What Matters More for the Output Drop After an Energy Price Increase: Household or Firm Energy Share?*

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June 3, 2006

Abstract

We perform sensitivity analysis over the calibration targets for energy use in Dhawan and Jeske (2006). Our exercise is motivated by the fact that Dhawan and Jeske target average energy use over the 1970-2005 period, while the observed energy use relative to output declined rapidly over the period. We therefore investigate how different energy ratios affect the response to energy price shocks. Specifically, we compute how alternative energy use calibration targets affect the output drop in response to an energy price hike. 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, yet still not large enough to account for a sizeable share of output fluctuations. We also find that a larger steady state household energy share slightly decreases the negative impact on output from an energy price hike.

JEL codes: E32, Q43
Keywords: Energy Prices, Business Cycles, Durable Goods

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*The views expressed here are not necessarily those of the Federal Reserve Bank of Atlanta or the Federal Reserve System.

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1 Introduction

We perform sensitivity analysis over the calibration targets for energy use in Dhawan and Jeske (2006). Our exercise is motivated by the fact that Dhawan and Jeske target average energy use over the 1970-2005 period, while the observed energy use relative to output declined rapidly over the period. We therefore investigate how different energy ratios affect the economy's response to energy price shocks. Specifically, we compute how alternative energy use calibration targets affect the output drop in response to an energy price hike.

Our research is motivated by the fact that during the past 35 years, energy use as a fraction of output has dropped significantly both for households and for firms. For example, energy use by households dropped from an average 5.29 percent of output during 1970-1985 to 3.97 percent during 1986-2005 – a drop by about 25 percent. On the firm side the reduction in energy use is even more pronounced. In the earlier period firm energy use was 6.46 percent of output, compared to 4.14 percent in the later period, which is a drop by about 36 percent.

We set up a dynamic stochastic general equilibrium (DSGE) model with stochastic energy prices and energy use both on the firm and household side. The model is identical to that used in Dhawan and Jeske (2006). We then study the size of the output drop in response to energy price increases. Specifically, we study how sensitive the output drop is to targeting alternative energy shares for both firm and household energy use.

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, yet still not large enough to account for a sizeable share of output fluctuations. We also find that a larger steady state household energy share slightly decreases the impact on output from an energy price hike.

Our paper proceeds as follows: Section 2 introduces our model with durable goods, Section 3 explains the parametrization, Section 4 goes through the numerical results and Section 5 concludes.

2 Model

The model is identical to the one in Dhawan and Jeske (2006), though without investment adjustment costs. Households consume non-durables and services outside of energy N, a service flow of durables D and household energy use E. They supply labor H and capital K to firms who combines 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 we solve is:

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

subject to:

$$\begin{aligned}
N_t+D_t+K_t+P_t\left(E_{h,t}+E_{f,t}\right) &= Y_t+\left(1-\delta_d\right)D_{t-1}+\left(1-\delta_k\right)K_{t-1}-AC_t^d-AC_t^k && (1)\\
Y_t &= Z_{y,t}\left(\eta K_{t-1}^{\psi}+(1-\eta)\,E_{f,t}^{\psi}\right)^{\frac{\alpha}{\psi}}H_t^{1-\alpha} && (2)\\
AC_t^d &= \frac{\omega_d}{2}\left(\frac{D_t-D_{t-1}}{D_{t-1}}\right)^2 && (3)\\
AC_t^k &= \frac{\omega_k}{2}\left(\frac{K_t-K_{t-1}}{K_{t-1}}\right)^2 && (4)
\end{aligned}$$

where AC_t^d and AC_t^k are quadratic adjustment costs to changing the stock in durable and fixed capital, respectively.

3 Calibration

3.1 Preference and technology parameters

The calibration exercise follows Dhawan and Jeske (2006) very closely. 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 $\beta = 0.99$. As in Kim and Loungani we use $\psi = -0.7$ and set $\rho = -3.0$ which according to Dhawan and Jeske (2006) generates household energy use close to that found in the data. 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 parameters $\gamma, \theta, \eta, \varphi, \delta_d, \delta_k$. In Table 1 we detail the average value of the four ratios during the entire period 1970-2005 as well as the two subperiods 1970-1985 and 1986-2005:

The two ratios durables to output ratio D/Y and the investment in durables to output ratio I_D/Y were essentially unchanged between the two subperiods. In our experiments we therefore assume that the targets for D/Y and I_D/Y are fixed at their averages over the entire sample, namely, 1.3668 and 0.0932, respectively.

However, the energy ratios E_h/Y and E_f/Y changed dramatically between the two subperiods. Household energy use as a share of income dropped by about one quarter, while firm energy use dropped by one third. We create a grid over both the E_h/Y and the E_f/Y and simulate the economy for all possible combinations of grid points. Specifically, we use a grid with equal step

Table 1: Calibration Targets

	Entire period 1970-2005	Subperiod 1 1970-1985	Subperiod 2 1986-2005	Change: 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%
$E_h/Y + E_f/Y$	0.0973	0.1175	0.0812	−30.90%

Source: Dhawan and Jeske (2006), Bureau of Economic Analysis, Energy Information Administration.

size of 10 points for both energy shares, thus we simulate a total of 100 economies.

In order to calibrate six remaining parameters $\gamma, \theta, \eta, \varphi, \delta_d, \delta_k$ we match moments from the data to those generated in the model in steady state.

3.2 Stochastic processes for energy prices and productivity

We use the same stochastic processes as in Dhawan and Jeske (2006). We assume that log-TFP follows an AR(1) process:

$$z_{y,t} = \rho_z z_{y,t-1} + \varepsilon_{z,t} \tag{5}$$

where $\rho_z = 0.95$ and $\varepsilon_{z,t} \overset{iid}{\sim} N\left(0, \sigma_z^2\right)$ with $\sigma_z = 0.007$.

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

$$p_t = \rho_p p_{t-1} + \varepsilon_{p,t} + \rho_\varepsilon \varepsilon_{p,t-1} \text{ with } \varepsilon_{p,t} \overset{iid}{\sim} N\left(0, \sigma_p^2\right), \tag{6}$$

with $\rho_p = 0.9753$, $\rho_\varepsilon = 0.4217$ and $\sigma_p = 0.0308$.

3.3 Adjustment costs

We calibrate the adjustment cost parameters in order to generate the same volatility in investment in durables and fixed capital as in the data. This is the same methodology that Dhawan and Jeske (2006) use to calibrate the adjustment cost parameters. Notice that we have to calibrate adjustment cost parameters in each of the 100 economies, because investment volatilities clearly depend on the energy shares.[1]

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[1] We also simulate the economy in the absence of adjustment costs. Results were very similar to the ones we report in the next section.

4 Numerical Results

We use the stochastic perturbation method, i.e., log-linearization around the steady state, to approximate the dynamics of our economy. From the first order conditions in Dhawan and Jeske, we derive eleven conditions guiding the dynamic behavior of eleven variables N, D, E_h, H, W, E_f, K, R, Y, I_D, I_K plus two equations for the shocks. We then run the program Dynare Version 3.0 to generate a first order approximation for the policy function (see Collard and Juillard (2001) for the methodological details).

We study how an energy price shock affects output under the alternative targets for the energy shares on the household and firm side. We use three alternative measures to study the output effect:

1. The maximum drop in output. We measure drop of output following an energy price increase.

2. The average drop in output. As a measure of the average output loss we use:

$$L^y = \frac{\sum_{t=1}^{\infty} \beta^{t-1} \left(\exp\left(\tilde{y}_t\right) - 1\right)}{\sum_{t=1}^{\infty} \beta^{t-1}} = (1-\beta) \sum_{t=1}^{\infty} \beta^{t-1} \left(\exp\left(\tilde{y}_t\right) - 1\right) \tag{7}$$

   where $\tilde{y}_t$ is the impulse response function, i.e., the log deviation from the steady state. One can think of L^y as translating the time-varying output loss in the impulse response function into one constant permanent loss in every period.

3. The output volatility due to energy price shocks. We switch off the stochastic process for productivity and simulate the economy subjected to energy price shocks alone. We then simulate the 1000 economies of length 144 quarters each (which is the same length as the interval 1970Q1-2005Q4) and compute the average output volatility over the 1000 simulations.

We plot our results in Figure 1. The three panels in that figure are contour plots of the three alternative measures. 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 values are as in the 1986-2005 subperiod.

For all three alternative measures, we 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 when we examine the slope of the contours.

To understand this artifact we analyze three calibrations with different energy shares as listed in Table 2. For our benchmark calibration we pick the economy with energy shares on both the

Table 2: Energy Shares

	Energy share	
economy	Household	Firm
Benchmark: (energy shares as in 1970-1985)	5.29%	6.46%
LF: Lower E_f/Y (firm share as in 1986-2005)	5.29%	4.14%
LH: Lower E_h/Y (household share as in 1986-2005)	3.97%	6.46%

firm and household side at the upper right corner in Figure 1, which represents the share values in the 1970 to 1985 time-period. Next, we lower the firm energy share to match the average for the subperiod 1986-2005 (lower right corner in Figure 1). We call this economy LF. The third calibration, called LH, is the one with lower household energy use calibrated to the average in the 1986 to 2005 period (upper left corner in Figure 1)

We plot the impulse response functions to a one standard deviation shock to the energy price in the three alternative calibrations in Figure 2. Consistent with the observations from the Figure 1, the benchmark and the LH economy have very similar output impulse response functions, while the LF economy displays a much smaller impact on output. We also notice that the rebalancing effect between durable and fixed investment is more pronounced in the LF economy. This happens because as Dhawan and Jeske (2006) pointed out, 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 impulse response functions for firm energy in the three alternative calibrations, we notice that the economy LF displays the least percentage drop. In contrast, in the impulse response function for household energy use, the percentage drop is the lowest in the LH economy. This is because of the curvature of both the utility and production function whereby the social planner can more easily reduce the use of the more abundant energy component.

To further analyze the source of the differences between the output IRFs we decompose the output response or production function into its components: hours worked, capital stock and firm energy use. Specifically we can write the output deviations from steady state as:

$$\tilde{y}_t = z_{y,t} + \zeta_h \tilde{h}_t + \zeta_k \tilde{k}_{t-1} + \zeta_e \tilde{e}_{f,t} \tag{8}$$

where the tilde stands for the log-deviation from steady state and the ζ are:

$$\zeta_h = (1-\alpha)\,,\; \zeta_k = \alpha\frac{\eta}{\eta + (1-\eta)\left(\frac{E_f}{K}\right)^{\psi}},\; \zeta_e = \alpha\frac{(1-\eta)\left(\frac{E_f}{K}\right)^{\psi}}{\eta + (1-\eta)\left(\frac{E_f}{K}\right)^{\psi}} \tag{9}$$

We plot the three components in Figure 3. As we saw in the IRFs in Figure 2, the LF economy displayed a lower drop in output than the benchmark. Most of this difference is due to the energy component $\zeta_e\tilde{e}_{f,t}$. As mentioned before the drop in energy is lowest in economy LF, but in addition to that, the parameter ζ_e is also smaller because of the lower energy to capital ratio.

The contribution from capital is negligible initially, but as time goes by the cumulative effect of the capital adjustment is substantial. After 40 quarters the contribution from capital is larger than those of hours worked and energy in all the three calibrations. The drop due to capital in the LF economy is also much smaller than the benchmark, which is consistent with the strong rebalancing effect for LF mentioned earlier. Finally, hours worked contribute about 0.1 percentage point drop in output (when $t = 2$) both in the benchmark case and the LH economy, and is about 0.07 percentage points in the LF economy. Additionally, notice that the drop in hours explains why in the LH economy the output drop is slightly larger than in the benchmark case.

5 Conclusion

In our paper Dhawan and Jeske (2006), we calibrate the model economy to match the energy shares observed in the data between 1970 and 2005. However, the energy share on both the household and firm side dropped significantly over this period. In this current paper we study how our model economy behaves under alternative calibrations for the household and firm energy ratios corresponding to different sub-periods of the data.

We find that the impact of the energy price on output is mainly driven by the firm energy share. Ceteris paribus, the lower the steady state firm energy share, the lower is the impact on output from an oil price shock. This is true for the all the three measures of output impact we use. The result is due to two effects. First, the percentage drop in firm energy use as a response to a rise in the energy price is less pronounced. Second, the impact of a drop in firm energy use is less severe as it has a lower share in the production function.

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 less household energy use.

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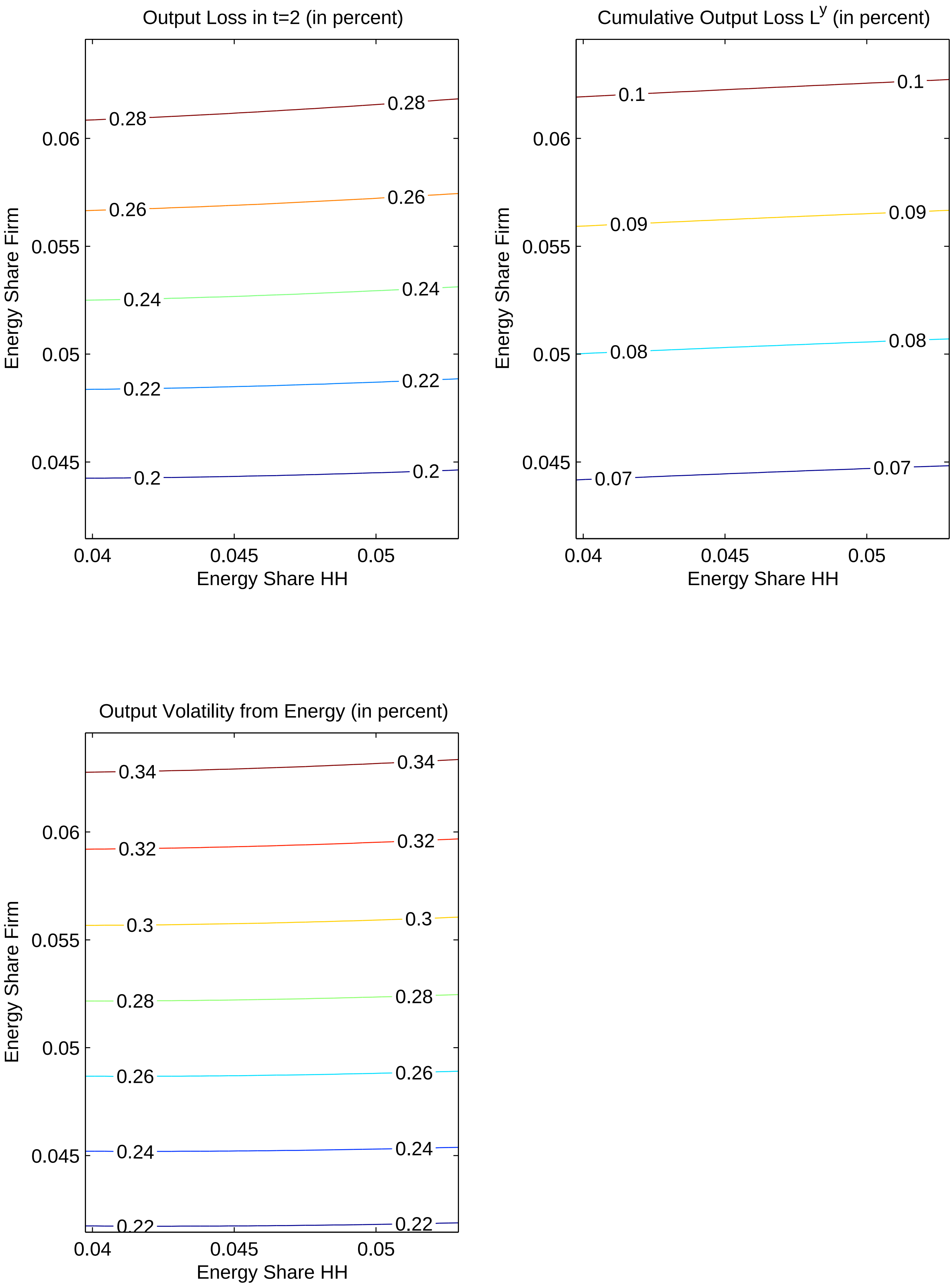
Figure 1: Effect of energy price shocks on output


Output Loss in t=2 (in percent)

Cumulative Output Loss L^y (in percent)

Output Volatility from Energy (in percent)

Figure 2: Impulse Responses to a one standard deviation shock to P. In percent.

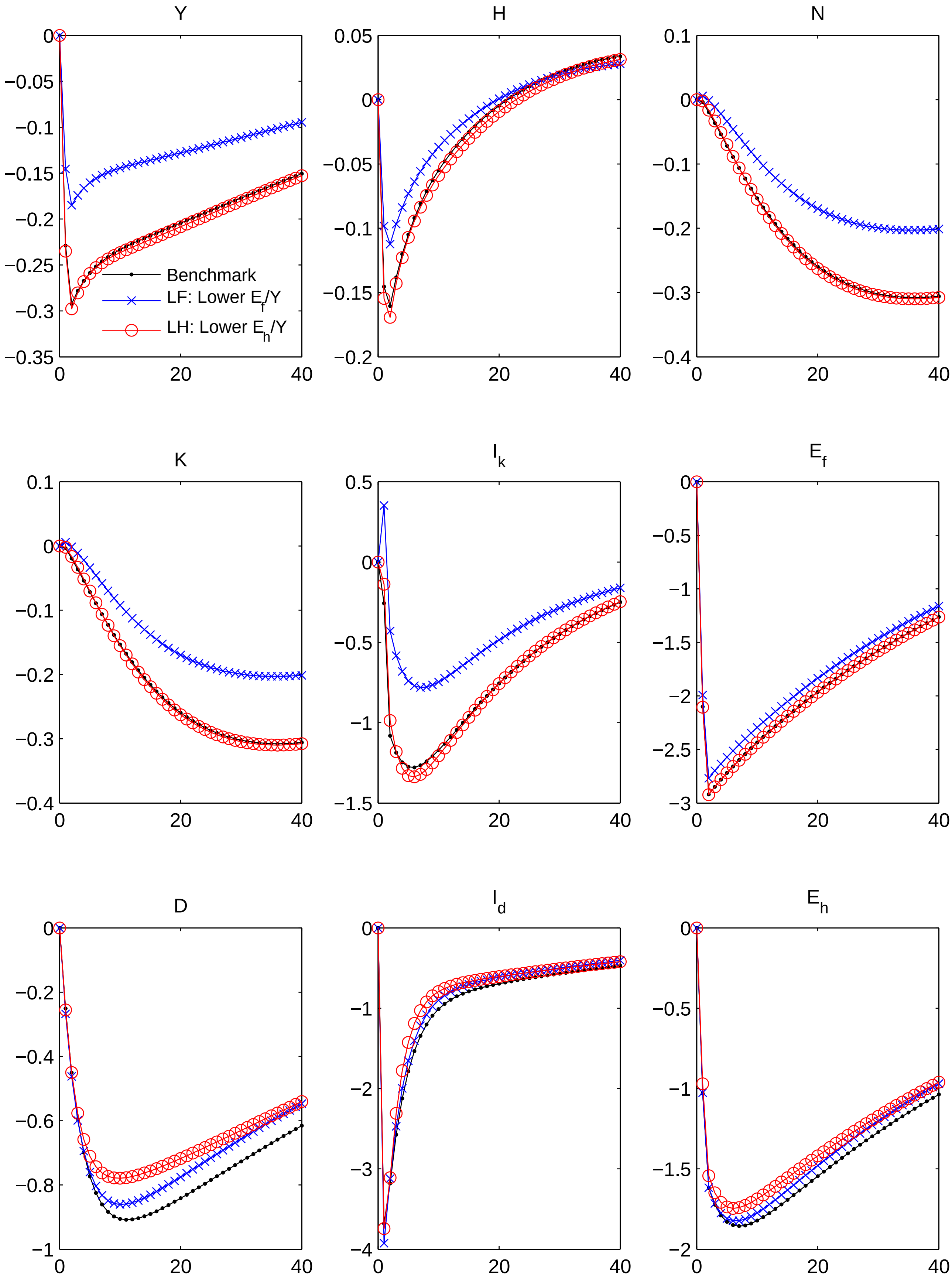


Figure 3: Decomposing the output impulse response into its components: hours worked, capital stock and energy use. For easier comparison we used the same scale in the three charts. In percent.