. Thus consumption falls less on impact. The decline is GDP on impact is also higher due to lower investment. When I make the energy price shocks highly persistent ($\phi_m = 0.9999$), entry falls less on impact. But the drop in entry is protracted and leads to a prolonged decline in number of firms. The drop in GDP is around 0.8 percent and is persistent. The contribution of the extensive margin is much bigger compared to the intensive margin. Firm level output goes back to its original steady state quickly, but the adjustment in the number of firms takes much longer. This suggests that if energy price increases are persistent, they impact GDP mainly through the extensive margin.

5.4 ARMA Process for Energy Prices

I estimate an ARMA process for energy prices following Kim & Lougani (1992). Figure 7 presents the impulse responses. The stochastic process for real energy prices is given as:

$$log\left(P_{mt}\right) = 0.988 \log\left(P_{mt-1}\right) + \varepsilon_{m,t} + 0.255\varepsilon_{m,t-1} \qquad \varepsilon_{m,t} \sim N(0, 0.124^2)$$

The impulse responses are closer to the empirical responses and produce a drop in GDP of 1.1 percent. The response of entry is fairly similar to the empirical response where I get a U shaped response of Entry. This specification also gives a bigger drop in GDP compared to our baseline model. Figure 10 presents the impulse responses.

Thus, comparing the impulse responses across the models, one can see that entry does serve as a transmission channel for aggregate shocks and amplifies the effect of shocks. The baseline DSGE model predicts the right sign in terms of response of entry[23]. In terms of correlations presented in Table 3, the model captures the positive correlation of entry with respect to GDP and the negative correlation of entry with respect to oil prices. However the baseline model with an AR (1) process for energy price shocks does not generate the hump shaped response of entry or GDP in the empirical impulse responses. The ARMA specification performs better in this respect. In spite of the simple structure of the model (no capital, variable utilization of capital, investment adjustment costs, nominal stickiness, habits in consumption etc.) it does capture the response of entry reasonably well and also the fact that entry is much more sensitive to oil shocks compared to GDP.

The VAR model also understates the response of entry to energy price shocks, as it does not include introduction of new product lines in existing firms which would be captured in the theoretical model. Moreover, both the VAR model and the theoretical model understate the importance of the extensive margin in propagation of energy price shocks because firm exits may also be responsive to energy price shocks.

6 Conclusion

This paper builds a framework to incorporate energy price shocks in a model of firm entry. I show entry is an important channel for propagation of shocks and magnifies the effects of energy price increases. This has been an important caveat for RBC models with the share of energy in production being really small. The other approaches to modeling energy rely on variable markups and endogenous utilization of capital as amplification mechanisms. I demonstrate that even without variable markups (markups are constant in the baseline model) or endogenous utilization, amplification is possible if the role of firm entry is analyzed. The empirical evidence presented in this paper also suggests that entry responds significantly to energy price shocks. In spite of the fairly simple structure of the model, it successfully captures the response of entry as well as the fact that entry is much more sensitive to energy price shocks compared to GDP.

However while the DSGE model does significantly better than a RBC model, it is not able to match the responses in the data completely. A better specification of the energy price shock might help solve the problem. Also, the baseline model understates the impact of energy price shocks on the extensive margin. In particular, exit of firms is exogenous in my model. If firm exits respond to energy prices it might make the extensive margin even more sensitive to energy price fluctuations and generate a bigger impact on GDP.

Table 1

Variable	Data Source/Series	VAR variables
Oil Price	FRED, BLS/WPU0561	$OIL = 100 * ln(ROP_t/ROP_{t-1})$
Entry	SCB/BLS	NE=$100 * ln(Entry_t/Entry_{t-1})$
Real GDP	BEA	$GDP = 100 * ln(GDP_t/GDP_{t-1})$
DEF	BEA Implicit GDP Deflator	$DEF = 100 * \ln(DEF_t/DEF_{t-1})$
Fed Funds rate	Board of Governors, FEDFUNDS	$ff = Federal\ Funds\ rate$

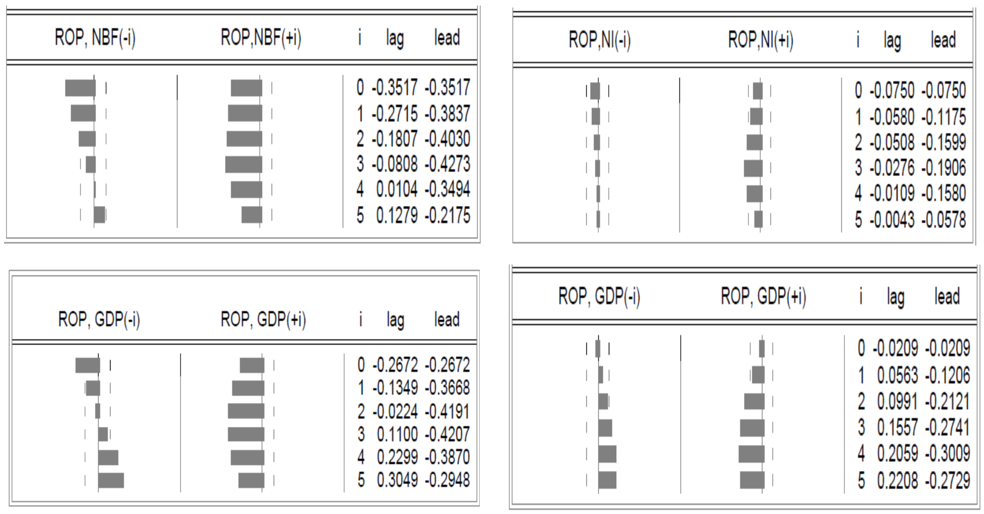
Table 2: Calibrated Parameters

Parameter	Value	Source	Interpretation
β	0.99	BGM(2012)	Discount factor
θ	3.8	BGM(2012)	Elasticity of substitution
φ	4	BGM(2012)	Frisch elasticity
χ	0.924271	BGM(2012)	Disutility of labor
f_e	1	BGM(2012)	Entry cost
α	0.9505	Author(2014)	Share of labor
δ	0.025	BGM(2012)	Exit shock
ϕ_z	0.978	BGM(2012)	Persistence of productivity shock
σ_{ε_Z}	0.0072	BGM(2012)	Standard deviation of productivity shock
σ_{m_Z}	0.127	Estimated	Standard deviation of energy price shock
ϕ_m	0.99	Estimated	Persistence of Energy Price Shock

Table 3

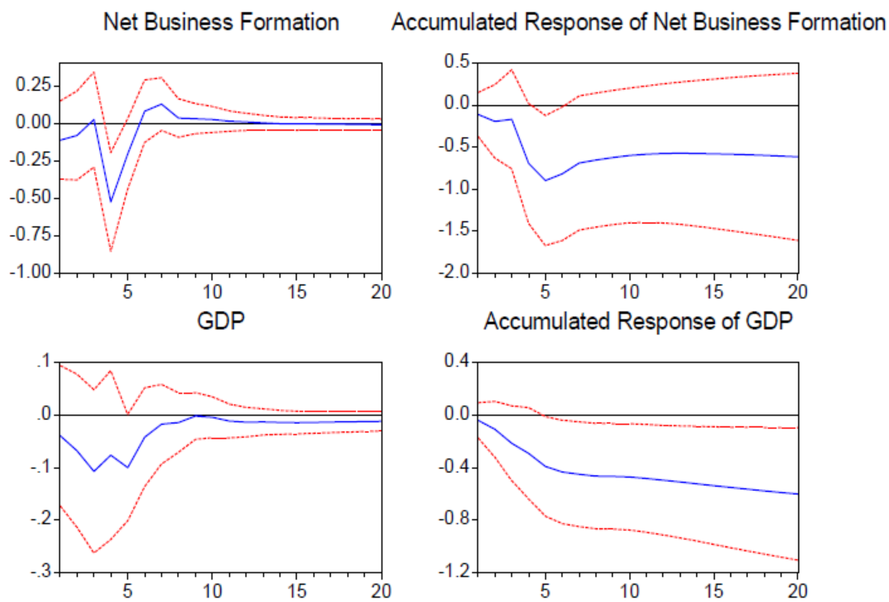
Correlations	Data (HP Filtered)	Data (Growth Rates)	Baseline DSGE
New Incorporations, Oil	0.07	0.05	-0.56
New Incorporations, GDP	0.56	0.24	0.95
Net Business Formation, Oil	-0.35	-0.12	-0.56
Net Business Formation, GDP	0.73	0.51	0.95

Figure 1



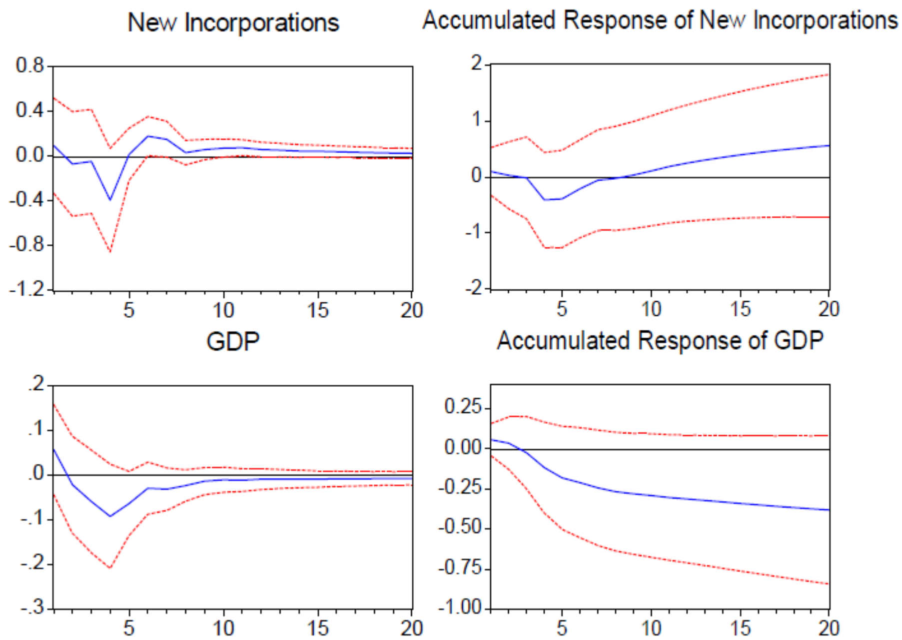
Note: The figures above represent cross-correlations of real oil prices (ROP) and the measures of entry such as Net Business Formation (NBF) and New Incorporations (NI). The cross-correlations with respect to GDP are also reported for the two datasets.

Figure 2. Impulse Responses to real oil price shock (VAR)



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 First column responses are the growth rates while the second column gives the accumulated responses.

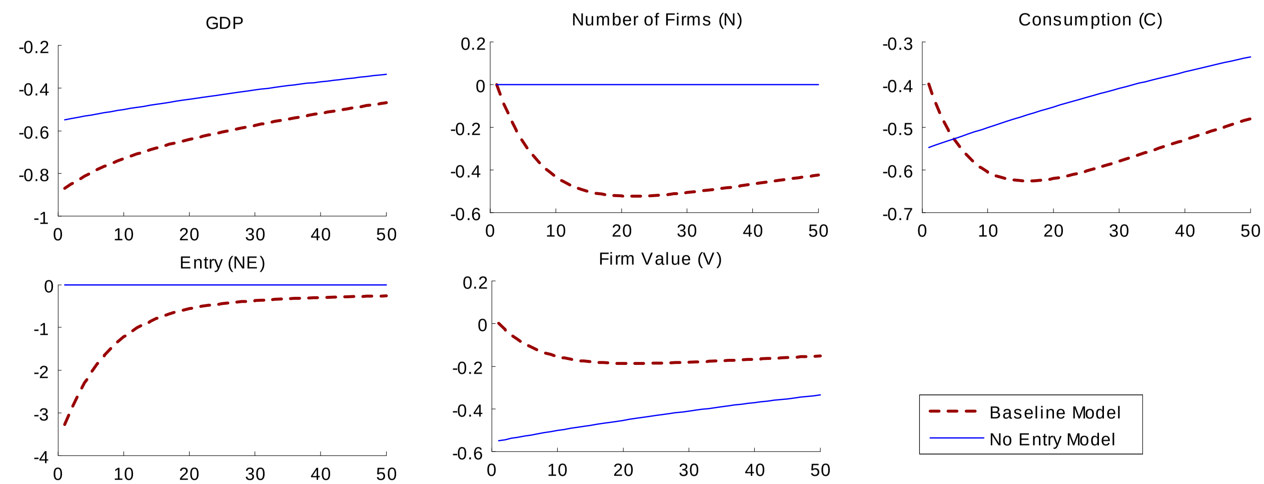
Figure 3. Impulse Responses to real oil price shock (VAR)



Notes: See notes to Fig 2.

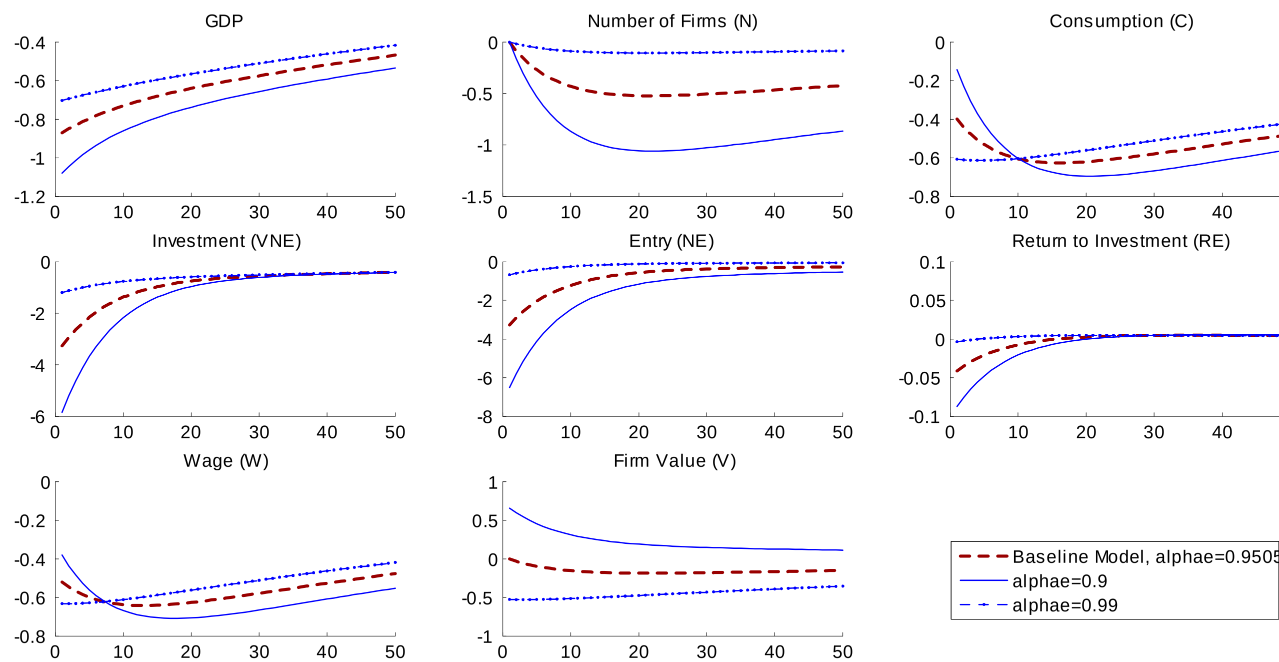
Note: See notes to Figure 2.

Figure 4: Impulse Responses to a 10% p_m shock Baseline Model versus No Entry model



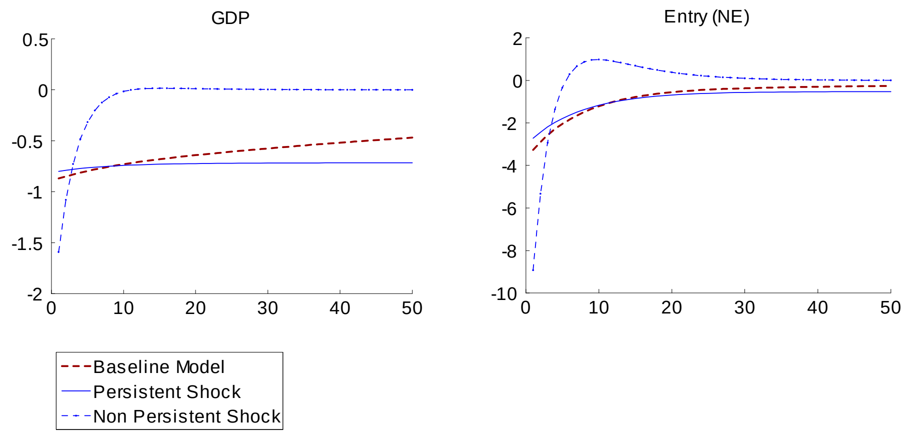
Note: All impulse responses are scaled to a 10 percent increase in energy prices. The horizontal axis represents time in quarters. The vertical axis shows percent deviations of variables from the steady state. The dashed line represents the baseline model while the solid line is the no entry model.

Figure 5: Impulse Responses to a 10% p_m shock Baseline Model versus Different Entry Intensities



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. The dashed line represents the baseline model (alpha=0.9505), The dotted line entry less energy intensive case (alphae=0.99) and the solid line represents the case when entry is more energy intensive (alphae=0.9)

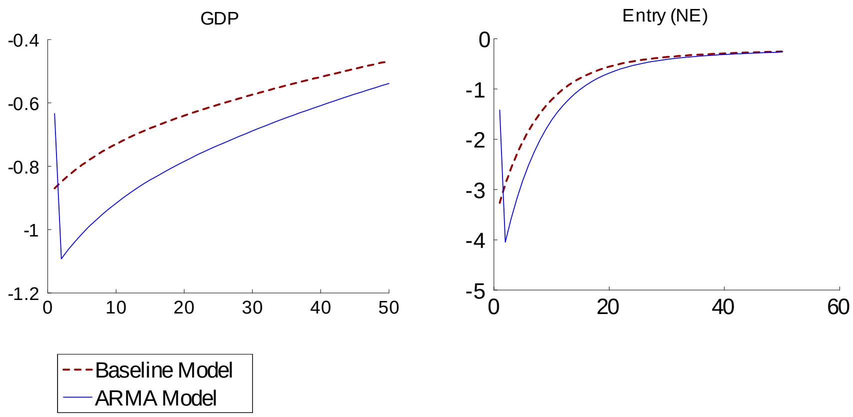
Figure 6: Impulse Response to a 10% p_m shock, Highly Persistent versus Non Persistent shock



Note: All impulse responses are scaled to a 10 percent increase in energy prices. The persistence of the energyprice shock is taken to be 0.9999 (solid line), 0.7 (dotted line) and 0.99 (dashed line) respectively.

Figure 7: Impulse Response to a 10% p_m shock,

ARMA Specification



Note: All impulse responses are scaled to a 10 percent increase in energy prices. The ARMA specification follows from Kim and Lougani (1992).

Notes

[1]Sunk costs and lag to build help generate procyclical profits in contrast to frictionless entry models. In addition, it captures the fact that the number of firms is fixed in the short run as in BGM (2012). Models with instantaneous entry and no sunk costs cannot address the issue of both pro-cyclical profits and entry (Chatterjee and Cooper, 1993, Devereux, Head and Lapham, 1996). In these models, free entry drives profits to zero every period. Since rising energy costs have a direct impact on profits and the entry mechanism, I follow the BGM (2012) approach.

[2]The entry series is constructed from New Business Incorporations from Economagic (1959: II-1993: II) and from Private Sector Births from Bureau of Labor Statistics (1993: III-2013: IV). The Net Business formation data is from Survey of Current Business. The source of data and transformations are given in Table 1. The monthly data series was converted to quarterly series by aggregating over three months for New Incorporations while for the Net Business formation index three month average is used.

[3]All the series are logged and HP filtered. The reported correlations are the correlations between the deviations from trend for the two series.

[4]The data runs from 1959: II-2013: IV for New Incorporations and from 1954: III-1994: IV for Net Business Formation. The first correlation which is calculated over the longer dataset is insignificant at 95% level while the second correlation is significant.

[5]This correlation is not significant at the 95% level. This may be due to higher responsiveness of Net Business Formation to shocks in general or due to increased resilience of the U.S. economy in recent years.

[6]Note: Pretesting in VARs lead to impulse response estimates that have lower coverage rates and larger MSEs than a VAR in levels. For a comparison of the advantages and disadvantages of pretesting vs. running a VAR in levels see Gospodinov, Herrera and Pesavento, 2013.

[7]Running a VAR with growth rate of Federal Funds rate does not significantly alter the results.

[8]I identify oil shocks in terms of real oil prices for comparison with results in theoretical models. The results are very similar when nominal oil prices are used instead. The nominal oil price series

is the Spot Oil Price (WTI Series) available from FRED. Real oil prices are calculated by dividing the nominal oil price series by the GDP deflator.

[9]The first variable in the VAR is the real price of oil followed by the federal funds rate, Entry, GDP and GDP deflator in the Cholesky ordering.

[10]Only Entry and GDP responses are shown in the paper.

[11]I follow the same ordering scheme as above for this VAR, except entry is measured as New Incorporations.

[12]Since there is a one-to-one correspondence between firms and products, the model can also be interpreted in terms of firm entry or creation of new products. The second interpretation allows for contribution of product creation and destruction over the business cycle.

[13]Since there are no fixed costs of production, all entering firms continue producing till they are hit by the exogenous death shock.

[14]See Melitz (2003). The exit shock is exogenous in this model. If firm exits respond to shocks, we may get an even bigger amplification for oil price shocks. For models with both endogenous entry and exit see Patra (2016). In terms of the literature, there is conflicting evidence as to whether exit is countercyclical or acyclical.

[15]This implies the oil producing country does not produce any consumption goods and their only source of income is the earnings from oil production. See Backus & Crucini (2000) for a similar approach.

[16]Investment on the intensive margin can be included by including capital in the model. However inclusion of capital may allow for another intertemporal reallocation channel and dampen the impact of shocks on entry.

[17]The empirical section demonstrates the possibility of a unit root in the real oil price series. Given that the focus of this paper is to capture the effect of oil prices on firm entry and the resulting amplification effect on output, the stationarity assumption is made for tractability.

[18]For this estimation, I fit a AR (1) model to logged real oil price data.

[19]I use Dynare to obtain the numerical results.

[20]For brevity, the impulse responses and model dynamics for the productivity shock are not

discussed in the paper. However comparison of model generated impulse responses from the two shocks show that the energy price shocks act like a negative productivity shock which is consistent with the approach in the existing literature.

[21]This can be easily seen by substituting for λ_t^p from equation 3, I can then write $v_t = fe\frac{\rho_t}{\mu}$.

[22]In the data, the persistence of oil price shocks varies from 0.9-0.99 depending on the sample period. I also do not find a significant change in persistence of the oil price series for the sample.

[23]The model is robust to different specifications of the production function. Changing the production function to a CES form generates impulse responses which are qualitatively very similar to the baseline results. For this exercise, I set the substitution parameter between energy and labor to be 0.75. The calibrated value of α is set to be 0.9788 so that the share of energy expenditure is the same as in the baseline Cobb-Douglas case (4 percent). The main difference between the CES and the Cobb-Douglas production functions is that the drop in energy imports is less than proportional in the CES case. But this difference is insignificant here due to the small share of energy in value added.

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6.1 Appendix:

6.1.1 Steady State: Baseline Model

I assume productivity and the real price of energy are constant in the steady state, $Z_t = Z,\ p_{mt} = p_m$. From the Euler equation I get $d/v = \frac{r+\delta}{1-\delta}$ (using $\beta = 1/(1+r)$) where r is the steady state interest rate. Gross return (re) on shares can be defined as $1 + d/v = \frac{1+r}{1-\delta}$. The law of motion for firms gives $N_e = \frac{\delta}{1-\delta}N$, which implies number of successful entry must equal exits to keep the number of firms constant in the steady state. Equation (8) I gives us the share of profit in manufacturing output $\frac{dN}{Y^c} = (1 - \frac{1}{\mu}) = \frac{1}{\theta}$. Share of investment in manufacturing output is $\gamma = \frac{vN_e}{Y^c} = (1 - \frac{1}{\mu})\frac{\delta}{r+\delta} = \frac{1}{\theta}\frac{\delta}{r+\delta}$ (from the last two results). Share of entry energy expenditure in manufacturing output is given as $\frac{p_m M_t^e}{Y^c} = (1-\alpha)\frac{vN_e}{Y^c} = (1-\alpha)\gamma = (1-\alpha)\frac{1}{\theta}\frac{\delta}{r+\delta}$. The share of manufacturing energy expenditure in manufacturing is given as $\frac{p_m M_t^c}{Y^c} = \frac{(1-\alpha)}{\mu}$. The Ratio of total energy expenditure to manufacturing output is given as $\frac{p_m M}{Y^c} = (\frac{1}{\mu} + \gamma)(1-\alpha)$. The share of consumption in manufacturing output is given as $\frac{C}{Y^c} = \left[1 - (\frac{1}{\mu} + \frac{1}{\theta}\frac{\delta}{r+\delta})(1-\alpha)\right]$. $\frac{C}{Y} = \frac{1}{(1+\gamma)}\frac{C}{Y^C} = \frac{1}{(1+\gamma)}\left[1 - (\frac{1}{\mu} + \frac{1}{\theta}\frac{\delta}{r+\delta})(1-\alpha)\right]$ is the share of consumption in gross output, $\frac{vN_e}{Y} = \frac{\delta}{\delta+\theta(r+\delta)}$ is share of investment in gross output. $\frac{dN}{Y} = \frac{r+\delta}{\delta+\theta(r+\delta)}$ is the share of profits in gross output , $\frac{wL}{Y^c} = (\frac{1}{\mu} + \gamma)\alpha$ is the share of labor income in manufacturing output. $\frac{wL}{Y} = \frac{\alpha}{(1+\gamma)}\left(\frac{1}{\mu} + \gamma\right)$ is the share of labor income in gross output . $\frac{p_m M}{Y} = \frac{1}{(1+\gamma)}(\frac{1}{\mu} + \gamma)(1 - \alpha)$ is the share of energy expenditure in gross output.