# [*WHERE DO OIL PRICE SHOCKS SPREAD ALONG FIRM INNOVATION?*]

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## Overview

Two contrasting perspectives are present regarding the influence of energy prices on innovation. The first view originates from the price-induced innovation theory (Hicks, 1932). It suggests that technological changes may be propelled by escalating costs of factors, thereby inciting a shift towards the substitution of more expensive factors (Acemoglu 2003). Prior studies have furnished evidence that surges in energy prices would spur innovation, particularly energy-efficient innovations (He et al., 2022; Popp, 2002).Conversely, other research underscores that oil price uncertainty could exert a damaging effect on corporate outcomes. For instance, oil price volatility stemming from price changes could considerably curtail firm investments (Maghyereh and Abdoh, 2020). It also impedes firm innovation as the uncertainty surrounding future economic growth deters further investment in R&D activities (Amin et al., 2023). These divergent perspectives introduce complexity to the understanding of how oil price shocks affect energy technological change.

Previous studies have highlighted the impact of energy prices on innovation, but understanding which firms suffer the most is crucial for the development of sustainable innovation policies that can reduce dependency on fossil fuels. Therefore, in this study, we compiled a unique dataset of publicly listed firms, supplemented with detailed information on energy technological innovation, to explore how and where the effects of oil price shocks permeate firm innovation.

## Methods

In our investigation of the effects of oil price shocks on energy innovation, we conduct a comparative analysis between 'dirty' firms, those engaged in fossil fuel energy innovations, and their counterparts not involved in such innovations. This comparison is made during periods of high and volatile oil prices relative to periods of low and stable oil prices. We evaluate the impact of oil price shocks with a lag of three periods, acknowledging that there is typically a significant time lapse from the initial innovation input to patent output. Moreover, firms tend to exhibit more flexible technology choices in the long run (Antosiewicz and Witajewski-Baltvilks, 2021). The persistence of these impacts is further scrutinized in our subsequent analysis. To achieve this, we utilize an ordinary least squares (OLS) regression model.

$$Lepat_{i,t+3} = \alpha + \beta Dirty_i * Oilprice_t + \rho Oilprice_t + \delta dirty_t + \gamma' X_{i,t} + \theta_i + \vartheta_t + \varepsilon_{i,t} \quad (1)$$

The dependent variable  represents the log-form of energy patent applications plus one for firm *i* at year in the baseline analysis. The dummy indicator equals 1 if firm *i* is a dirty firm that engages in fossil fuel energy innovations, and 0 otherwise. The variable  represents oil price shocks, taking the value of 1 during periods of relatively high and volatile oil prices, and 0 otherwise. This is identified using a two-state Markov switching model. If oil price shocks impede energy innovations in dirty firms relative to clean ones, the coefficient of the interaction term, should be negative and statistically significant. $X_{it}$ refers to the set of control variables. $\theta_i$ and $\vartheta_t$ denote the firm fixed effects and year fixed effects, respectively.

## Results

Our findings reveal that oil price shocks suppress innovation in 'dirty' firms compared to 'clean' ones. By differentiating between energy sources, we found that oil price shocks stimulate innovation in affordable clean energy, such as solar. Furthermore, we discovered that the negative effects on innovation extend to firms in downstream industries and those with a higher level of supplier and customer concentration. The negative impacts of oil price shocks can be attributed to financial difficulties, both external and internal, as well as firms' proactive risk and information strategies.

This study furnishes fresh evidence on how oil price shocks permeate firm innovation. Using a constructed firm-level innovation dataset, we discover that high and volatile oil prices significantly curtail energy innovation in fossil fuel firms relative to their counterparts. However, we observe a markedly positive impact on innovation in cost-effective clean energy, especially in solar energy, in the wake of oil price shocks. Our findings suggest a potential energy transition from fossil fuels to affordable renewable energy, catalyzed by oil price shocks. These results hold steady even after employing instrumental variable tests, firm-by-patent empirical strategies, spatial error tests, and other robustness checks.

Moreover, we pinpoint the contagion effect of oil price shocks across industries and over time. Our findings divulge that fossil fuel firms located downstream in the industrial chain, as well as those with greater supply chain concentration, are more susceptible to this negative impact. Significantly, this stifling effect lingers over a prolonged period and becomes more pronounced in less experienced firms. We demonstrate that the adverse impact of oil price shocks on 'dirty' firms' innovation can be attributed to tighter external financing constraints, more severe internal financial distress, and heightened risk and information management motivation for 'dirty' firms. This suggests that 'dirty' firms may curb R&D activities to avert costs and additional risks engendered by a surging and uncertain crude oil market.

## Conclusions

This research offers novel insights into the ripple effect of oil price shocks on corporate innovation. We classify corporate innovation by both its origin and outcome, equipping us to explore the possibility of technology substitution in the face of escalating and volatile oil prices. Our method of quantifying oil price changes concurrently considers both swift price hikes and associated uncertainty. We shed light on the diverse long-term responses among firms to fluctuating and rising oil prices.

Our study underscores that oil price shocks have indeed curtailed R&D activities in the realm of fossil fuel innovation. Our findings hint at the potential for a transition to clean energy in response to shifts in the energy market. However, we augment these studies by offering more specific evidence on the biased technological change, indicating that the energy transition triggered by oil price fluctuations is effective only for cost-effective clean energy, rather than all forms of energy innovation. Consequently, our findings also suggest that relying exclusively on market-based instruments as a cure-all for sparking innovation is inadequate; suitable policy interventions are essential to stimulate technological change.

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