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What determines the output drop after an energy price increase: Household or firm energy share?☆

Rajeev Dhawan [a], Karsten Jeske [b,*]

[a] J. Mack Robinson College of Business, Georgia State University, P.O. Box 3988, Atlanta, GA 30302, United Sates
[b] Mellon Capital Management, Investment Research, 50 Fremont Street, Suite 3900, San Francisco, CA 94105, United States

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ABSTRACT

We investigate a DSGE economy's response to energy price hikes for changing firm and household energy shares over the 1970–2005 period. Simulation results indicate that the economy's output response is mainly determined by the firm rather than the household share.

1. Introduction

We motivate our research by the fact that during the past 35 years energy use as a fraction of output has dropped by 25% for households and 36% for firms.[1] We set up a dynamic stochastic general equilibrium (DSGE) model to study the magnitude of output drop to an energy price shock for different energy shares for firms and households. Simulation results indicate that the magnitude of the economy's output response to energy price shocks is mainly determined by the firm energy share. In fact, keeping firm energy share constant, increasing the household energy share actually decreases the output response. Thus, a normative implication is that if policy makers are concerned about output fluctuations from energy price shocks, encouraging a reduction in the energy share on the production, rather than the household side, ought to be their primary concern. This challenges the efforts of the current U.S. energy policy that focuses on reducing household energy use, for example through tighter passenger car fuel efficiency standards. Additionally, we find that a model with higher energy use calibrated to the 1970–1985 period generates slightly higher output responses to an energy price hike, but still not large enough to account for a sizeable share of output fluctuations, confirming the results of Kim and Loungani (1992).

2. Model

The model is identical to the one in Dhawan and Jeske (in press). Households consume non-durables and services excluding energy N, a service flow of durables D and household energy use E_h. They supply labor H and capital K to firms who combine them together with firm energy consumption E_f into output Y. Both household and firm energy consumption have to be purchased from abroad at relative price P.

Then the social planner's problem is:

$$\max E \sum_{t=0}^{\infty} \beta^t \left[\varphi \log N_t^{\gamma} \left(\theta D_{t-1}^{\rho} + (1-\theta) E_{h,t}^{\rho} \right)^{\frac{1-\gamma}{\rho}} + (1-\varphi) \log(1-H_t) \right]$$

subject to:

$$N_t + I_{d,t} + I_{k,t} + P_t \left(E_{h,t} + E_{f,t} \right) = Y_t - AC_t^d - AC_t^k \tag{1}$$

$$Y_t = Z_{y,t} \left(\eta K_{t-1}^{\psi} + (1-\eta) E_{f,t}^{\psi} \right)^{\frac{\alpha}{\psi}} H_t^{1-\alpha} \tag{2}$$

$$I_{d,t} = D_t - (1-\delta_d) D_{t-1}, I_{k,t} = K_t - (1-\delta_k) K_{t-1} \tag{3}$$

$$AC_t^d = \frac{\omega_d}{2} \left(\frac{D_t - D_{t-1}}{D_{t-1}} \right)^2, AC_t^k = \frac{\omega_k}{2} \left(\frac{K_t - K_{t-1}}{K_{t-1}} \right)^2 \tag{4}$$

☆ The views expressed here are not necessarily those of Mellon Capital Management.

* Corresponding author. Tel.: +1 415 267 6226; fax: +1 415 975 2301.
E-mail addresses: rdhawan@gsu.edu (R. Dhawan), karstenj@mcm.com (K. Jeske).

[1] We compute energy shares as nominal spending on energy divided by nominal GDP at annual frequency.

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Table 1
Calibration targets

	Entire period	Subperiod 1	Subperiod 2	Change:
	1970–2005	1970–1985	1986–2005	Subperiod 1 vs. 2
D/Y	1.3668	1.3582	1.3737	+1.14%
I_D/Y	0.0932	0.0927	0.0935	+0.82%
E_h/Y	0.0456	0.0529	0.0397	−24.87%
E_f/Y	0.0517	0.0646	0.0414	−35.84%

Source: Bureau of Economic Analysis, Energy Information Administration.

where I_d and I_k are investment in durables and fixed capital, respectively. AC_t^d and AC_t^k are quadratic adjustment costs to changing the stock of durable and fixed capital, respectively. Z_y is total factor productivity (TFP).

3. Calibration

One model period corresponds to one quarter in the data. Throughout this paper we assume that $\alpha=0.36$ and the time preference factor is $\beta=0.99$. We use $\psi=-0.7$ as in Kim and Loungani and set $\rho=-3.0$.[2] We keep the two calibration targets $K/Y=12$ and $H=0.3$ fixed. These two targets together with the remaining four targets D/Y, I_D/Y, E_h/Y, and E_f/Y pin down six remaining parameters γ, θ, η, φ, δ_d, δ_k.[3] In Table 1 we detail the average value of the four ratios during the entire period 1970–2005 and the two subperiods 1970–1985 and 1986–2005. The durables to output ratio (D/Y) and the investment in durables to output ratio (I_D/Y) were essentially unchanged between the two subperiods. Thus, we fix the targets for D/Y and I_D/Y at their average over the 1970–2005 period. However, the energy ratios E_h/Y and E_f/Y changed dramatically between the two subperiods. Hence, we create a grid over the E_h/Y and the E_f/Y targets (equal step size of 10 points) and simulate the economy for all possible combinations.

We assume that the energy price follows an ARMA(1,1) process.

$$p_t = \rho_p p_{t-1} + \varepsilon_{p,t} + \rho_\varepsilon \varepsilon_{p,t-1} \text{ with } \varepsilon_{p,t} \overset{\text{iid}}{\sim} N\left(0, \sigma_p^2\right), \tag{5}$$

with $\rho_p=0.9753$, $\rho_\varepsilon=0.4217$ and $\sigma_p=0.0308$ as in Dhawan and Jeske (in press).[4]

4. Numerical results

We compute the impulse response of output after a one standard deviation hike in energy price for alternative targets of energy shares. We plot the maximum drop in output in Fig. 1.[5] The energy shares E_h/Y and E_f/Y in the upper right corner represent the 1970–1985 subperiod and the lower left corner represents the 1986–2005 subperiod. First, notice that the impact on output is small across all calibrations. The maximum output drop after a one standard deviation shock to the energy price is below 0.3%. Thus, even a two-standard deviation shock to the energy price brings about an output drop of no more than 0.6 percentage points below steady state, hardly enough to cause a recession. Thus, energy shocks are not the prime cause for business cycle fluctuations as also found by Kim and Loungani (1992).

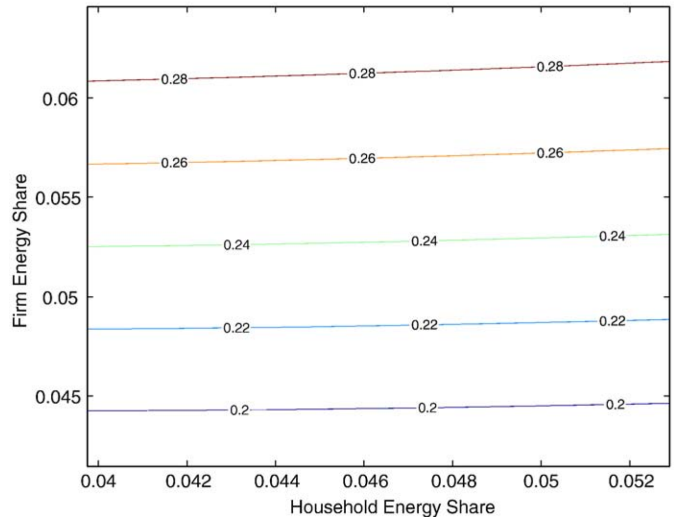

Fig. 1. Contour plot of maximum output drop after a one standard deviation hike in P. In percent.

We also find that it is solely the firm energy share that determines the energy shock impact. In fact, if we increase the household energy share we even slightly *decrease* the energy effect on output. To help understand this result, we pick three specific calibrations with different energy shares as listed in Table 2. Our benchmark calibration is for the economy with firm and household energy shares in the 1970 to 1985 time-period. Next, for calibration LF, we lower the firm energy share to match the average for the 1986–2005 subperiod. The third calibration, called LH, is the one with lower household energy use calibrated to the average in the 1986 to 2005 time-period.

In Fig. 2, we plot the impulse response functions (IRFs) to a one standard deviation shock to the energy price in the three alternative calibrations. Consistent with the observations from Fig. 1, the benchmark and the LH calibration have very similar output impulse response functions, while the LF calibration displays a much smaller impact on output.

Notice that the IRFs for I_d and I_k display a rebalancing effect: investment in durables drops substantially as a response to an energy price hike to allow for a smaller drop (or even a rise in the LF calibration) in fixed investment in the initial period. As pointed out by Dhawan and Jeske (in press), the source of the rebalancing effect is the difference in the energy to capital ratio between the firm and the household. That differential is most pronounced in the case of our second calibration LF when we lowered firm energy use.

Comparing the IRFs for firm energy use in the three alternative calibrations, we notice that the LF calibration displays the lowest percentage drop. In contrast, in the IRFs for household energy use, the percentage drop is the lowest in the LH calibration. One can call this a rebalancing effect of energy use: if the household energy share is high relative to the firm energy share, the representative household can more easily reduce the use of the more abundant energy component E_h.

Table 2
Energy shares

Calibration	Household	Firm
Benchmark: (energy shares as in 1970–1985)	0.0529	0.0646
LF: Lower E_f/Y (firm share as in 1986–2005)	0.0529	0.0414
LH: Lower E_h/Y (household share as in 1986–2005)	0.0397	0.0646

[2] This ρ generates a volatility of E_h close to that in the data. See Dhawan and Jeske (in press). Our results are robust for a variety of different ρ.

[3] See the appendix in Dhawan and Jeske (in press) for the details of the calibration exercise.

[4] The procedure to pin down adjustment cost parameters of Eq. (4) involves simulating the model with a TFP process as in Dhawan and Jeske (in press) to match the observed investment volatilities in the data. We do this in each of the 100 simulated economies because investment volatilities depend on the energy shares. We also conducted the simulations without adjustment costs and the results were qualitatively similar.

[5] We compute the IRFs with the software Dynare 3.0. See Collard and Juillard (2001) for the methodological details. Other measures, such as a discounted sum of the output drops or the output volatility from energy shocks yield the same qualitative results. See Dhawan and Jeske (2007).

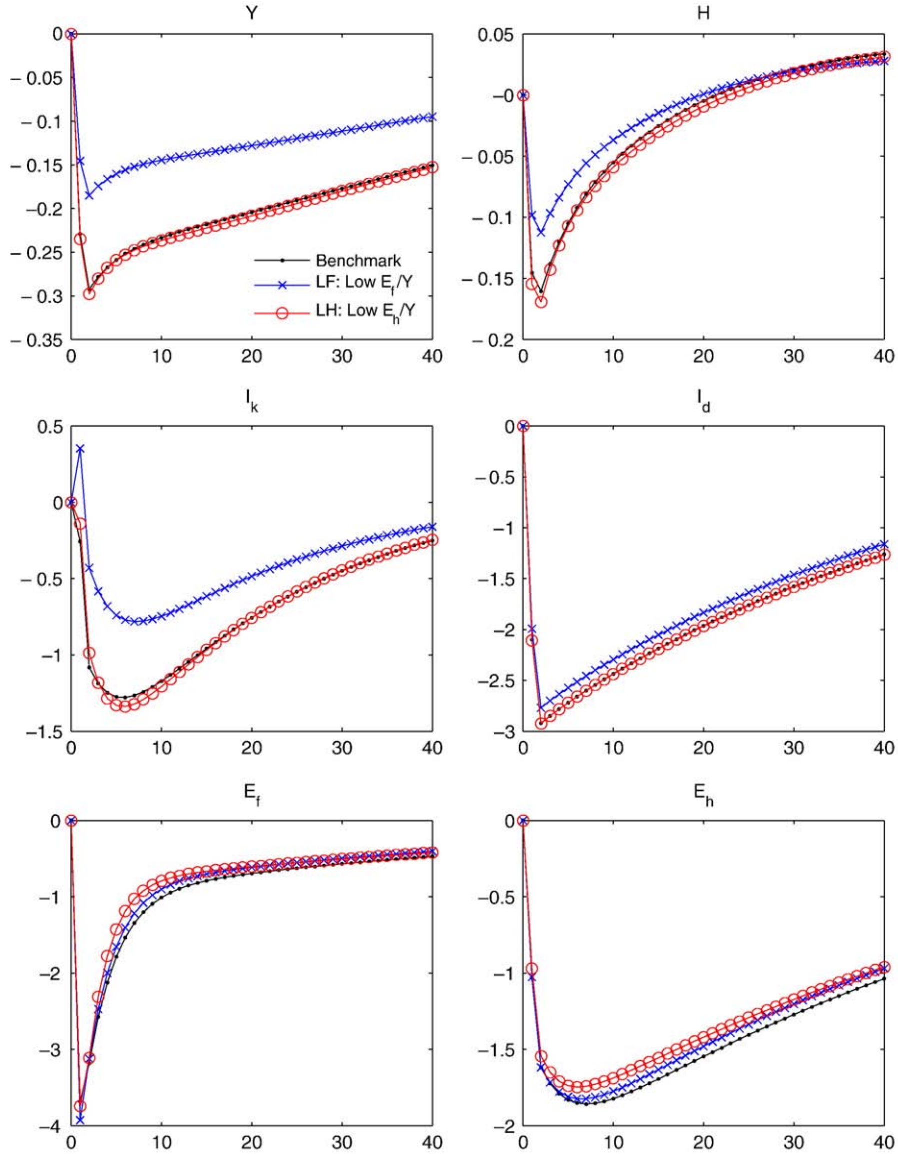

Fig. 2. Impulse responses to a one standard deviation hike to *P*. In percent.

To understand the differential drops in the IRFs, we decompose the output response into input components: hours worked, the capital stock and firm energy use. Assuming constant productivity we log-linearize the output Eq. (2):

$$y_t = \zeta_{\mathrm{h}} h_t + \zeta_{\mathrm{k}} k_{t-1} + \zeta_e e_{\mathrm{f},t} \tag{6}$$

where the small letters stand for the log-deviation from the steady state and

$$\zeta_{\mathrm{h}} = (1-\alpha), \zeta_{\mathrm{k}} = \alpha \frac{\eta K^{\psi}}{\eta K^{\psi} + (1-\eta) E_{\mathrm{f}}^{\psi}}, \; \zeta_e = \alpha \frac{(1-\eta) E_{\mathrm{f}}^{\psi}}{\eta K^{\psi} + (1-\eta) E_{\mathrm{f}}^{\psi}} \tag{7}$$

We plot the three components of Eq. (6) in Fig. 3. Initially, the energy component $\zeta_e e_{\mathrm{f},t}$ contributes the most to the output drop in all three calibrations, with calibration LF having the smallest impact. This happens because the drop in firm energy use (E_{f}) is lowest in the calibration LF (see Fig. 2), coupled with the fact that the parameter ζ_e is also smaller because of the lower energy to capital ratio.

In all three calibrations, the initial contribution from capital component ($\zeta_{\mathrm{k}} k_{t-1}$) is negligible, but over time the cumulative effect of the capital adjustment is substantial. After 40 quarters, capital's contribution is larger than those of hours worked and energy. The capital adjustment in the LF calibration is also much smaller than the benchmark calibration. This is despite the fact that the LF calibration, with a lower firm energy share compared to the benchmark, has a higher ζ_{k}. However, the LF calibration has a very strong rebalancing effect, which results in a lower drop in the capital stock than the benchmark and more than makes up for the higher ζ_{k}. Finally, hours worked contribute about 0.1 percentage points to the output drop in $t=2$ (roughly a third of the total) in both the benchmark case and the LH calibration and about 0.07 percentage points in the LF calibration.

Moreover, Fig. 3 shows that the larger output drop of the LH calibration is due to hours worked dropping slightly more than in the benchmark. In the LH calibration, firm energy use drops slightly more than in the benchmark, but its direct effect on output is very small — the lines for the LH economy and the benchmark in the lower panel of Fig. 3 are almost indistinguishable. However, the slightly larger drop in

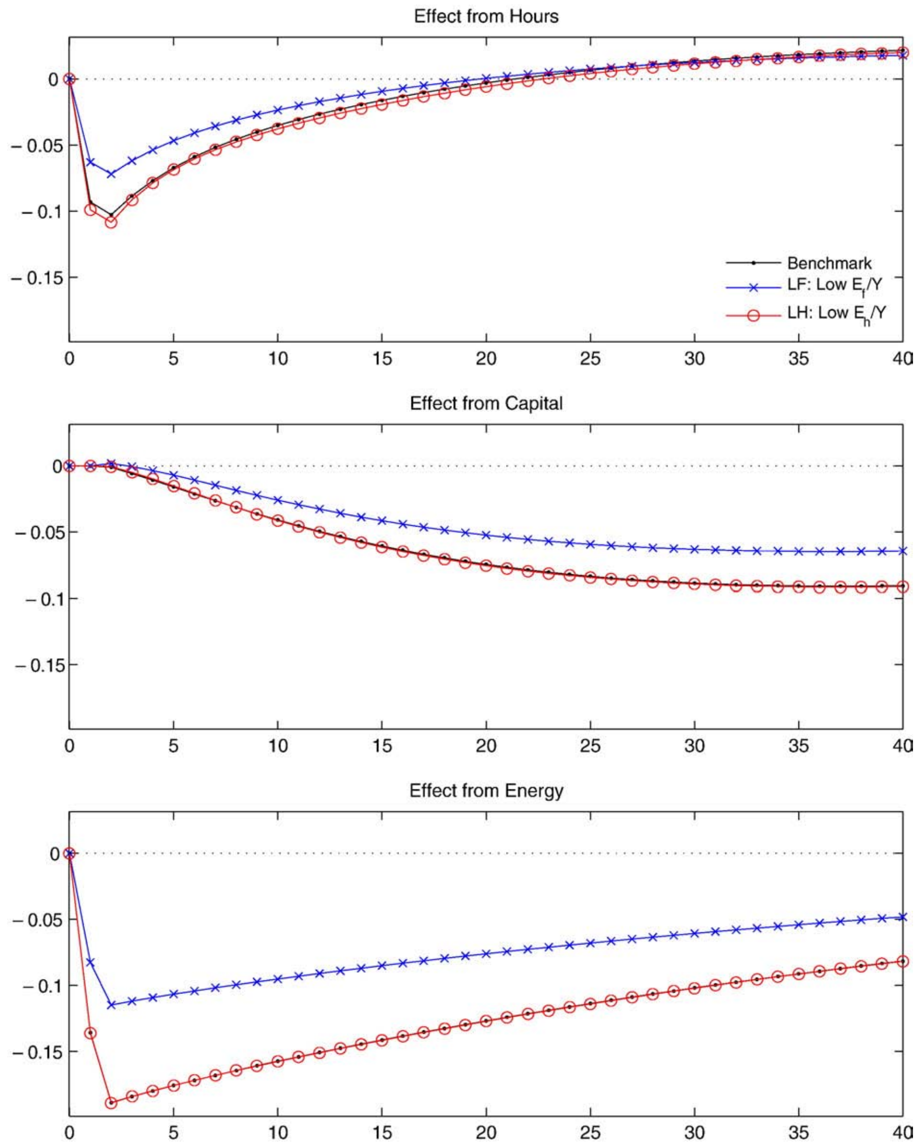

Fig. 3. Decomposing the output impulse response into its components. In percent.

firm energy use in the LH calibration is enough to lower the marginal product of labor which reduces the hours and resulting in a larger output drop.

5. Concluding remarks

Our simulations show that the impact of an energy price hike on output is mainly due to the firm energy share. Our output decomposition analysis indicated that this is the result of two forces. First, the direct effect by construction, is the share of energy in the production function. Second, is the rebalancing of energy use by the representative household, whereby the percentage drop in firm energy use is smaller when the energy share in the production function is lower. We also find that decreasing the household energy share slightly increases the impact of an energy price increase on output. This effect is due to a larger drop in hours in the economy with lower household energy use.

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