Effect of energy price increases on economic activity

Macroeconomics II

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Abstract

Energy price increases have long been recognized as potential shocks to economic activity, often leading to significant contractions. This literature review explores the macroeconomic implications of energy price increases within the framework of perfect competition theory. Drawing on the work of Mary G. Finn in her paper "Perfect Competition and the Effects of Energy Price Increases on Economic Activity," the review critically examines the modeling assumptions, mechanisms, and main results presented in Finn's analysis, providing a critical analysis of Finn's model, discussing its strengths, limitations, and implications for macroeconomic theory.

Keywords: Energy prices, technology shocks, perfect competition, economic activity

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1 Introduction

Economists have for long been interested in the empirical evidence of the relationship between energy price shocks and macroeconomic performance. In fact, energy price increases have historically been associated with significant economic disruptions, starting from the oil crisis of 1974 to the more recent energy crisis in Europe. The oil crisis of 1974, triggered by geopolitical tensions and supply disruptions, sent shockwaves through the global economy, leading to soaring energy prices and widespread economic turmoil. More recently, Europe has faced its own challenges with energy supply disruptions, highlighting the vulnerability of economies to fluctuations in energy markets, especially when supply is not diversified and it is subject to geopolitical tensions.

These events have highlighted the profound impact that fluctuations in energy prices can have on economic activity, starting from higher inflation to lower productivity and lower economic growth, prompting extensive research into understanding the underlying mechanisms and implications for macroeconomic theory. Moreover, energy price shocks can amplify business cycle fluctuations and pose challenges for monetary and fiscal policy in stabilizing the economy.

The focus of this paper is on exploring how changes in energy prices influence economic activity, how this relationship is modeled in macroeconomic activity and how this mechanism works. To shed light on this complex relationship we turn to the work of Mary G. Finn (2000) and her paper "Perfect Competition and the Effects of Energy Price Increases on Economic Activity", examining how the effects of energy price increases on declines in U.S. output and real wages can be explained also within the framework of perfect competition theory, challenging previous assumptions by Rotember and Woodford (1996) that only imperfect competition adequately explain these effects.

Our analysis will discuss Finn’s modeling approach and assumptions, we will look at the paper's main result and assess its strengths and limitations, comparing it to alternative theoretical frameworks. Finally we will discuss the broader implications of Finn’s findings for macroeconomics theory and how it has contributed to more recent literature in the matter.

2 Research Question

With the recent Russian invasion of Ukraine and the closure of Nord Stream 1 pipeline announced by Russia on August 19, 2022, Europe has faced an unprecedented energy crisis, questioning the structure of its energy supply, especially concerning its major consumers, Germany, France, and Italy.

In this context, it is important to examine the various studies conducted on the effects of an increase in energy prices on an economy. The link between rising energy prices and economic activity has long posed an interpretational problem. Despite representing a small share of a country's production, its effects are durable and significant.

Following the study "Invariance properties of Solow’s productivity residual," Robert E. Hall (1988) observed that the Solow residual (a standard measure of technology) tends to decrease with rising energy prices. This allows interpreting an energy price shock as a negative technological shock.

In 1991, Mary G. Finn developed a perfect competition model ("Energy price shocks, Capacity utilization and Business cycle fluctuations") differing from classical models such as those of Rasche and Tatom (1981) by transmitting energy price shocks through endogenous fluctuations in capital utilization and the flow of capital services entering the production function. In other words, here, energy is necessary for capital utilization. Imposing this model on American data would provide a "true" measure of technological growth different from the Solow residual.

The main breakthrough was made by Rotemberg and Woodford (RW) in 1996 with "Imperfect Competition and the Effects of Energy Price Increases on Economic Activity," explaining that by modifying the standard neoclassical growth model, assuming imperfect competition, the effects of an oil shock on real wages and production are easier to explain and of plausible magnitude. However, a theory of perfect competition seems inconsistent for them in explaining these phenomena.

Through this study, Mary G. Finn attempts to show that the conclusions reached by Rotemberg and Woodford are also applicable to her perfect competition model developed in 1991. This new approach will thus capture the widespread and intuitive idea that an increase in energy prices acts as a negative technological shock, inducing a contraction in economic activity, and demonstrate quantitative consistency with American data regarding the correlations between the Solow residual and energy prices.

3 Modeling Assumptions and Mechanism

The economy developed in the model produces a final good invested and used to purchase energy from abroad based on three factors: labor, capital, and energy.

Several assumptions are also in place:

Capital, which, as explained earlier, varies endogenously, is never fully utilized due to energy costs and depreciation. Households are all identical and own identical firms. Markets are perfectly competitive.

The firm:

We have a representative firm maximizing its profit subject to its production function:

$$\max_{(l_t, k_t u_t)} \pi_t = y_t - w_t l_t - r_t k_t u_t$$

subject to the production function:

$$y_t = F(z_t l_t, k_t u_t) = (z_t l_t)^{\theta} (k_t u_t)^{(1-\theta)},\ 0 < \theta < 1 .$$

Here, we denote *ku(t)* as the capital services, defined as the product of the beginning-of-period capital stock (k) and the capital utilization rate (u) during the period t. Additionally, we have z as the exogenous technology variable and θ as the parameter representing the labor share in production. The function F is a neoclassical production function with the only difference being the inclusion of u.

The household:

The representative household has the following preferences:

$$E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, l_t), \quad U(.) = \frac{\left[c_t^{\varphi}(1-l_t)^{(1-\varphi)}\right]^{(1-\alpha)} - 1}{(1-\alpha)},$$

$$0 < \beta, \varphi < 1, \quad \alpha > 0$$

With utility exhibiting standard characteristics, increasing with consumption and decreasing with labor time.

The household invests a portion of the final output in capital formation each period, as stipulated by the following motion law, which features a variable depreciation rate to capture an acceleration of depreciation with the capital utilization rate u:

$$k_{t+1} = (1-\delta(u_t))k_t + i_t, \quad \delta(u_t) = \frac{\omega_0 u_t^{\omega_1}}{\omega_1},$$

$$0 < \delta(.) < 1, \omega_0 > 0, \omega_1 > 1,$$

Now, it's appropriate to explain the role of energy in this model. The basic premise is that energy complements the flow of capital services in the following manner :

$$\frac{e_t}{k_t} = a(u_t), \quad a(u_t) = \frac{\upsilon_0 u_t^{\upsilon_1}}{\upsilon_1}, \quad \upsilon_0 > 0, \upsilon_1 > 1$$

Here, *e(t)* represents the usage of energy and its relationship with capital is symbolized by the function *a(ut)*, which states that the more capital is utilized, the more energy is used (at an increasing rate). The costs of capital utilization are now clearly stated: energy costs and depreciation costs prevent full utilization of capital. If the energy cost margin were absent, energy usage would be absent from the model. If capital depreciation were constant as in a classical model, the transmission of energy fluctuations would be limited to a single channel of direct production function, as in the Rotemberg and Woodford model :

$$y_t = (z_t l_t)^{\theta} \left[k_t^{\left(1-\frac{1}{\upsilon_1}\right)} e_t^{\frac{1}{\upsilon_1}} \left(\frac{\upsilon_1}{\upsilon_0} \right)^{\frac{1}{\upsilon_1}} \right]^{(1-\theta)}$$

Here, the energy relationship has been integrated into the production function to better illustrate this direct production function channel of energy.

The indirect channel, captured by the depreciation factor, thus represents the main difference between this model and previous studies.

The final constraint on the household is its budget constraint :

$$w_t l_t + r_t k_t u_t = c_t + i_t + p_t e_t$$

With p being the relative price (exogenous, potentially determined in a global market) of energy.

The problem of the representative household is thus to maximize its intertemporal utility by choosing its consumption, the labor it provides, the capital invested, and its capital utilization.

Competitive equilibrium:

Competitive equilibrium is achieved when firms and households optimize their decisions and all markets reach a state of equilibrium. This equilibrium is implicitly defined by the capital motion law, the energy relationship, and subsequent equations.

$$-U_2(c_t, l_t) = U_1(c_t, l_t) w_t . \qquad w_t = F_1(z_t l_t, k_t u_t) z_t .$$

$$\delta'(u_t) k_t + p_t a'(u_t) k_t = r_t k_t . \qquad r_t = F_2(z_t l_t, k_t u_t) .$$

$$U_1(c_t, l_t) = \beta E_t U_1(c_{t+1}, l_{t+1}) [r_{t+1} u_{t+1} + (1 - \delta(u_{t+1})) - p_{t+1} a(u_{t+1})] .$$

$$y_t = F(z_t l_t, k_t u_t) = c_t + i_t + p_t e_t .$$

Notably, wages and rents are equal to their respective marginal productivities, as are the various first-order conditions (FOCs) and the economy's resource constraint obtained by including the wage and rent functions in the budget constraint. Thus, production is entirely absorbed by consumption, investment, and energy purchases, with pe interpreted as the value added of y per unit of energy from the rest of the world.

By specifying the economy in competitive equilibrium, the effect of an increase in energy prices on the economy is now interpretable.

A positive shock to energy prices would therefore lead to a decrease in energy (e) and capital utilization (u). This reduction in energy levels would, in turn, result in a decline in production (y), labor productivity, and thus wages (w). The decrease in wages logically leads to a reduction in the quantity of labor (l). Moreover, as the effects of the increase in (p) persist, future marginal productivity of capital also declines, inducing reductions in investment (i) and capital (k) : $P\nearrow$ $e\searrow$ $u\searrow$ $y\searrow$ $w\searrow$ $l\searrow$ .... $i\searrow$ $k\searrow$.

The effects associated with the indirect channel, meanwhile, will further accentuate the reductions in investment and capital.

Calibration and results :

Regarding the quantitative aspect of the results obtained, the calibration method, pioneered by Kydland and Prescott (1982), involves assigning specific values to the model's parameters and variables when they are stable, as well as to the process (p). Some of these values are borrowed from other studies on the US economy, while the remaining values are deduced from the equilibrium relationships of the model's steady state. The time period of the model is defined as a quarter, ensuring coherence with this unit of time guides the calibration.

The calibration of the parameters and the values obtained at the steady state are listed in the following table :

TABLE 1

PARAMETER AND STEADY-STATE-VARIABLE VALUES

Preferences	Production	Steady-State Variables
$\beta = 0.99$	$\theta = 0.70$	$y = 1.000$
$\alpha = 2.00$	$\omega_0 = 0.04$	$c = 0.774$
$\varphi = 0.32$	$\omega_1 = 1.25$	$i = 0.183$
	$\upsilon_0 = 0.01$	$e = 0.043$, $pe/y = 0.043$
	$\upsilon_1 = 1.66$	$p = 1.000$
		$z = 1.546$
		$l = 0.300$
		$k = 7.322$, $\delta = 0.025$
		$u = 0.820$

4 Main Results

Rotemberg and Woodford (1996) investigated the consequences of energy price shocks on the U.S. economy within the context of imperfect competition. Their analysis focused on the response of key economic variables to exogenous innovations in nominal energy prices, particularly examining the behavior of real energy prices, private value added, and the value-added real wage. The findings of their study revealed a pronounced and persistent impact of energy price increases on economic activity. Notably, real energy prices exhibited a positive and highly persistent response to exogenous shocks, peaking approximately five to six quarters later.

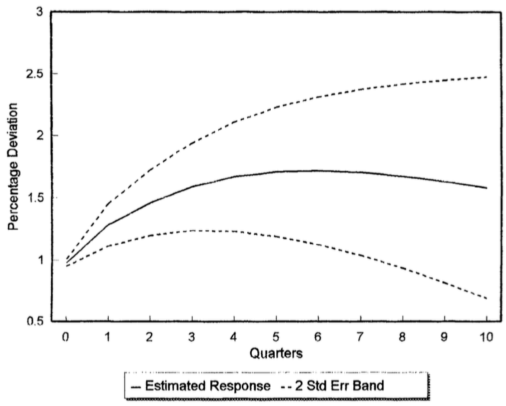

FIG. 1. Estimated Real Energy Price Response

Concurrently, private value added and the value-added real wage experienced significant contractions following energy price increases, with the most severe effects observed around the same period as the peak in real energy prices. The same happens to U.S. value added real wage, as for the U.S. private value added, with the severest decline being 0.09 percent five to six quarters after the exogenous shock, as shown from Rotember and Woodford (1996).

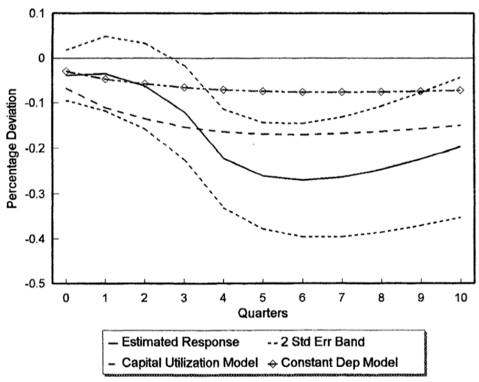

FIG. 2. Estimated and Simulated Value Added Responses

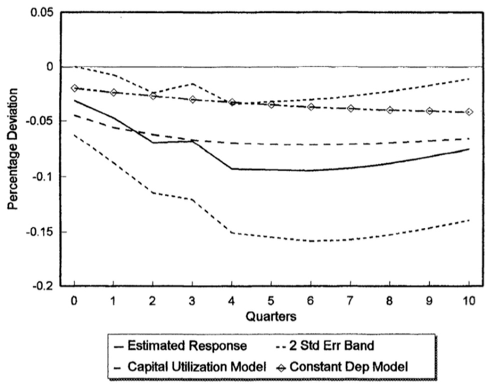

FIG. 3. Estimated and Simulated Real Wage Responses

It is now interesting to see how a change in the framework of this economy can change RW results. Finn's analysis shows the capacity of perfectly competitive theory with endogenous capital utilization replicates the empirical responses exhibited in the U.S. data. The study compares two models: the perfectly competitive theory with endogenous capital utilization and its special case with constant depreciation, against empirical data. Both models simulate the effects of a one-time 1 percent exogenous innovation in nominal energy prices on value added and the value-added real wage, mirroring the conditions observed in the U.S. economy, as we can see in figures 2 and 3. In the capital utilization model, the response of value added closely mirrors the empirical response, with a persistent and almost U-shaped contraction observed. Similarly, the model accurately predicts the long-lasting and approximately U-shaped reduction in the value-added real wage. Conversely, the constant depreciation model generally fails to capture the depth of the recession experienced in the U.S. economy, with contractions in value added and value-added real wages notably smaller than observed empirically. Finn's analysis concludes that the perfectly competitive theory with endogenous capital utilization offers a more successful explanation for the empirical responses observed, compared to the standard theory. This suggests that energy price increases induce substantial and persistent contractions in economic activity, a phenomenon explained more effectively by the perfectly competitive theory with endogenous capital utilization.

5 Critical analysis and existing literature

Finn's most important contribution lies in her incorporation of energy usage for capital, modeling energy use as a function of capacity utilization. This innovative approach has since been adopted and expanded upon in other studies, such as Bao Tan Huynh (2016), which extends the incorporation of energy usage to household dynamics, broadening the analysis to include the essential role of energy in consumer behavior. Other studies have used this same incorporation of energy usage for capital in their research looking beyond the traditional focus on recessionary effects of energy price shocks. For example, studies like Katayama (2013) have leveraged Finn's approach to investigate the diminishing effect of oil prices shock, thanks to factors such improved energy efficiency and a lower degree of persistence of oil price shock, a trend that has continued also in more recent years.

However, while Finn's model offers valuable insights into the transmission mechanisms of energy price shocks, it has been noted that her analysis does not explicitly address the business cycle properties of the model in response to such shocks (Rajeev Dhawan, Karsten Jeske, 2008). This gap raises questions about the share of output fluctuations explained by energy price shocks and the broader volatility of key economic variables such as investment, consumption, and output. Furthermore, without accounting for real rigidities, such as real wage rigidities, these models fail to capture meaningful trade-offs between inflation and output gap stabilization, questioning the optimality of policy responses to oil shocks during periods of high inflation volatility in the 1970s (Anton Nakoiv and Andrea Pescatori, 2010).

Finn's work can be situated within a broader literature on the link between oil and the macroeconomy, as noted by Anton Nakoiv and Andrea Pescatori (2010). Alongside other contribution by Kim and Lougani (1992), Rotemberg and Woodford (1996), Leduc and Sill (2004), and Carlstrom and Fuerst (2005), the models differ in their treatment of oil within the economy, ranging from a consumption good to a standard productive input or a factor linked to capital utilization. However, it is difficult to show that responses to oil price shocks are as important and persuasive as they are in these model, additionally to the fact that they all share the assumption of either exogenous oil prices or oil supply, a premise that has been questioned for its theoretical and empirical validity, an assumption that is in fact deemed theoretically unappealing and inconsistent with empirical evidence. As per Kilian (2008), the absence of an empirically supported model regarding the supply channel necessitates caution in expecting global oil price shocks to exert significant effects on the domestic economy. Responding to these challenges, an alternative branch of the literature has emerged, focusing on the reduction in demand for goods and services triggered by energy price shocks, rather than treating them solely as aggregate supply shocks or productivity shocks for domestic production. This perspective shows the transmission channel of energy price shocks as being on the demand side of the economy. Hamilton (2008) emphasizes this mechanism, highlighting how energy price shocks disrupt consumers' and firms' spending on goods and services other than energy. This view is echoed by Lee and Ni (2002), who suggest that most U.S. firms perceive energy price shocks as impacting the demand for their products rather than affecting production costs. Moreover, policymakers widely share the perception that energy price increases primarily slow economic growth through their effects on consumer spending (Bernanke, 2006).

6 Conclusion

Historically, energy price increases have been associated with significant and persistent recessions in economic activity. While theories of imperfect competition have traditionally been used to explain these effects, Finn's analysis demonstrates that a theory of perfect competition can also account for these empirical observations. At the core of the perfectly competitive theory proposed by Finn is the intuitive idea that energy price increases act similarly to adverse technology shocks, inducing contractions in economic activity. However, the novelty lies in the relationship between energy usage and capital services, where energy is essential for obtaining the service flow from capital, thereby amplifying the impact of energy price shocks on economic activity.

While many questions remain regarding the effects of energy price shocks, Finn's analysis highlights the importance of considering market structure and capital utilization in understanding the macroeconomic implications of energy price fluctuations. Critically, the issue of endogenous versus exogenous energy prices remains a key question. While the reviewed analysis assumes exogenous energy prices, the literature raises questions about the validity of this assumption and its implications for understanding the transmission mechanisms of energy price shocks. To conclude, as already remarked by Kilian in 2008, our understanding of energy price shocks and their economic effects has evolved significantly. Previously, the prevailing view held that major crude oil price increases were exogenous to the U.S. economy, often attributed to political disturbances in the Middle East. However, recent evidence suggests that large and sustained increases in oil prices may primarily stem from demand-side factors, particularly when the capacity to increase crude oil production is limited. This observation shows the importance of considering both demand and supply shocks in the global crude oil market when analyzing the nature and effects of energy price shocks, especially in an economy in transition as the one we are leaving in, where it seems that shocks in supply can be quickly solved as it recently happened in Europe, even though we previously thought it would be much more disruptive.

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