Oil-Price Volatility, Familiarity, and the Asymmetric Transmission of Energy Shocks

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Abstract

Adverse oil-supply shocks contract European investment by more than favorable supply shocks expand it. Scaled to the median absolute quarterly shock in Baumeister and Hamilton (2019), cumulative EU10 investment is 0.79 log points higher after a favorable shock and 1.79 log points lower after an adverse shock. Only the contraction's 90 percent interval excludes zero. A favorable supply shock lowers the oil price, and an adverse shock raises it. Models that move the oil price in the same way as productivity produce a more nearly symmetric response. We ask what mechanism generates the asymmetry, and whether that mechanism becomes more important as the shock grows.

We treat an oil shock as a price change together with a rise in future price dispersion. The price change moves production costs. Greater dispersion widens the distribution of firm cash flows and discourages investment, so volatility reinforces a price increase and offsets part of a price decline. Larger supply shocks are followed by higher oil-price volatility, which gives the same interaction a role in the effect of shock size.

We develop a heterogeneous-agent, two-sector model in which this risk is transmitted through firm cash flows, idiosyncratic equity risk, and household portfolio concentration. Firms differ in oil intensity, choose capital and planned variable inputs before the oil-price state is realized, and finance operating inputs before revenue arrives. The interaction of oil-price uncertainty with an idiosyncratic revenue

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shock produces substantial dispersion in individual-firm returns. A sufficiently low realization forces the firm to liquidate its capital, so individual-firm returns are more volatile than diversified sectoral returns. Households are persistently familiar with the sector in which they work. An individual firm in that sector is their familiar concentrated investment, while diversification across firms and sectors requires costly financial participation. This structure connects labor income, employer-sector risk, and portfolio choice.

An increase in oil-price volatility widens the distribution of firm cash flows and raises the dispersion and downside risk of individual-firm returns, especially in the oil-intensive sector. Higher risk-adjusted required returns lead households to reduce investment in both sectors, with a larger decline where oil intensity is high. Because firms face decreasing returns in variable inputs, costly input adjustment, and state-dependent liquidation losses, the contraction in capital supply lowers productive capacity and wages. After an oil-price increase, higher costs, weaker cash flow, greater liquidation risk, and reduced risk-bearing capacity reinforce one another. After an oil-price decline, lower marginal costs would ordinarily stimulate activity, but the accompanying rise in return volatility still discourages concentrated investment. Volatility therefore attenuates the expansionary effect of favorable movements and amplifies the contractionary effect of adverse ones. MIT experiments that vary the oil-price level and conditional volatility separately and jointly reproduce this pattern: joint movements are asymmetric, price changes alone are close to symmetric, and the same increase in dispersion is more contractionary when it accompanies a price increase. The model also yields testable cross-sectional implications, since volatility should raise return dispersion, liquidation, and investment sensitivity most strongly among oil-intensive firms. We discipline aggregate labor compensation and oil expenditure with national-account targets, and we set the revenue-shock support and the liquidation loss to an average quarterly liquidation probability of 1.5 percent and a capital-weighted idiosyncratic return variance of 0.0038. The transitions are computed with a conventional nonlinear solution and with an almost-nonlinear level-k algorithm that re-solves household and firm policies nonlinearly, using precomputed on-impact derivatives only for small within-period market-clearing corrections.

Keywords: oil prices, uncertainty, household portfolios, familiarity, firm liquidation, heterogeneous agents, nonlinear transitions.
JEL codes: E21, E22, E32, G11, G32, Q43.

1 Introduction

Oil-price movements accompany both recessions and expansions, and energy is an important input into production. A substantial empirical literature finds that the effects of oil-price changes are nonlinear. Models that treat the oil price much as they treat productivity instead imply approximately linear responses. The open question is which mechanism produces the nonlinearity, and what that mechanism implies for large oil-price shocks.

This paper asks three questions. Does the economy respond asymmetrically to adverse and favorable oil-price shocks? If it does, what mechanism explains the asymmetry? Does that mechanism become more important as the shock grows?

The empirical answer uses the posterior-median oil-supply shock of Baumeister and Hamilton (2019). A positive realization raises oil supply and therefore lowers the oil price; a negative realization is adverse and raises the oil price. Section 2 estimates sign-specific local projections for aggregate EU10 investment. Scaled to the median absolute quarterly shock, cumulative investment is 0.79 log points higher after a favorable shock and 1.79 log points lower after an adverse shock. Only the contraction's 90 percent interval excludes zero. The same shocks are followed by higher oil-price volatility and wider dispersion in European energy prices. An oil shock is therefore a change in the price level together with a rise in future price risk. The price change moves production costs. The rise in risk discourages investment, reinforcing the contraction after a price increase and offsetting part of the expansion after a price decline. Small innovations, accompanied by limited changes in volatility, can remain close to a linear benchmark. Large innovations predict a wider future price distribution and activate liquidation and portfolio adjustment, so the same interaction can grow with shock size.

This measurement continues a debate that has moved forward in stages. Hamilton (1983, 2003) and the work that followed them argued that large oil-price increases have repeatedly preceded contractions and that sufficiently disruptive oil events need not have a mirror image in price declines. A later literature, built on newer VAR and structural-VAR methods, reached a more linear conclusion. Kilian (2009) stressed that an oil-price movement is not a primitive shock: supply, global-demand, and precautionary-demand disturbances can move the same price while producing different macroeconomic responses. Kilian and Vigfusson (2011) showed that censored oil-price specifications can exaggerate asymmetry and that a linear, approximately symmetric response is a useful benchmark for ordinary U.S. innovations.

Baumeister and Hamilton (2019) then challenged the identifying assumptions of those linear VARs with a Bayesian structural VAR that combines sign restrictions with explicit priors on the elasticities of oil supply and oil demand. Their decomposition still lives in a linear model, but it restores an important role for oil-supply shocks and finds delayed contractions in activity. The associated dataset is a monthly panel of world crude-oil production, global real activity, the real price of oil, and petroleum inventories. Each price movement is split into an oil-supply shock, an economic-activity shock, an oil-consumption demand shock, and an inventory-demand shock.

A more recent group of papers returns to sign and size nonlinearities with the oil-supply news instrument of Känzig (2021). Forni, Franconi, Gambetti, and Sala (2025) estimate a nonlinear proxy structural VAR for the United States and establish the sign asymmetry: news that raises the oil price produces a large and persistent decline in U.S. real activity, while news that lowers the price produces a smaller real expansion. They trace the asymmetry to uncertainty, which rises after a supply shock of either sign. Caravello and Martínez Bruera (2024) develop local projections that isolate sign nonlinearities from size nonlinearities and, applying the same Känzig news series to the United States, establish the size nonlinearity: the macroeconomic effect grows with the magnitude of the shock. Mareels (2026) uses externally identified oil-supply shocks in panel local projections for European countries and finds a related asymmetry at a longer horizon: temporary oil-price increases leave real GDP lower for more than a decade, while temporary price decreases do not generate comparable lasting gains. These results reestablish sign asymmetry and size nonlinearity for identified supply disturbances. The sign asymmetry in this paper is the European investment response above, and the rise in oil-price volatility after larger supply shocks is its link to size nonlinearity.

The baseline series is the oil-supply shock of Baumeister and Hamilton (2019). The surprises in Känzig (2021) are constructed from high-frequency futures moves around OPEC announcements and therefore miss several of the large historical supply disruptions that matter for nonlinear adjustment. The Baumeister–Hamilton shock is available over a long monthly sample, it aggregates to the quarterly frequency of investment, and it is the supply component of the price. Kilian (2009) shows that the macroeconomic response depends on which component moved the price, so the supply series is the empirical counterpart of the disturbance in the model. Forni, Franconi, Gambetti, and Sala (2025) also report that their asymmetry is robust when the shock is identified as in Baumeister and Hamilton (2019).

With the supply component isolated, the remaining question is why a price increase

and a price decline propagate differently. The model answers by separating the source of the innovation, its level and sign, and the subsequent conditional volatility of oil prices. Oil-price volatility changes the distribution of firm-level returns, and households' limited diversification determines how strongly that risk affects the supply of productive capital. The mechanism operates even when the innovation to the oil price is favorable. What matters for investment is not only the conditional mean of sectoral returns but also the covariance of returns with household marginal utility and the tail risk embedded in concentrated firm positions.

The economy contains a high-oil-intensity sector, denoted H, and a low-oil-intensity sector, denoted L. Firms pay for oil, labor, rented land, and adjustment expenditures before an idiosyncratic revenue shock is realized. When realized revenue cannot cover these obligations, the firm liquidates all surviving capital and loses a fixed fraction of it. Individual-firm equity therefore contains discrete downside risk that is absent from a representative sectoral claim. Because oil expenditures constitute a larger share of costs in sector H, oil-price volatility raises both the aggregate and idiosyncratic components of its return risk more strongly.

Households face persistent sectoral familiarity. A household's employment sector determines the individual-firm position that is easiest to hold, capturing employer-stock exposure, local information, and familiarity-based investment (Huberman, 2001; Benartzi, 2001; Van Nieuwerburgh and Veldkamp, 2009). The household chooses how much wealth to place in that concentrated firm and how much to diversify. Within the diversified account, it chooses the allocation between sectoral claims, but moving away from the familiar sector is costly. This structure makes idiosyncratic firm risk relevant for aggregate capital supply: the risk cannot be diversified away costlessly by assumption.

An increase in oil-price volatility then operates through three steps. First, it produces a spike in the dispersion and downside risk of firm returns, particularly in sector H. Second, familiarity and diversification costs cause the increase in individual-firm risk to raise the required compensation for holding productive capital. Investment falls in both sectors because general-equilibrium income and risk-bearing capacity decline, but the fall is larger in the high-oil-intensity sector. Third, lower capital supply reduces production and wages. The contraction is amplified by input adjustment costs and liquidation losses.

The same mechanism produces asymmetric responses to positive and negative oil-price innovations. When the oil price rises, higher costs and volatility jointly deteriorate cash flow and increase liquidation. When the oil price falls, the direct cost channel is expansionary, but volatility still increases portfolio risk and discourages investment. The

uncertainty channel therefore weakens the positive response to an oil-price decline and reinforces the negative response to an increase. Full-capital liquidation and endogenous portfolio adjustment make these responses nonlinear in shock size. This mechanism is related to the real-options and uncertainty-shock logic of Bloom (2009), but it acts through household risk bearing and capital ownership. The same objects yield the cross-sectional predictions already stated in the abstract: volatility should raise return dispersion, liquidation, and investment sensitivity most strongly among oil-intensive firms.

The paper makes four contributions. First, it documents that EU10 investment contracts by more after an adverse Baumeister and Hamilton (2019) supply shock than it expands after a favorable one, and that larger supply shocks are followed by higher oil-price volatility. Second, it builds an oil-dependent heterogeneous-agent production economy in which firms plan inputs before the oil state is realized, liquidation creates firm-level return dispersion, and employment-linked familiarity exposes wages and familiar equity to the same oil state. Familiarity-driven under-diversification can already distort aggregate investment in general-equilibrium production economies (Bhamra and Uppal, 2019); our contribution is to endogenize the relevant individual-firm risk through oil costs, revenue shocks, and liquidation, and to connect that risk to sectoral labor income. Third, the model shows how a rise in conditional volatility interacts with the sign of the oil-price innovation. Volatility amplifies the contraction after a price increase, offsets part of the expansion after a decline, and makes the macroeconomic response increase with shock size. Fourth, it computes almost-nonlinear MIT transitions using level-k belief updating and on-impact linear corrections, while preserving nonlinear household and firm policy functions and comparing the results with the true nonlinear solution. Starting from steady-state beliefs augmented by the announced shock path, each level re-solves the nonlinear household and firm policy paths backward, propagates the household distribution and sectoral capital forward, and clears labor, goods, and claim markets. The resulting paths update beliefs until anticipated and realized outcomes coincide. Precomputed on-impact derivatives are used only for small contemporaneous market-clearing corrections; anticipated policy responses, liquidation probabilities, portfolio choices, and distribution dynamics remain nonlinear. A first-order transition would suppress the dependence of those objects on the sign and size of the oil shock. The algorithm therefore preserves the mechanism's economically relevant nonlinearities while avoiding a complete dynamic re-solution after every small price correction.

Our quantitative strategy targets six steady-state moments: the land-rent share, the

oil-expenditure share, the labor-compensation share, the high-energy employment share, the quarterly liquidation rate, and the capital-weighted variance of idiosyncratic firm returns. Sectoral oil weights preserve the distinction between high- and low-oil-intensity production. The final-good weight on the high-energy sector is set to its share in our European industry classification. Capital–labor weights are adjusted to the aggregate wage bill and to the sectoral employment share. The revenue-shock distribution and the liquidation loss are set to match average quarterly liquidation near 1.5 percent and an idiosyncratic return variance of 0.0038. Swedish evidence on direct stock holding and professional proximity is the source for the familiarity costs, which remain at benchmark values until the sectoral premium and the concentrated-portfolio share are imposed as targets.

The remainder of the paper proceeds as follows. Section 2 presents the empirical motivation. Section 3 describes the model and mechanism. Section 4 discusses calibration. Section 5 presents the nonlinear MIT experiments. Section 6 explains the almost-nonlinear level-k transition algorithm. Section 7 concludes. Technical derivations, additional empirical figures, and the remaining MIT impulse responses appear in the appendix.

2 Empirical Motivation

This section examines how oil-supply disturbances relate to price risk, aggregate investment, and differences across energy-intensive and other industries. We combine European, Swedish, and U.S. evidence to motivate the model's transmission channels. The results document several relevant patterns, while the financial responses remain less precisely estimated.

2.1 Data

We use monthly posterior-median oil-supply shocks from Baumeister and Hamilton (2019), denoted by s_t, retaining their original signs. Quarterly shocks are sums of the three monthly observations. European data comprise domestic energy producer prices for ten EU economies in 2005–2019 and aggregate investment and GDP in 1996–2019. Oil volatility uses daily Brent prices converted into real Swedish kronor using SEK/USD and Swedish CPI, covering 1987–2025. Swedish industry investment begins in 1993; U.S. monthly data provide dividend dispersion through 2024 and an industry return premium through August 2026. Shock availability and lag requirements determine each

estimation sample. Appendix Figures 22, 27–29 describe the European price series and energy-intensity groups.

2.2 Supply shocks, price dispersion, and volatility

We distinguish cross-country price dispersion from time-series oil volatility. Let D_t be the cross-country standard deviation of log energy-price residuals after country and month fixed effects and country-specific trends. Let e_d be the residual from an AR(5) for daily real-oil-price log returns, expressed in log points. For the next $K \in \{1, 3, 6, 12\}$ calendar months, define

$$F^D_{t,K} = \left(\frac{1}{K} \sum_{j=1}^{K} D^2_{t+j} \right)^{1/2},$$
$$F^V_{t,K} = \left(\frac{252}{N_{t,K}} \sum_{j=1}^{K} \sum_{d \in t+j} e^2_d \right)^{1/2}, \tag{1}$$

where $N_{t,K}$ counts the daily innovations in the future window. Both measures exclude the shock month. For each measure $m \in \{D, V\}$, we estimate

$$F^m_{t,K} = \alpha^m_K + \beta^m_K |s_t| + \gamma^m_K U^m_{t-1} + u^m_{t,K}, \tag{2}$$

where U^m_{t-1} is the corresponding previous-month dispersion or realized volatility. Regression inference uses K-lag Newey–West standard errors; the binned-mean bars are descriptive intervals.

Figures 1 and 2 plot next-month binned means and $5\widehat{\beta}^m_K$. The dispersion association is strongest at the shortest horizon and fades thereafter. Oil-volatility estimates remain positive at longer horizons: a five-unit larger absolute shock is associated with approximately 14.5 and 11.3 additional log points of annualized volatility over six and twelve months. The corresponding 68% intervals exclude zero. Sign-specific estimates appear in Appendix Figures 23 and 24.

2.3 Aggregate asymmetry

We estimate quarterly local projections for aggregate EU10 investment. Writing S_t for the quarterly supply shock, define $S^+_t = \max\{S_t, 0\}$ and $S^-_t = \max\{-S_t, 0\}$. With

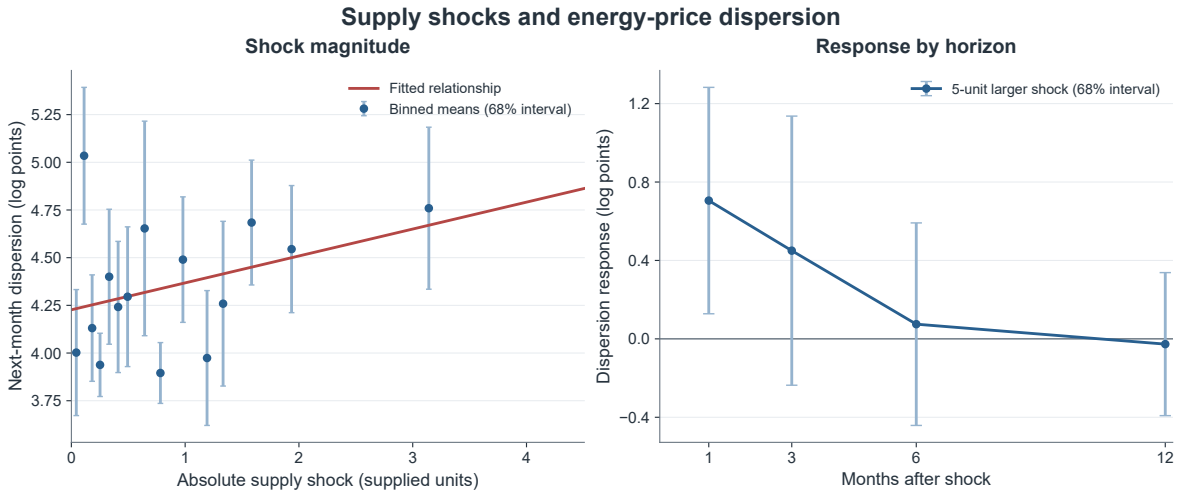


Figure 1: Supply-shock magnitude and EU10 energy-price dispersion. Left: next-month binned means, controlling for lagged dispersion. Right: effects of a five-unit larger absolute shock. Bars show 68% intervals.

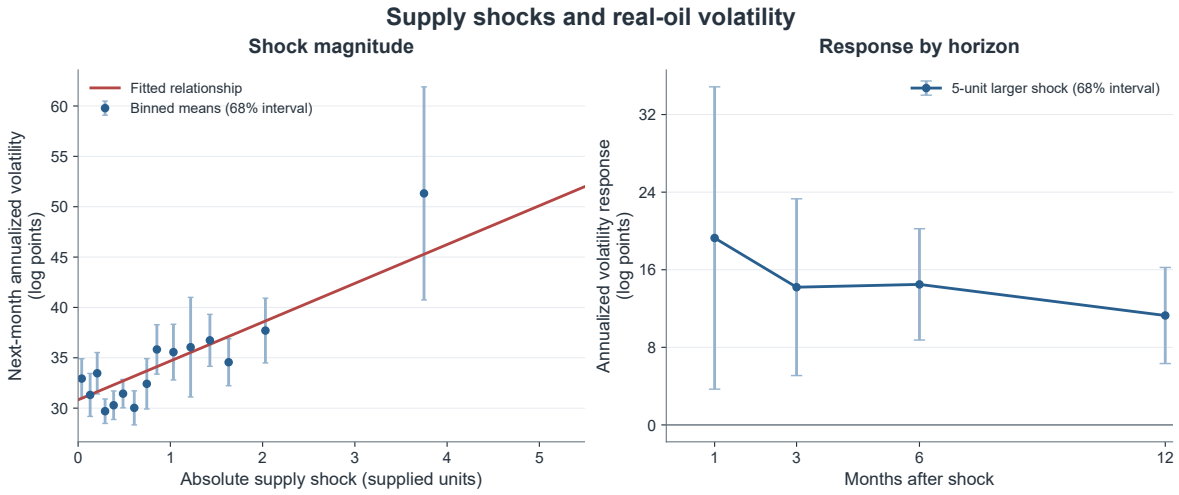


Figure 2: Supply-shock magnitude and annualized real-oil volatility. Left: next-month binned means, controlling for lagged volatility. Right: effects of a five-unit larger absolute shock. Bars show 68% intervals.

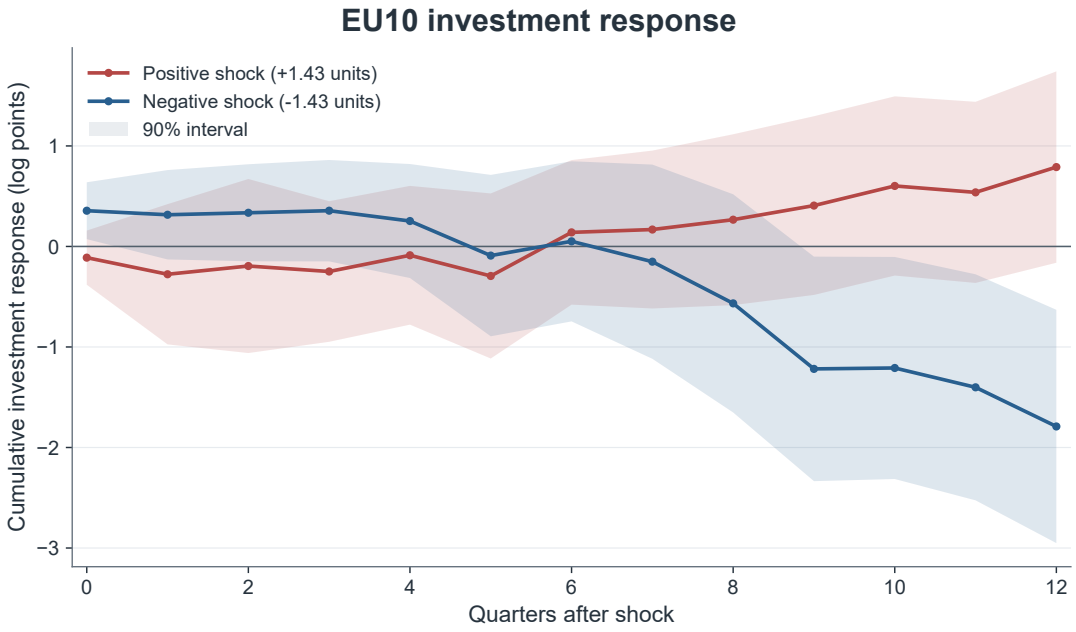


Figure 3: Cumulative EU10 investment responses to positive and negative supply shocks of the common median absolute size. Shading shows pointwise 90% intervals.

$i_t = 100 \log I_t$, the specification is

$$i_{t+h} - i_{t-1} = \alpha_h + \theta_h^+ S_t^+ + \theta_h^- S_t^- + \Gamma_h' Z_t + u_{t+h}, \tag{3}$$

where Z_t contains two lags of investment growth, GDP growth, real oil-price growth, inflation, the short rate, and both shock components, together with quarter indicators. Local-projection inference uses pointwise Newey–West intervals with $h + 1$ lags.

Figure 3 scales both responses to the common median absolute quarterly shock, approximately 1.43 shock units. At twelve quarters, the point estimates are 0.79 log points after a positive shock and -1.79 after a negative shock; only the latter 90% interval excludes zero. The paths suggest sign dependence, although most individual responses are imprecise. Shock-size extensions, the exclusion of 2009 shock origins, and the GDP counterparts are reported in Appendix Figures 25, 26, 31, and 32.

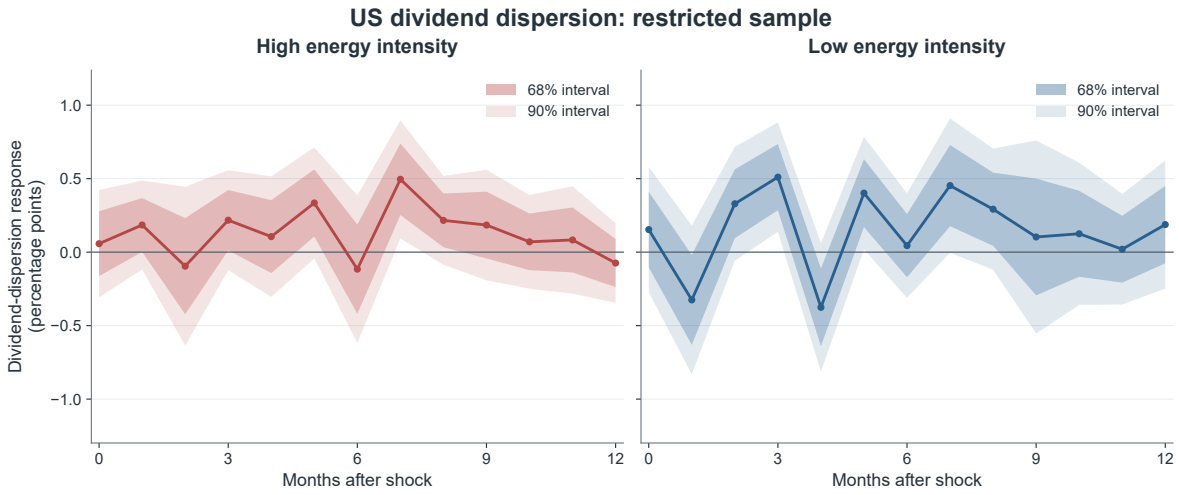


Figure 4: U.S. dividend-dispersion responses to a one-unit signed supply shock, by energy intensity. Dark and light shading show pointwise 68% and 90% intervals.

2.4 Cross-sectional facts

Dividend dispersion. For the United States, we use monthly dividend dispersion within high- and low-energy-intensity groups. For $g \in \{H, L\}$, we estimate

$$\text{Disp}_{g,t+h} = \alpha_{g,h} + \beta_{g,h} s_t + \Gamma'_{g,h} W_t + u_{g,t+h}, \qquad h = 0, \ldots, 12, \tag{4}$$

where W_t includes six lags of both groups' dispersion, the shock, U.S. industrial-production growth, inflation, the three-month Treasury rate, and real oil-price growth, together with month indicators. Figure 4 excludes the flagged 1998–2001 and 2020 episodes, including lag and response windows crossing them. The estimates provide limited evidence of a persistent increase in dispersion or a systematically larger high-intensity response. The full-sample counterpart is in Appendix Figure 33.

Return premia. We next examine the weighted U.S. return on energy-intensive industries minus the weighted return on other industries, denoted by P_t. This realized equity-return spread differs from the excess bond premium studied by Forni, Franconi, Gambetti, and Sala (2025). We project P_{t+h} jointly on $s_t^+ = \max\{s_t, 0\}$ and $s_t^- = \max\{-s_t, 0\}$, using six lags of the premium, both shock components, the same monthly U.S. macro controls, and month indicators.

Figure 5 reports impact estimates of -0.29 and 0.17 percentage points after positive and negative shocks, respectively; most subsequent responses are imprecise. Appendix

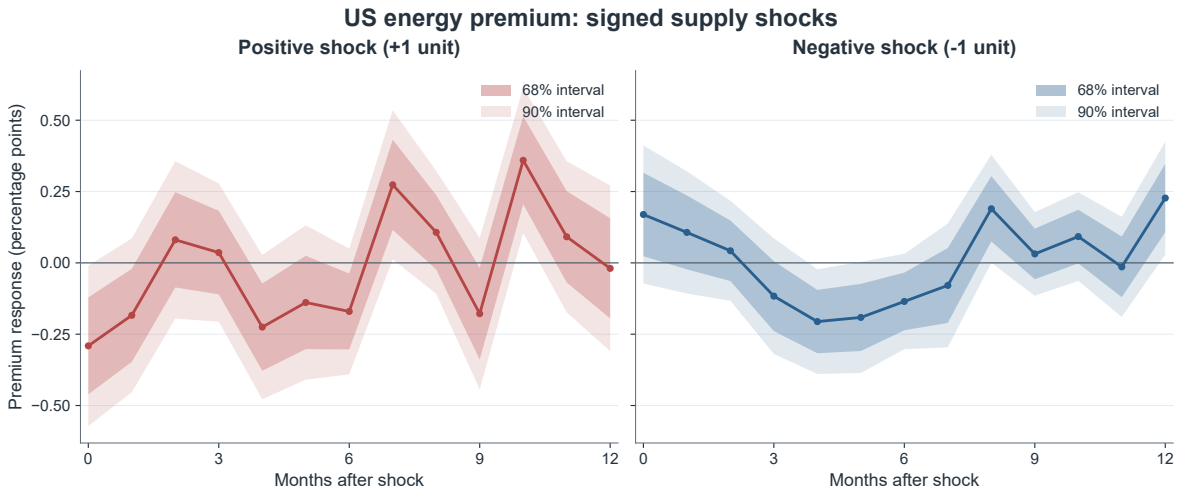


Figure 5: U.S. energy-intensity return-premium responses to positive and negative one-unit supply shocks, estimated jointly. Dark and light shading show pointwise 68% and 90% intervals.

Figure 34 instead projects the premium on $|s_t|$, imposing a common response to shock magnitude across signs.

Sectoral investment. Finally, we estimate the sign-specific investment projection separately for Swedish high- and low-energy-intensity industries over 1993–2019. Groups are fixed using 2015–2019 direct energy purchases divided by gross output: high intensity exceeds 5%, giving eight high- and 24 low-intensity industries. The controls follow (3), using each group's investment growth.

Figure 6 uses the same 1.43-unit reference magnitude as the aggregate exercise. Six quarters after a positive shock, the point estimates are -2.56 log points for high-intensity investment and 0.62 for low-intensity investment. Negative-shock responses are less stable. Appendix Figure 30 extends the sample through 2026Q2.

3 Model

3.1 Environment and timing

Time is discrete. There are two intermediate sectors, $s \in \{H, L\}$, that differ in oil intensity. A competitive final-good producer combines their output. Households differ in financial wealth a, labor productivity z, and sectoral familiarity $e \in \{H, L\}$. Aggregate

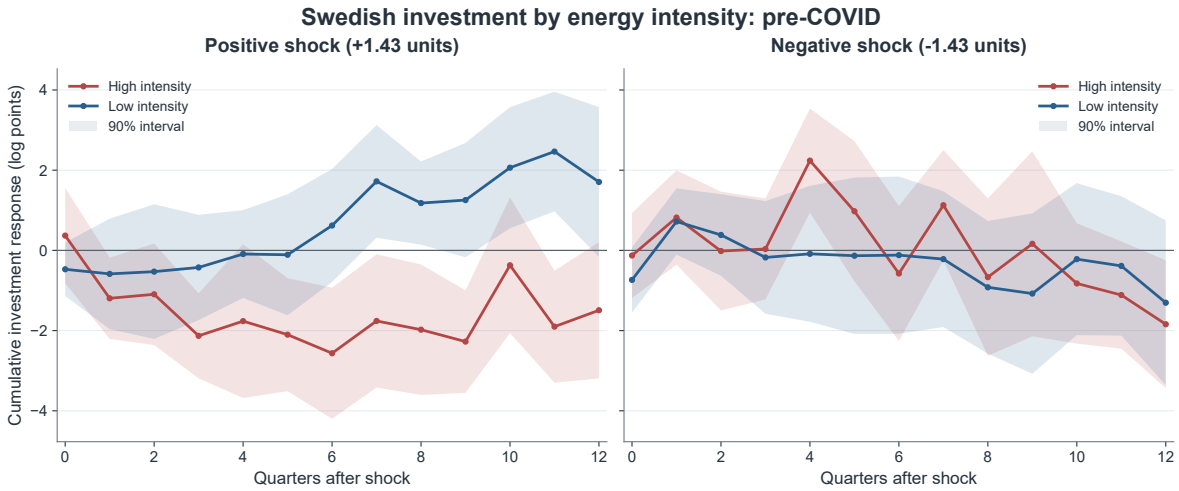


Figure 6: Cumulative Swedish investment responses by energy intensity, 1993–2019, at the common reference shock magnitude. Shading shows pointwise 90% intervals.

oil conditions determine the oil price and the distribution of sectoral returns.

Within a period the aggregate state is known before firms plan, the regional oil price is realized before spot markets clear, and the idiosyncratic revenue shock determines returns before households choose next period's capital. Figure 7 records the order. A region is a local oil-price island: a country inside the European Union, or a state inside the United States. Because the revenue shock is i.i.d., expected and realized aggregate goods demand and labor supply coincide, so the spot markets in the third event clear at the aggregates that households deliver after returns are realized.

3.2 Oil prices and volatility

The oil price in region j is

$$p_j^o = \bar{p}^o(1+\nu_j), \qquad \mathbb{E}[\nu_j] = 0, \qquad \mathrm{Var}(\nu_j) = \sigma_\nu^2. \tag{5}$$

MIT experiments allow both $\bar{p}_t^o$ and $\sigma_{\nu,t}$ to vary over time. This separation permits experiments involving a change in the expected oil-price level, a pure volatility shock, or a joint shock in which a positive or negative price innovation occurs under elevated volatility.

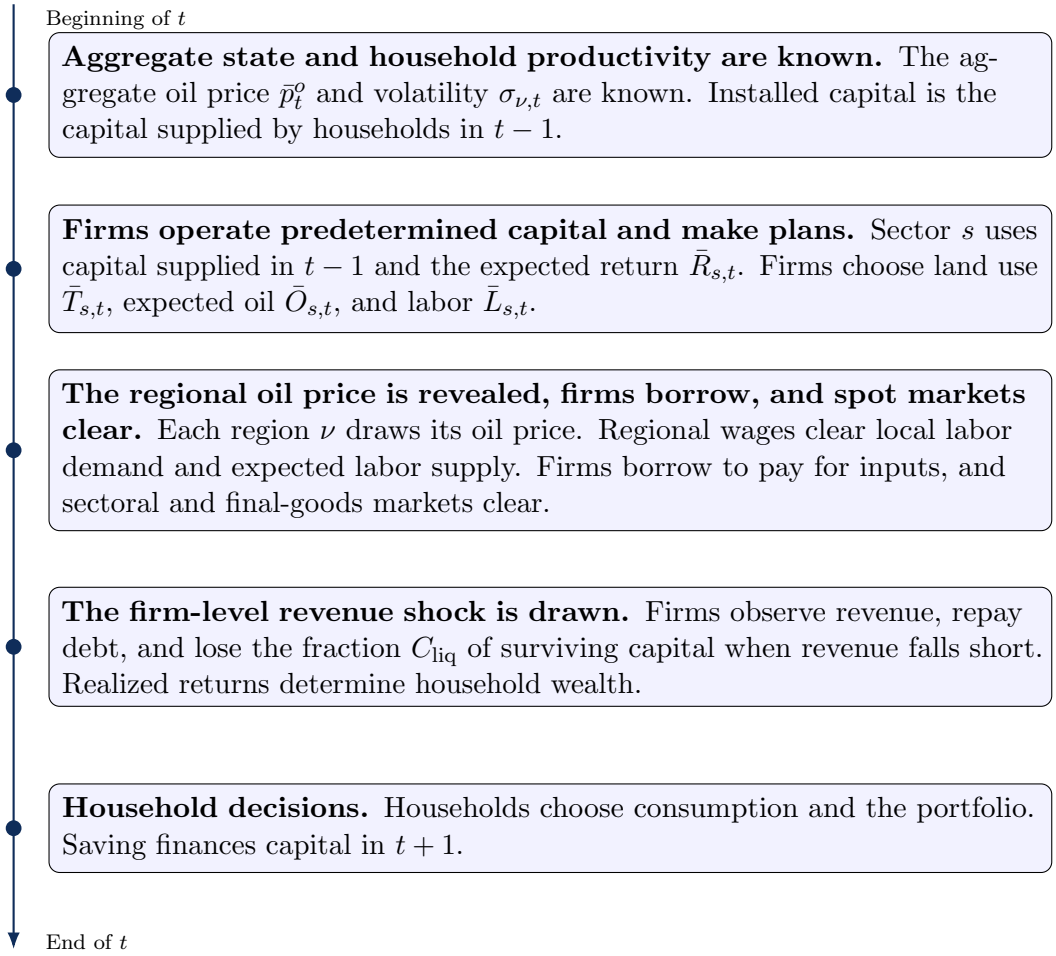


Figure 7: Timing inside a period.

3.3 Production

Define the capital–labor composite

$$M_{js} = \left[\alpha_{L,s} L_{js}^{\frac{\epsilon_f - 1}{\epsilon_f}} + \alpha_{K,s} K_s^{\frac{\epsilon_f - 1}{\epsilon_f}}\right]^{\frac{\epsilon_f}{\epsilon_f - 1}}, \tag{6}$$

Gross output combines oil, the capital–labor composite, and the fixed factor directly in one CES nest:

$$Y_{js}^g = \left[(1-\phi_s)\alpha_{0,s} O_{js}^{\frac{\rho_f - 1}{\rho_f}} + (1-\phi_s)\alpha_{LK,s} M_{js}^{\frac{\rho_f - 1}{\rho_f}} + \phi_s T_s^{\frac{\rho_f - 1}{\rho_f}}\right]^{\frac{\rho_f}{\rho_f - 1}}, \qquad \sum_s T_s = \bar{T}. \tag{7}$$

An exactly zero $\alpha_{0,s}$ omits oil from that sector's technology. The fixed aggregate supply $\bar{T}$ gives decreasing returns in the variable inputs and anchors scale. Sectoral land is allocated with a softmax transformation so that the land market clears exactly, and its competitive rent is rebated equally to households.

Firms choose planned oil and labor inputs, $\bar{O}_s$ and $\bar{L}_s$, before the aggregate oil realization. Deviations incur resource costs

$$\Phi_{js}^I = \kappa_O \frac{(O_{js} - \bar{O}_s)^2}{\bar{O}_s} + \kappa_L \frac{(L_{js} - \bar{L}_s)^2}{\bar{L}_s}. \tag{8}$$

Net sectoral output is $Y_{js} = Y_{js}^g - \Phi_{js}^I$.

3.4 Final goods

A competitive producer combines sectoral goods:

$$Y_j = A_Y \left[\omega Y_{jH}^{\frac{\eta - 1}{\eta}} + (1-\omega) Y_{jL}^{\frac{\eta - 1}{\eta}}\right]^{\frac{\eta}{\eta - 1}}. \tag{9}$$

The final good is the numeraire. Sectoral prices satisfy the dual price-index condition and sectoral demand equations associated with (9).

3.5 Firm finance, liquidation, and individual-firm returns

Variable inputs, adjustment expenditures, and land rent are paid before an idiosyncratic revenue shock ζ_i is realized. Firm i in sector s and aggregate state j owes

$$D_{js} = p_j^o O_{js} + w_j L_{js} + p_{js}\Phi_{js}^I + q_T T_s. \tag{10}$$

Revenue is $\zeta_i p_{js} Y_{js}^g$, with $\mathbb{E}[\zeta_i] = 1$. The firm liquidates whenever

$$\zeta_i p_{js} Y_{js}^g < D_{js}. \tag{11}$$

Liquidation destroys the fraction C_{liq} of surviving capital. The expected real loss is therefore

$$\mathcal{L}_{js} = C_{\text{liq}}(1-\delta)K_s \Pr\left(\zeta_i < \frac{D_{js}}{p_{js}Y_{js}^g}\right). \tag{12}$$

The benchmark revenue shock is uniform. Numerically, narrow linear ramps are placed at the two support edges to make the density and liquidation derivatives continuous; this approximation is arbitrarily close to the uniform benchmark away from the endpoints.

Individual-firm returns retain the discrete downside exposure generated by liquidation. Diversified sectoral returns integrate over ζ_i. Oil volatility matters disproportionately for concentrated investors because

$$\text{Var}(R_{js}^i) = \text{Var}\big(\mathbb{E}[R_{js}^i \mid j]\big) + \mathbb{E}\big[\text{Var}(R_{js}^i \mid j)\big], \tag{13}$$

and the second term can rise sharply when liquidation moves into the support of the idiosyncratic shock.

3.6 Households

Household preferences are

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma}}{1-\sigma} - \psi \frac{n_t^{1+\gamma}}{1+\gamma}\right], \tag{14}$$

where γ is the inverse Frisch elasticity. The consumption composite permits nonhomothetic oil demand:

$$C = \left[\chi_o^{1/\epsilon_o} c^{\frac{\epsilon_o - 1}{\epsilon_o}} + (1-\chi_o)^{1/\epsilon_o}(o - \underline{o})^{\frac{\epsilon_o - 1}{\epsilon_o}}\right]^{\frac{\epsilon_o}{\epsilon_o - 1}}. \tag{15}$$

The subsistence term $\underline{o}$ is set to zero at the baseline calibrations, so oil demand is homothetic.

The familiarity state follows

$$\Pi_e = \rho_e I + (1 - \rho_e)\mathbf{1}\bar{\pi}_e', \tag{16}$$

where $\bar{\pi}_e$ is the invariant familiarity distribution. In the baseline, this distribution is anchored to average sectoral labor and moves with it in the MIT transitions.

3.7 Portfolio choice and diversification

Let $d \in [0, 1]$ denote the share of savings placed in a diversified account, and let $\theta \in [0, 1]$ denote the low-oil-sector share within that account. The remaining fraction $1 - d$ is invested in an individual firm from the household's familiar sector. The gross portfolio return is

$$R_p' = (1 - d)R_{i,e}' + d\left[(1 - \theta)R_H' + \theta R_L'\right]. \tag{17}$$

Let $\theta_e^0 = 0$ for an H-familiar household and $\theta_e^0 = 1$ for an L-familiar household. Diversification uses resources according to

$$\Phi(W, d, \theta; e) = W\left[\kappa_d d^2 + \kappa_s d^2(\theta - \theta_e^0)^2\right]. \tag{18}$$

The household budget constraint is

$$x + \left[1 + \kappa_d d^2 + \kappa_s d^2(\theta - \theta_e^0)^2\right] W = a + w_j z n + \tau_T, \tag{19}$$

where $x = c + p_j^o o$ and $\tau_T = q_T \bar{T}$ is the equal land-rent transfer. Next period's financial wealth is

$$a' = R_p' W. \tag{20}$$

The savings Euler equation is

$$\lambda\left[1 + \kappa_d d^2 + \kappa_s d^2(\theta - \theta_e^0)^2\right] = \beta\mathbb{E}[\lambda' R_p']. \tag{21}$$

The portfolio conditions compare marginal-utility-weighted returns. Thus an asset with a high mean return can remain unattractive if it performs poorly in states with high marginal utility or if it exposes the household to sufficiently large idiosyncratic downside risk.

3.8 The volatility–familiarity mechanism

Consider an increase in σ_ν around a given mean oil price. In sector H, cash flows become more sensitive to the aggregate oil state. The liquidation threshold in (12) moves through the firm-shock distribution, increasing both liquidation probability and the variance of individual returns. For a familiar investor, reducing this exposure requires a higher d. Doing so is costly, and reallocating the diversified account toward the other sector is additionally costly when it moves away from θ_e^0.

The household therefore responds along both the intensive and extensive portfolio margins. Risk-adjusted capital supply to sector H falls directly. Sector L also has a direct risk channel: its positive oil weight makes its cash flow and liquidation threshold vary with oil-price volatility, while state-contingent wages transmit oil risk to both sectors according to their labor intensities. Capital supply to sector L can fall further because lower wealth and higher marginal utility reduce aggregate risk-bearing capacity. These direct and general-equilibrium effects distinguish the model from a pure portfolio-reallocation economy in which capital moves one-for-one from H to L.

The asymmetry follows because volatility interacts differently with the direct cost effect of the price innovation. For a price increase, both channels reduce investment and activity. For a price decline, the direct cost effect raises desired production, while the volatility–portfolio channel lowers capital supply. The latter offsets the former. Full liquidation, borrowing constraints, and nonlinear portfolio costs make the offset state dependent and stronger for larger shocks.

4 Calibration

The model period is one quarter. Parameters are divided into external assignments, normalizations fixed at one, and objects adjusted to six steady-state moments. The final-good productivity A_Y, the labor-disutility coefficient, baseline labor productivity, and the aggregate land endowment are normalizations and are set to one. They are not calibrated. The only parameters left free of both an external source and a moment are the input-plan adjustment costs κ_L and κ_O, with the restriction $\kappa_L = 2\kappa_O$.

4.1 Sectoral technology

Sector H is mapped to oil-intensive production and sector L to less oil-intensive activity. Their oil weights preserve a sizable but not exclusive difference in oil exposure. The

Table 1: Working parameterization

Parameter	Description	Value	Source/target
β	Discount factor	0.99	Kydland and Prescott (1982)
σ	Relative risk aversion	3	Aiyagari (1994)
γ	Inverse Frisch elasticity	2	Chetty (2012); Chetty et al. (2011)
ρ_z	Earnings persistence	0.95	Cooley and Prescott (1995)
σ_z	Earnings innovation s.d.	0.08	Iacoviello and Pavan (2013)
δ	Depreciation	0.015	Cooley and Prescott (1995)
χ_o	Normal-good CES weight	0.90	Audzei and Sutóris (2024)
ϵ_o	Household oil substitution	0.30	Natal (2012)
ρ_f	Oil–(KL)–land elasticity	0.30	Natal (2012)
ϵ_f	Capital–labor elasticity	0.50	Chirinko (2008); Knoblach, Roessler, and Zwerschke (2020)
η	Cross-sector elasticity	0.75	Atalay (2017)
ω	Weight on sector H	0.20	Own EU industry classification
$\alpha_{0,H}, \alpha_{0,L}$	Oil weights	0.175, 0.025	High/low oil-intensity distinction
κ_O	Oil plan-adjustment cost	1.0	Free; $\kappa_L = 2\kappa_O$
κ_L	Labor plan-adjustment cost	2.0	set on $[0.5, 1, 1.5]$ for robustness
ρ_e	Familiarity persistence	0.90	Employment persistence
κ_d	Firm-diversification cost	0.001	Calvet, Campbell, and Sodini (2007); Betermier, Calvet, and Sodini (2017)
κ_s	Cross-sector portfolio cost	0.005	Sectoral return premium

Notes: Values are the current benchmark. The Stone–Geary oil floor is zero and is omitted. The six internally calibrated objects—ϕ_s, $\bar{p}^o$, $\alpha_{L,s}$, $\alpha_{K,s}$, $\mathrm{Var}(\zeta)$, and C_{liq}—are reported with their targets in Table 2. κ_d and κ_s remain at these values until they are matched to the concentrated-portfolio share and the high-energy return premium. The oil weights are reported before the common technology scaling used in the code. Normalizations set to one are omitted.

final-good weight $\omega = 0.20$ is the high-energy sector's share in our European industry classification for 2015–2019, and η governs substitution following relative-price movements. Capital–labor weights are not fixed in advance. With $\alpha_{K,s} = 1 - \alpha_{L,s}$, the two labor weights are adjusted jointly to an aggregate labor-compensation share of 0.60 and a sector-H employment share of 0.30. Labor compensation, the residual capital share, and land rent are 0.60, 0.35, and 0.05 of GDP. Oil expenditure is 0.08 of GDP. Oil is an intermediate input, so it is not counted in GDP; the implied total of factor and oil bills is 1.08 of GDP. The elasticity of substitution between capital and labor is set to $\epsilon_f = 0.50$. Chirinko (2008) places the long-run aggregate elasticity in a range of roughly 0.4 to 0.6, and the meta-analysis of Knoblach, Roessler, and Zwerschke (2020) centers on a value near one half.

The costs of missing the input plan, κ_O and κ_L, are the remaining free parameters. A proportional miss of size $e = (x - \bar{x})/\bar{x}$ costs κe^2 units of the planned input, so $\kappa \in [0.1, 2]$ means that a 10 percent deviation costs between 0.1 and 2 percent of the planned oil bill or wage bill. That interval is the order of magnitude of the convex factor-adjustment costs surveyed by Hamermesh and Pfann (1996) and estimated by Hall (2004). The benchmark sets $\kappa_O = 1.0$ and $\kappa_L = 2.0$. Labor receives the larger cost because hours are harder to reset within the quarter than spot energy purchases (Hamermesh and Pfann, 1996).

4.2 Households and portfolios

The productivity process uses standard quarterly persistence and dispersion. Relative risk aversion is $\sigma = 3$, the intermediate value in the incomplete-markets calibration of Aiyagari (1994). The inverse Frisch elasticity is $\gamma = 2$, so the Frisch elasticity is one half. Chetty (2012) finds that an intensive-margin Frisch elasticity of one half is consistent with the micro evidence once optimization frictions are allowed for, and Chetty et al. (2011) report the same central intensive-margin value. The labor-disutility coefficient is a normalization equal to one.

The portfolio costs are reserved for two moments that are not yet imposed. κ_d governs the share of saving kept in the concentrated familiar firm. The source for that share is the direct-stockholding evidence in Calvet, Campbell, and Sodini (2007) and the finding in Betermier, Calvet, and Sodini (2017) that professionally close stocks account for about 16 percent of direct stockholdings. κ_s governs how costly it is to tilt the diversified account away from the familiar sector, and it will be used to match the return premium

of the high-energy sector over the low-energy sector in our industry portfolios. Until those two targets are imposed, the parameters stay at $\kappa_d = 0.001$ and $\kappa_s = 0.005$.

4.3 Firm risk and liquidation

The idiosyncratic revenue shock is approximately uniform, with narrow endpoint ramps used only to smooth derivatives. Its support is the instrument for the liquidation rate. Liquidation destroys the fraction C_{liq} of surviving capital and is the instrument for the idiosyncratic return variance. The two objects are solved jointly, because a wider revenue-shock support changes both the frequency of liquidation and the dispersion of returns among surviving firms, while a larger liquidation loss widens the gap between liquidation and repayment returns.

The sixth moment is the capital-weighted variance of idiosyncratic firm returns. Inside each sector s and region j, firm returns are measured as deviations from the mean return in that region. Let ω_ζ be the probability weights on the revenue shock and π_j the probability of region j. The sectoral variance and the aggregate moment are

$$v_s = \sum_j \pi_j \sum_i \omega_{\zeta,i} \left(R_{ijs} - \bar{R}_{js}\right)^2, \qquad v = \sum_s \frac{K_s}{K_H + K_L} v_s. \tag{22}$$

Subtracting $\bar{R}_{js}$ removes the variation that comes from the regional oil price itself, so v is within-region dispersion. The weights K_s are installed capital. The target is $v = 0.0038$ per quarter. That number is the square of the pooled cross-sectional standard deviation of the mild-loss payout that replaces the adjusted dividend with the quarterly return when that return lies in $(-20\%, 0)$, with zero-dividend years included and 1998–2001 and 2020 left out. The corresponding standard deviation is 6.16 percent. The same capital weights and revenue-shock probabilities define the liquidation rate, whose target is 0.015 per quarter, about 5–6 percent at an annual frequency. The variance moment uses the returns themselves, including the liquidation return on the shortfall side of that threshold.

For the household calculation, the full firm-return distribution is reduced to four weighted groups: liquidation, low surviving, middle surviving, and high surviving. This is a numerical quadrature rather than an additional calibration target. It preserves group probabilities and conditional means and is checked against diversified sectoral mean returns.

Table 2: Moments used to discipline the working calibration

Moment	Target	Primary adjusted object	Calibrated value
Land rent / model GDP	0.05	ϕ_s	0.03
Firm and household oil expenditure / model GDP	0.08	$\bar{p}^o$	0.175
Aggregate labor compensation / model GDP	0.60	$\alpha_{L,s}$	0.60, 0.70
Sector-H employment share	0.30	$\alpha_{K,s} = 1 - \alpha_{L,s}$	0.40, 0.30
Average quarterly liquidation probability	0.015	$\mathrm{Var}(\zeta)$	0.0208
Idiosyncratic return variance, (22)	0.0038	C_{liq}	0.30

Notes: Wealth-distribution moments and average hours are not calibration targets. Calibrated values are those of the current working parameterization. Sectoral pairs are reported as sector H, then sector L. The residual capital share is 0.35 of GDP. Oil is an intermediate input, so labor, capital, and land add to 1 of GDP and the oil bill of 0.08 of GDP brings total expenditure to 1.08 of GDP. The return-variance target is the square of the pooled mild-loss dispersion that uses quarterly returns in $(-20\%, 0)$. $\mathrm{Var}(\zeta)$ is the variance of the approximately uniform revenue shock with support $[0.75, 1.25]$. C_{liq} is the share of surviving capital destroyed in liquidation. The final-good weight ω is set externally to 0.20. The portfolio costs κ_d and κ_s are reserved for the concentrated-portfolio share and the high-energy return premium and are not yet adjusted to those moments. The liquidation rate and v are capital-weighted and are solved jointly.

5 Nonlinear MIT Experiments

We report five main experiments. Each shock is unexpected on impact, after which agents have perfect foresight over the deterministic paths of aggregate distributions and prices, while idiosyncratic shocks remain uncertain.

5.1 Oil-price increases and declines

The first pair of experiments changes the expected oil-price level while holding conditional volatility at its baseline value. These experiments isolate the conventional cost and income channels. The second pair applies the same mean-price paths under elevated volatility. Comparing the two pairs identifies how uncertainty changes the propagation of favorable and adverse price movements.

5.1.1 A decrease in average prices

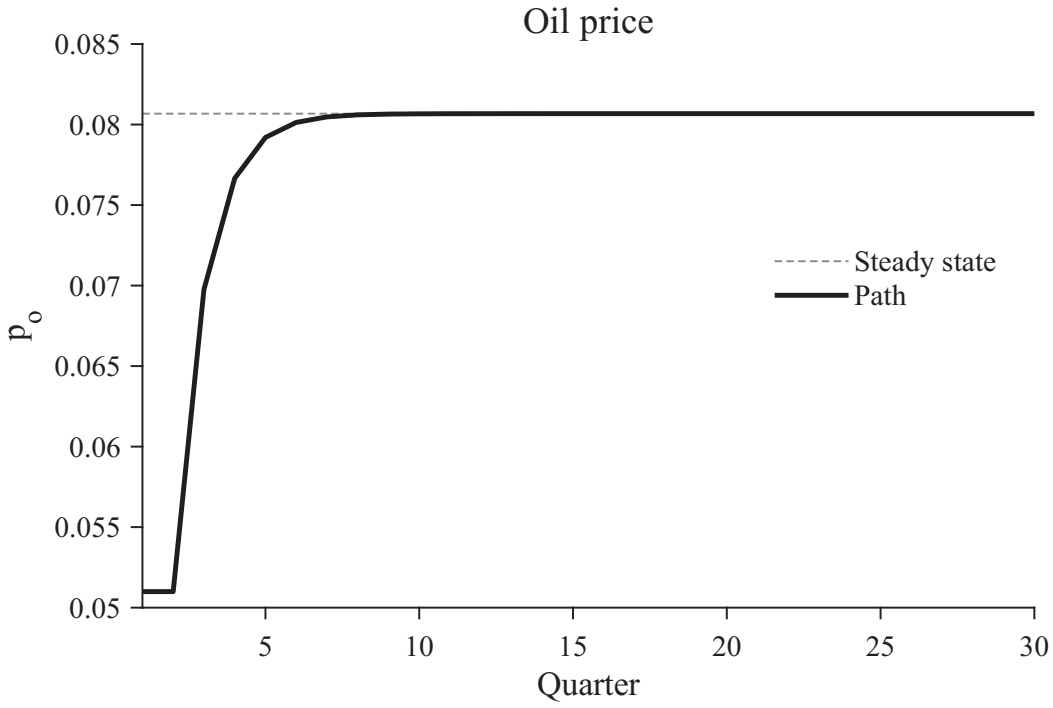
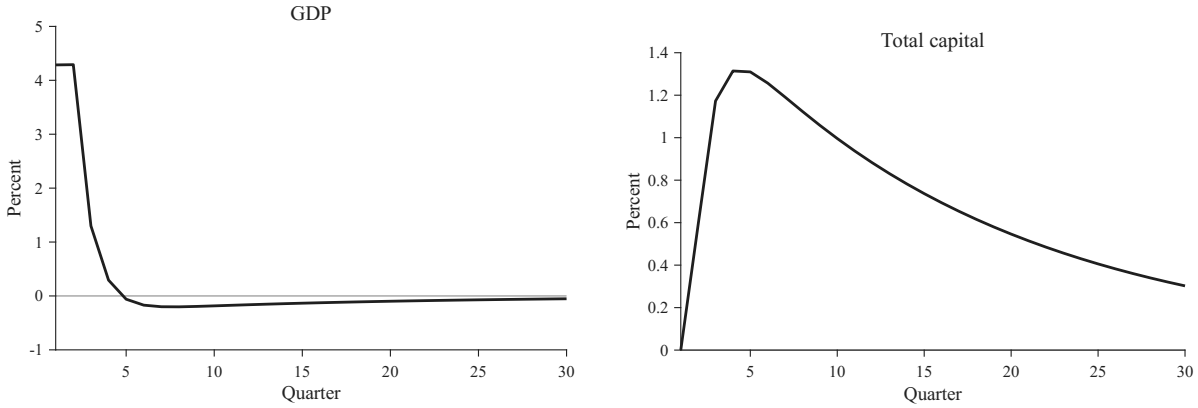
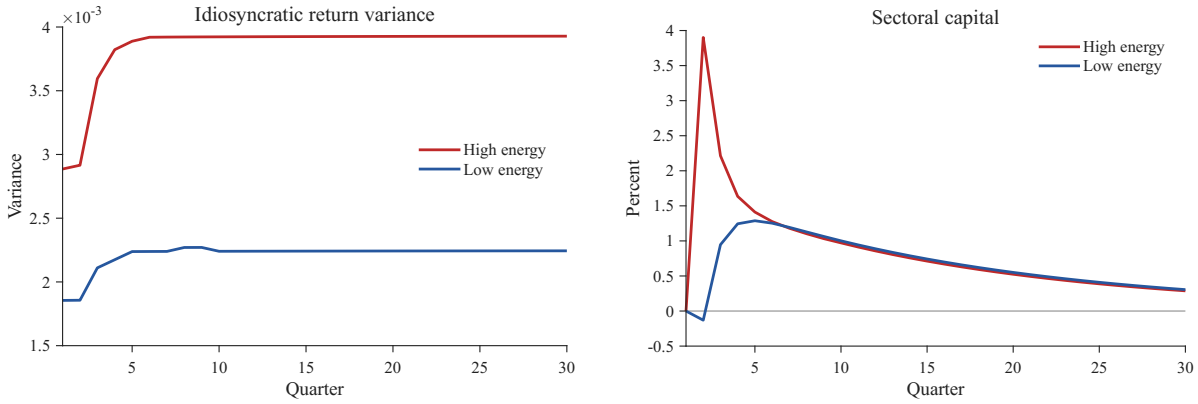


Figure 8: Shock path for a pure decrease in prices



(a) GDP response (b) Capital response

Figure 9: Aggregate responses to a decrease in average oil price



(a) Variance response (b) Sectoral capital response

Figure 10: Sectoral responses to a decrease in average oil price

5.1.2 An increase in average prices

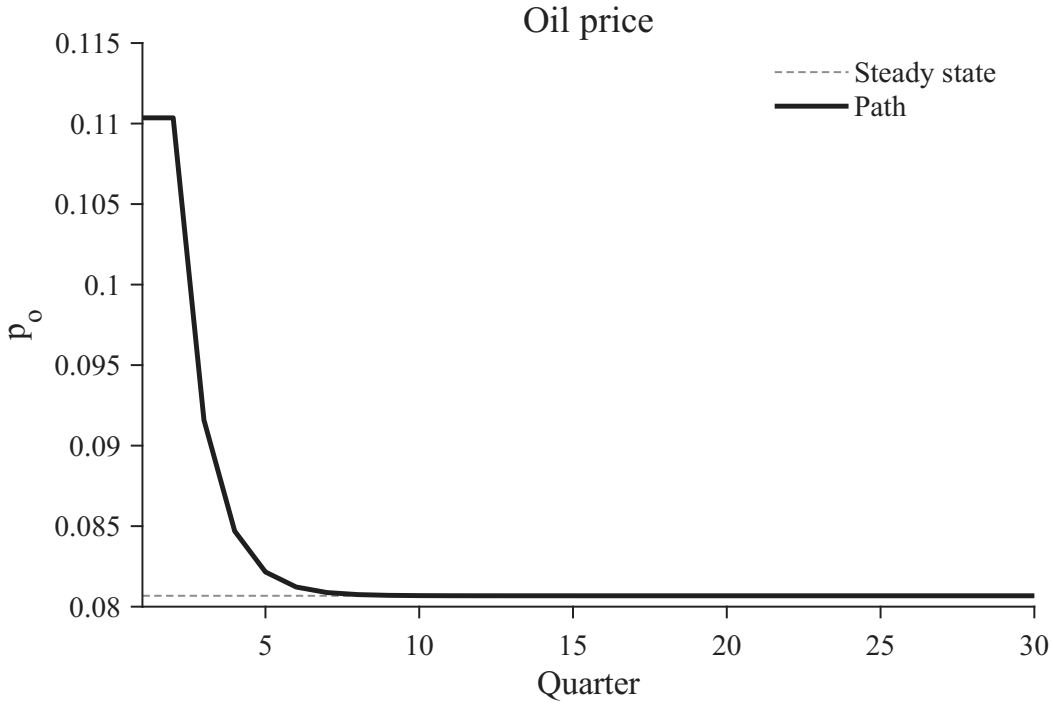
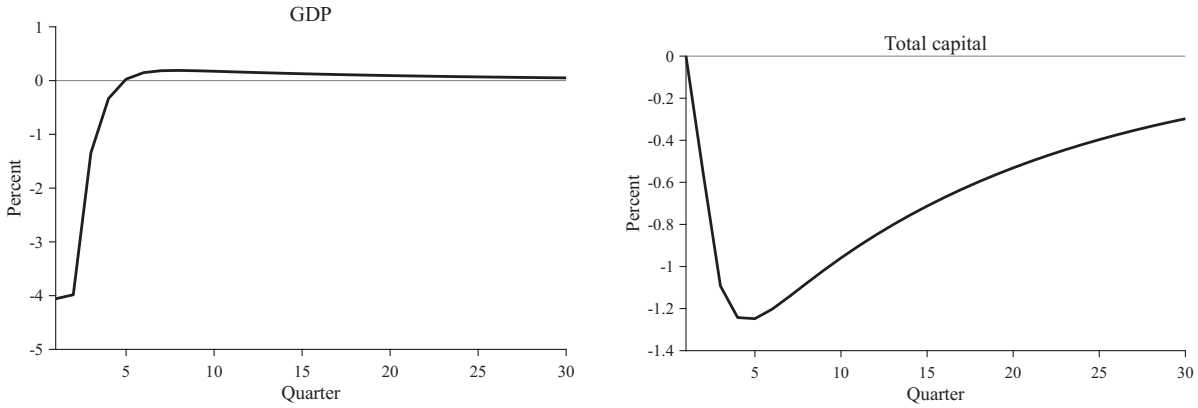
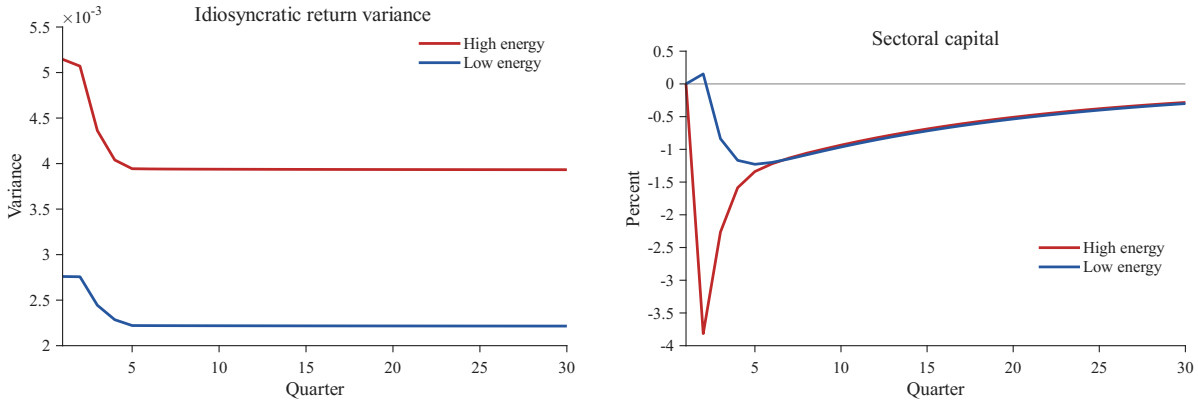


Figure 11: Shock path for a pure increase in prices



(a) GDP response (b) Capital response

Figure 12: Aggregate responses to an increase in average oil price



(a) Variance response (b) Sectoral capital response

Figure 13: Sectoral responses to an increase in average oil price

5.2 Pure volatility shocks

A pure volatility experiment raises $\sigma_{\nu,t}$ while holding $\bar{p}_t^o$ fixed. The model predicts a decline in sector-H capital, a smaller but generally nonzero decline in sector-L capital, and a rise in the required return spread. The response of sector L distinguishes the aggregate risk-bearing mechanism from a pure reallocation channel.

5.2.1 An increase in volatility

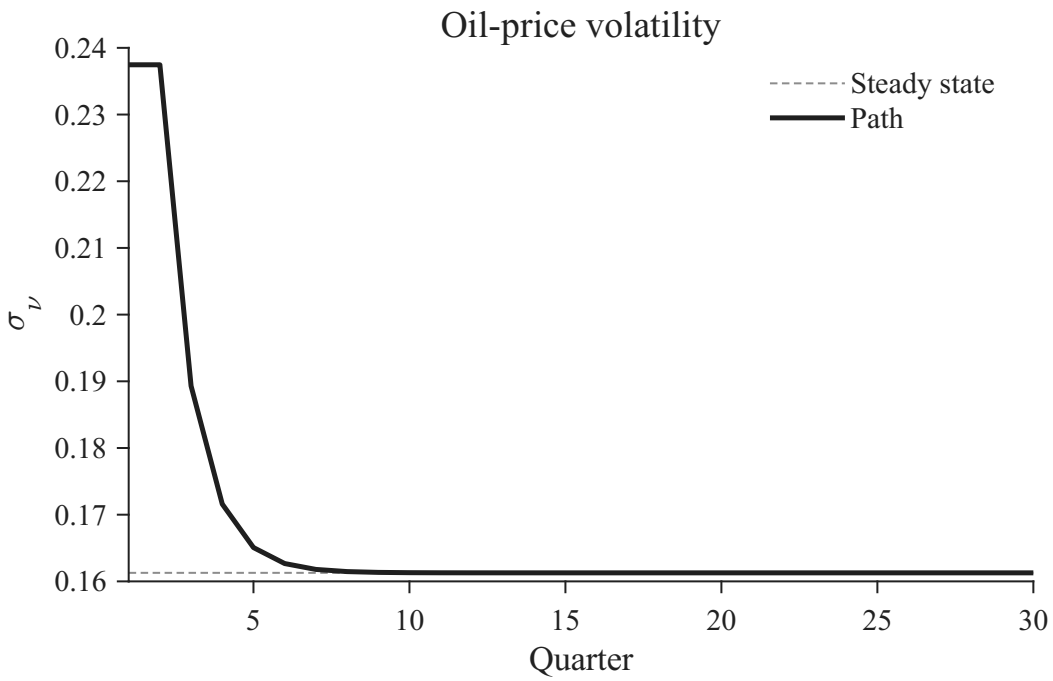
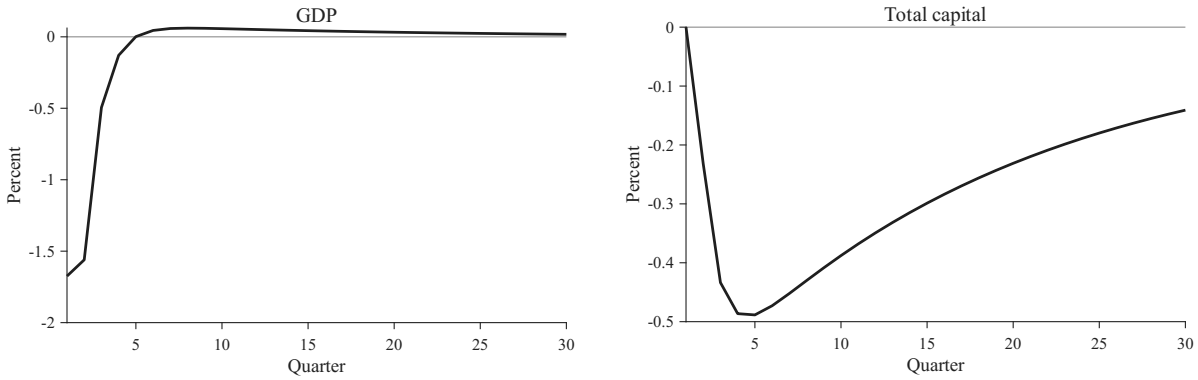
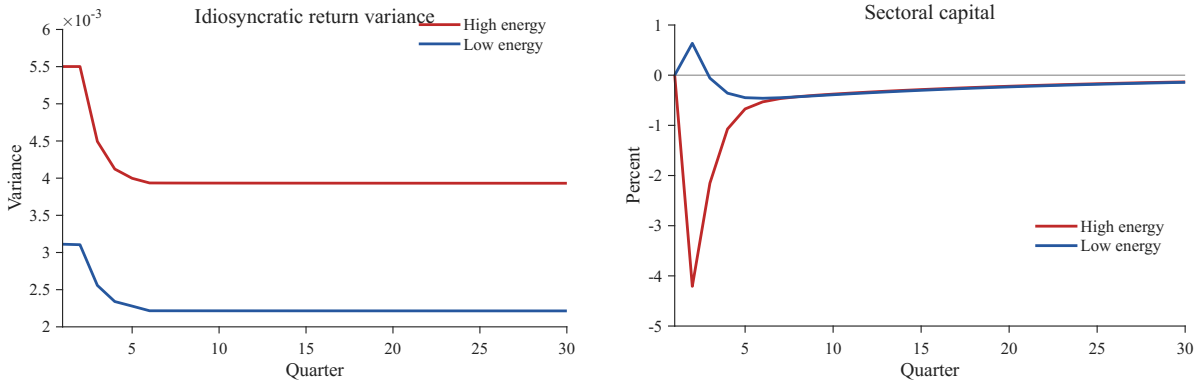


Figure 14: Shock path for a pure increase in volatility



(a) GDP response (b) Capital response

Figure 15: Aggregate responses to an increase in volatility



(a) Variance response (b) Sectoral capital response

Figure 16: Sectoral responses to an increase in volatility

5.3 Asymmetry and nonlinearity

To compare the model with the asymmetric response of positive and negative oil-price shocks in the data, we combine each mean-price path with a common variance shock. The joint experiments reproduce the empirical asymmetry. They also show that the isolated price and volatility shocks display little nonlinearity, whereas the joint responses do: the incremental effect of the variance shock is larger when it accompanies a price increase than when it accompanies a price decline.

5.3.1 Effect of volatility in a price decline

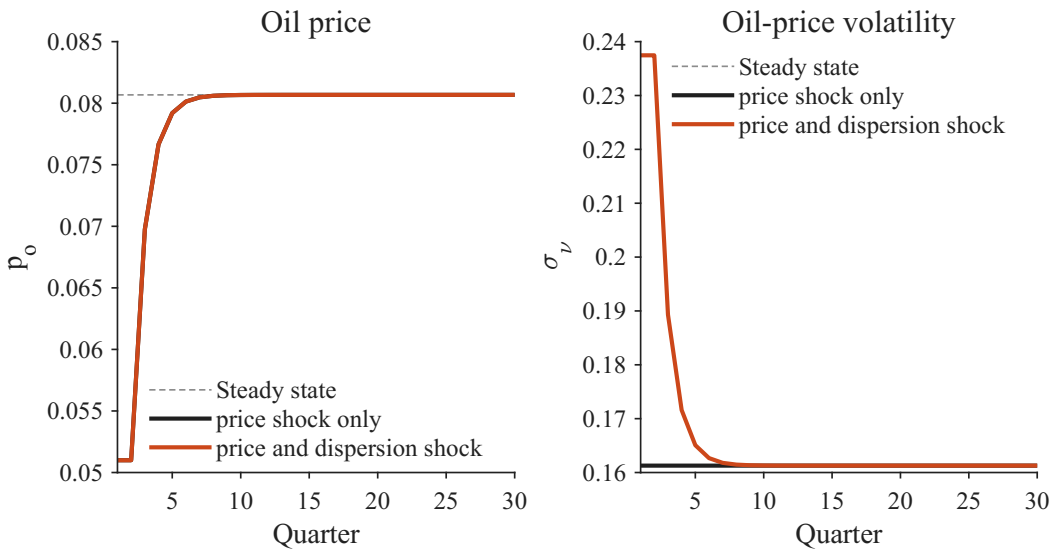
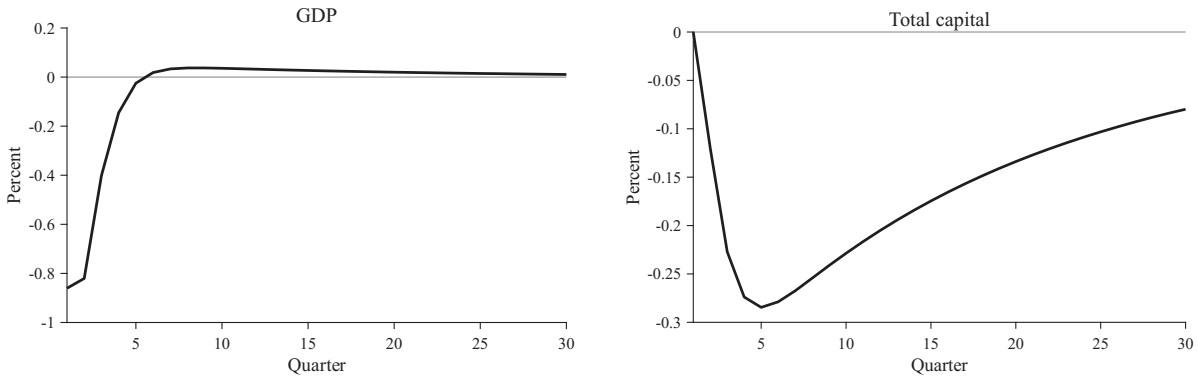


Figure 17: Shock paths for a price decline with and without a volatility shock



(a) GDP response (b) Capital response

Figure 18: Difference in aggregate responses to a price decline with and without a volatility shock

5.3.2 Effect of volatility in a price increase

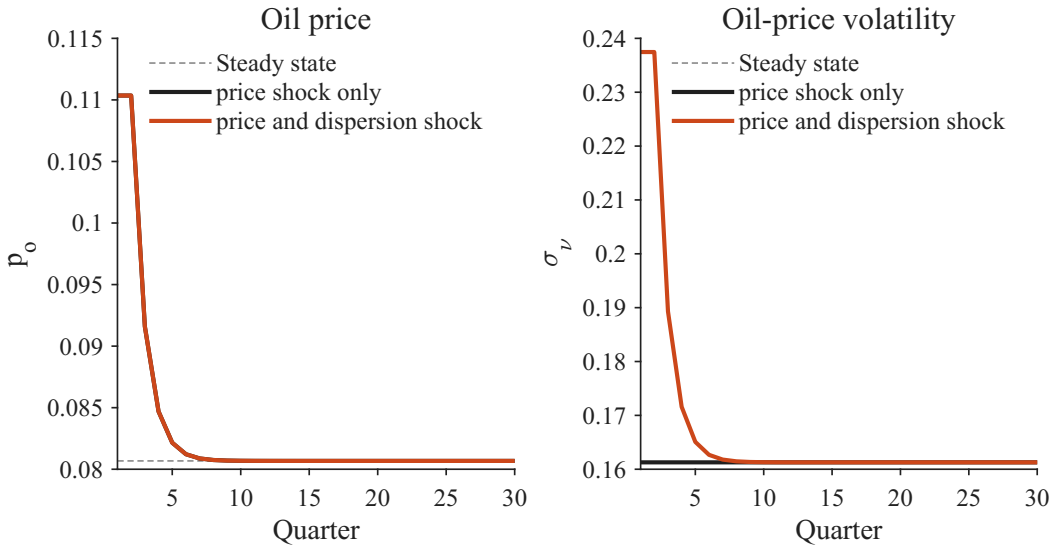
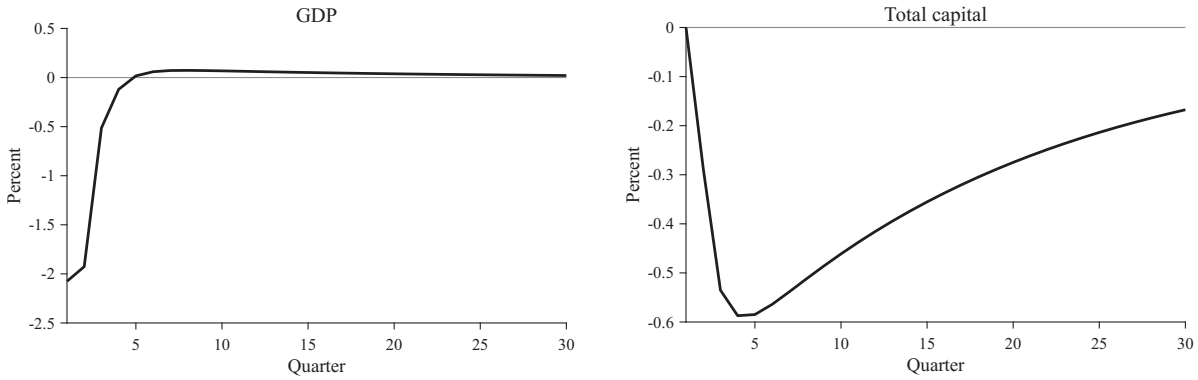


Figure 19: Shock paths for a price increase with and without a volatility shock



(a) GDP response (b) Capital response

Figure 20: Difference in aggregate responses to a price increase with and without a volatility shock

Table 3: MIT transition results

Outcome	Price decline	Price increase	Volatility shock	$\Delta(P^{-}_{\text{w.V}} - P^{-}_{\text{w.o.V}})$	$\Delta(P^{+}_{\text{w.V}} - P^{+}_{\text{w.o.V}})$
Peak output response	4.96	-4.39	-1.65	-1.10	-2.03
Peak total investment response	44.7	-39.4	-15.1	-7.35	-29.2
Peak sector-H capital response	3.92	-2.89	-3.92	-3.36	-4.49
Peak sector-L capital response	1.42	-1.27	1.16	1.10	1.27
Peak liquidation (p.p.)	-0.51	0.48	0.71	0.51	0.87
Peak variance ($\times 10^4$)	-6.4	5.9	8.4	6.1	10

5.4 Mechanism and counterfactuals

Two mechanisms operate in the model. The first is a decline in firm capital demand as the shadow cost of production rises with uncertainty. The second is a decline in households' willingness to invest under that same uncertainty. To isolate each channel we rerun the MIT experiment in five counterfactuals, changing one input at a time and holding the remaining calibrated objects fixed. These counterfactuals are:

(i) set the within-sector diversification cost to zero;
(ii) set the between-sector diversification cost to zero;
(iii) set the liquidation penalty to zero;
(iv) eliminate familiarity persistence;
(v) equalize oil intensity across sectors.

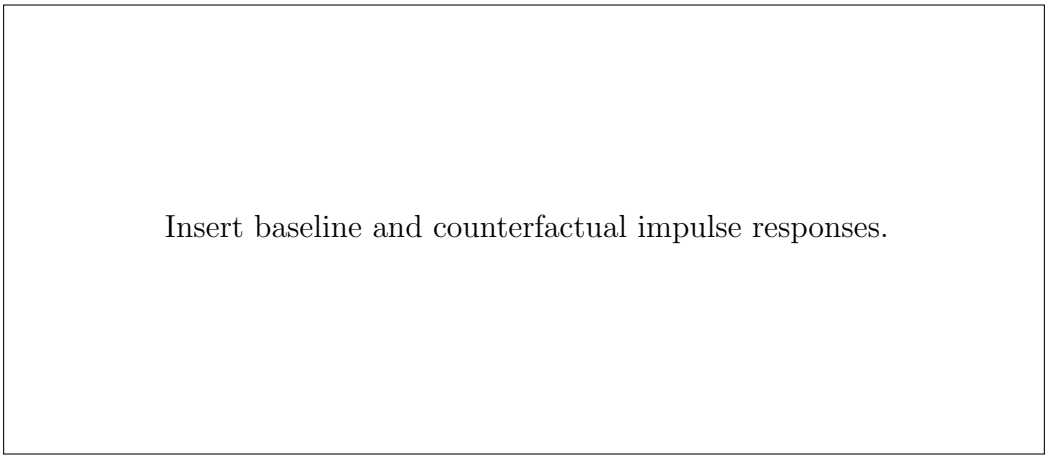


Figure 21: Decomposing the volatility–familiarity mechanism

6 An Almost-Nonlinear Level-k Algorithm for MIT Transitions

The MIT experiments generate nonlinear responses because liquidation probabilities, household portfolio shares, borrowing constraints, and firm input choices move with the level and sign of the shock. We therefore use an almost-nonlinear algorithm that combines level-k learning with local on-impact corrections. Dynamic household and firm policies remain nonlinear conditional on believed paths; linearity is used only to accelerate small contemporaneous market-clearing adjustments.

6.1 Belief levels and the equilibrium fixed point

Let B^k denote the collection of paths believed at level k, including state-contingent wages, sectoral returns, oil prices and dispersion, firm demand scales, and market-clearing prices. Let $\mathcal{S}(B)$ be the nonlinear policy operator and $\mathcal{C}$ the forward simulation and clearing operator. One level of the algorithm is

$$P^k = \mathcal{S}(B^{k-1}), \qquad X^k = \mathcal{C}(P^k, B^{k-1}), \qquad B^k = \mathcal{M}(B^{k-1}, X^k), \tag{23}$$

where $\mathcal{M}$ applies damping and, in later iterations, Gaussian weights over recent levels. Level zero consists of steady-state endogenous paths together with the announced oil-price and volatility paths. At convergence,

$$B^\star = X^\star,$$

so beliefs agree with realized equilibrium outcomes. Level-k is used as a computational fixed-point iteration, not as an assumption that households or firms permanently stop at a finite reasoning level.

6.2 Nonlinear anticipated policies

At each level, households solve their complete policy path backward given the believed paths of wages, sectoral and individual-firm returns, oil prices, and transition probabilities. Consumption, labor, saving, the diversified share, and the sectoral portfolio share are therefore nonlinear policy functions. The household distribution is subsequently propagated forward using realized returns and the nonlinear policy-induced transition matrix.

Firms solve backward policy functions over lagged sectoral capital. For every on-grid current capital choice $K_{s,t}$, the capital first-order condition is inverted to recover the endogenous lagged state $K^{\text{endo}}_{s,t-1}$ that rationalizes that choice. These endogenous points are interpolated back to a fixed lagged-capital grid. Post-horizon policies use a cached steady-state continuation. The baseline MIT exercises set

$$\boxed{\kappa_K = 0}.$$

Positive capital-adjustment costs are reserved for robustness exercises; oil and labor planning costs remain active.

6.3 On-impact response banks

Re-solving both dynamic programs after every small within-period price update would be prohibitively expensive. Before the level iteration, we therefore place standardized innovations at an interior date, $T_{\text{shock}} = 50$, and compute normalized one-step response banks:

$$J_{\text{oi}}^{HH} = \frac{\partial(x, W', d, \theta, n)}{\partial(w_j, R_j^H, R_j^L, \text{wealth})}, \qquad J_{\text{oi}}^{F} = \frac{\partial(K, R, w, L, O, Y)}{\partial(\text{wage ladder}, \bar{R}, \text{firm scale})}. \tag{24}$$

If current clearing inputs differ only slightly from the believed inputs, a policy object g is corrected locally:

$$g^{\text{current}} \approx g^{\text{belief}} + J_{\text{oi}}\Delta. \tag{25}$$

The firm policy is first interpolated at realized lagged capital and then corrected. If return-induced wealth revaluation exceeds the admissible local range, the household distribution transition is rebuilt using realized returns instead of relying on the local correction.

6.4 Forward clearing and belief updating

Within each date, the algorithm iterates on the wage ladder to close state-contingent labor gaps, on sectoral claim prices to close the two capital markets, and on the firm demand scale to close the goods market. It then advances sectoral capital and the household distribution. Expected sectoral returns are recovered from claim prices and next-period payoffs. The resulting cleared paths become the input to the next belief level.

6.5 Algorithm summary

Step 1. Construct level-zero beliefs from steady-state endogenous paths and the announced paths for $\bar{p}_t^o$ and $\sigma_{\nu,t}$.

Step 2. Precompute household and firm on-impact response banks at the interior shock date.

Step 3. Given level-$(k-1)$ beliefs, solve nonlinear household policies backward and nonlinear firm capital policies by backward inversion.

Step 4. Starting from the initial distribution and capital stocks, clear wages, claim markets, and the firm demand scale date by date using local on-impact corrections.

Step 5. Propagate the household distribution and sectoral capital forward, rebuilding transitions whenever wealth revaluation leaves the local range.

Step 6. Convert cleared outcomes into level-k belief paths and update them with damping and recent-level weighting.

Step 7. Repeat until the maximum normalized belief distance and all market residuals satisfy their tolerances.

The procedure preserves nonlinear anticipated policy responses, exact liquidation probabilities, portfolio corners, and the dependence of realized wealth on returns. Its approximation is confined to local contemporaneous corrections inside each date's clearing loop. This compromise is substantially cheaper than repeatedly resolving both dynamic programs after every price update while retaining the nonlinearities needed to compare large positive and negative oil shocks.

7 Conclusion

This paper proposes a portfolio-based explanation for the asymmetric transmission of oil-price shocks. Oil-price volatility raises idiosyncratic firm-return risk, especially in oil-intensive production. Employment-linked familiarity and costly diversification prevent households from costlessly neutralizing this risk. Investment consequently falls across sectors, productive capacity contracts, and the favorable effect of an oil-price decline is attenuated while the adverse effect of a price increase is amplified.

The framework connects three objects typically studied separately: oil-price uncertainty, firm-level distress, and household portfolio concentration. Its nonlinear solution is important because liquidation, borrowing constraints, and portfolio corners cannot be summarized adequately by first-order dynamics. Future revisions will discipline the empirical shock process and portfolio parameters more tightly and use microdata to test the predicted interaction between oil intensity, ownership concentration, and firm investment.

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A Figures

The figures below provide the descriptive context and additional specifications referenced in Section 2. Shock signs and normalizations match the corresponding main-text exercises. Monthly regressions use complete observations without interpolation; inference retains the calendar spacing across missing or excluded observations.

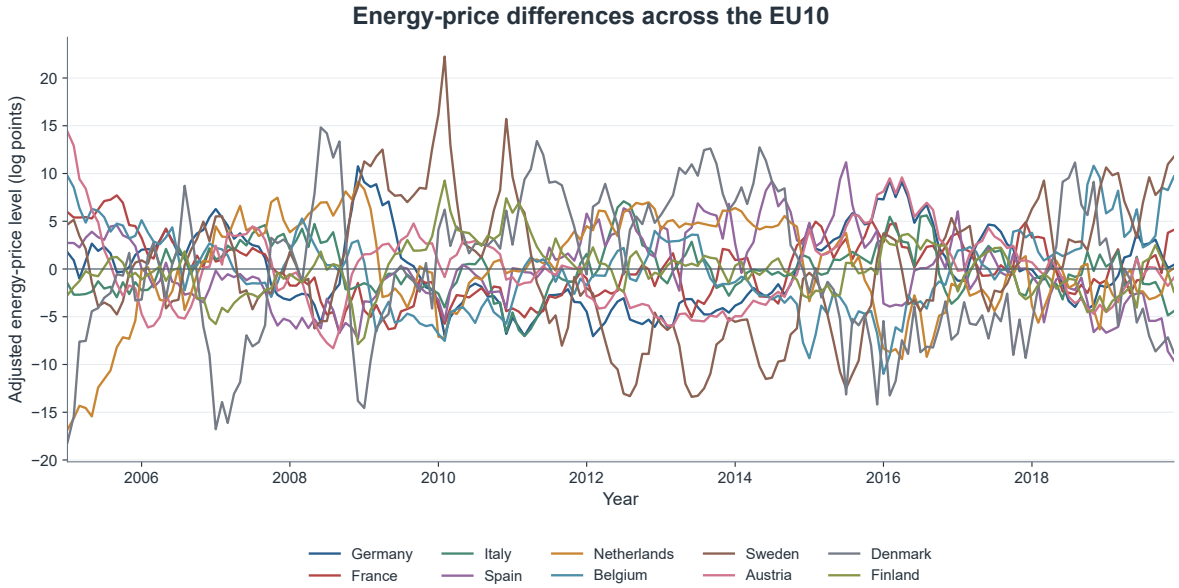


Figure 22: EU10 domestic energy-price residuals, 2005–2019, after country and month fixed effects and country-specific linear trends.

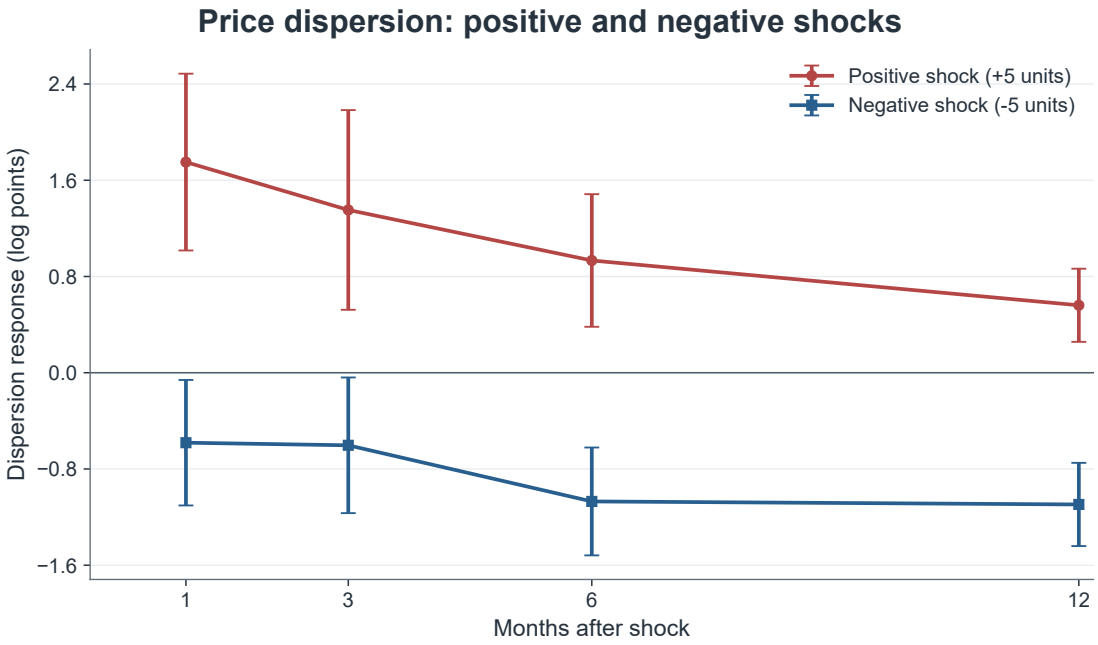


Figure 23: Future EU10 energy-price dispersion after positive and negative five-unit supply shocks, estimated jointly. Bars show pointwise 68% intervals.

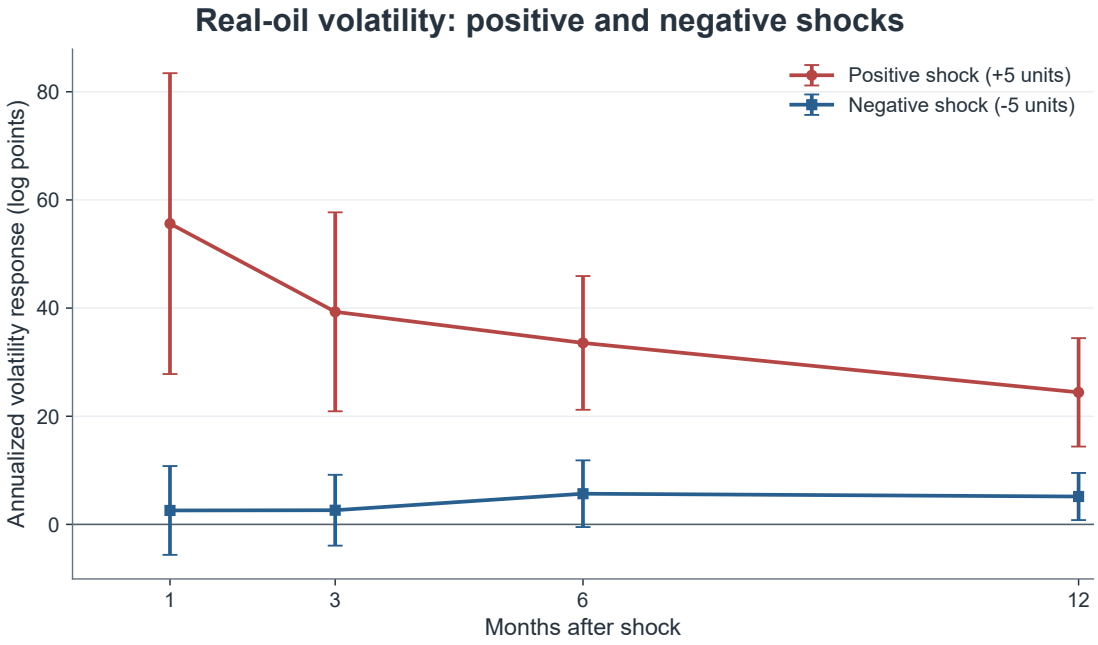


Figure 24: Future annualized real-oil volatility after positive and negative five-unit supply shocks, estimated jointly. Bars show pointwise 68% intervals.

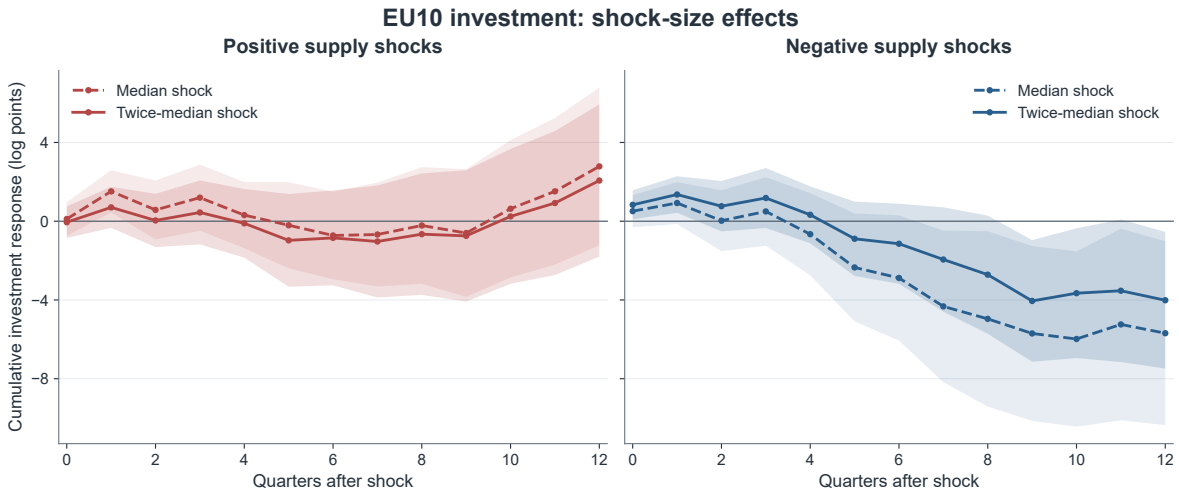


Figure 25: EU10 investment responses at the median and twice-median shock magnitudes in a continuous threshold specification. Shading shows pointwise 90% intervals.

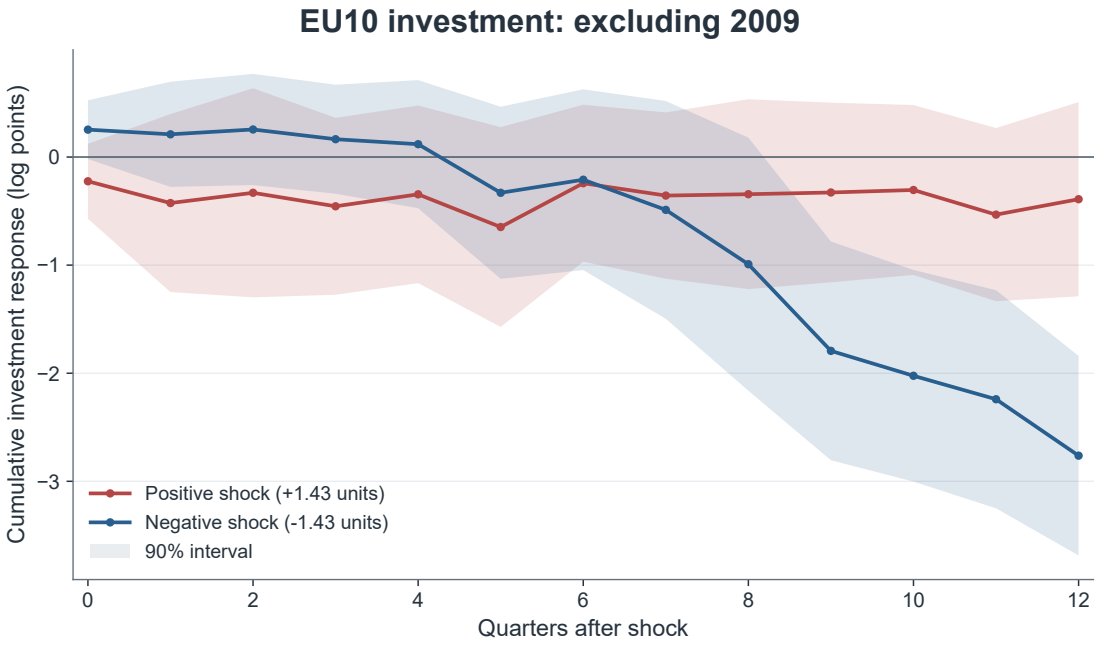


Figure 26: EU10 investment responses excluding 2009 shock-origin quarters, with the full-sample reference magnitude held fixed. Shading shows pointwise 90% intervals.

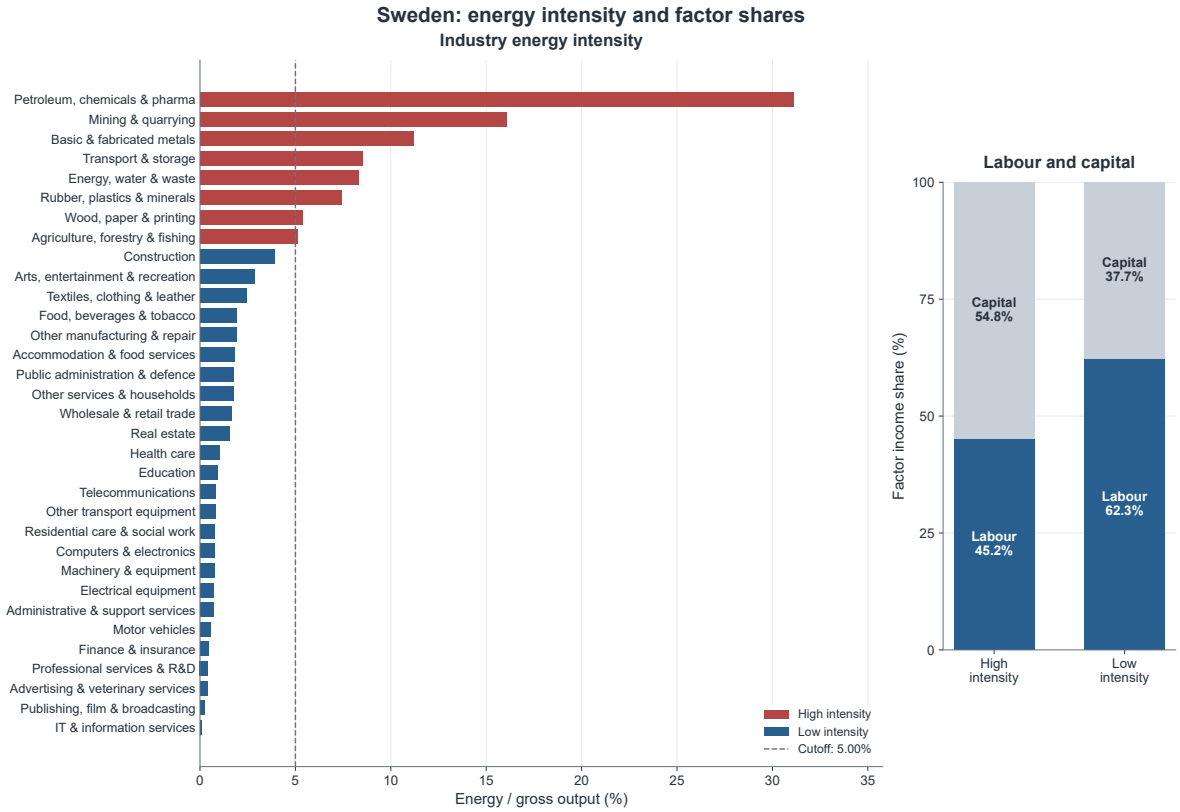


Figure 27: Swedish industry energy intensity and normalized labour and capital income shares. Classification uses 2015–2019 energy purchases relative to gross output and a 5% cutoff.

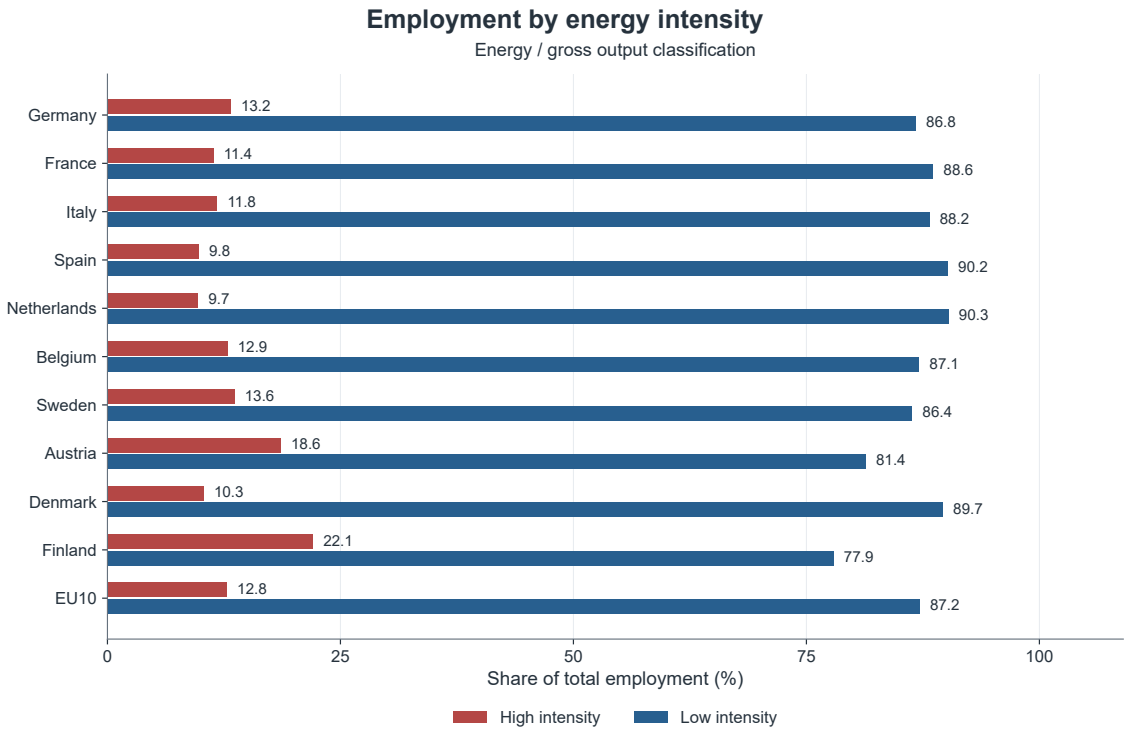


Figure 28: Employment shares of high- and low-energy-intensity groups, using the energy-purchases-to-gross-output classification.

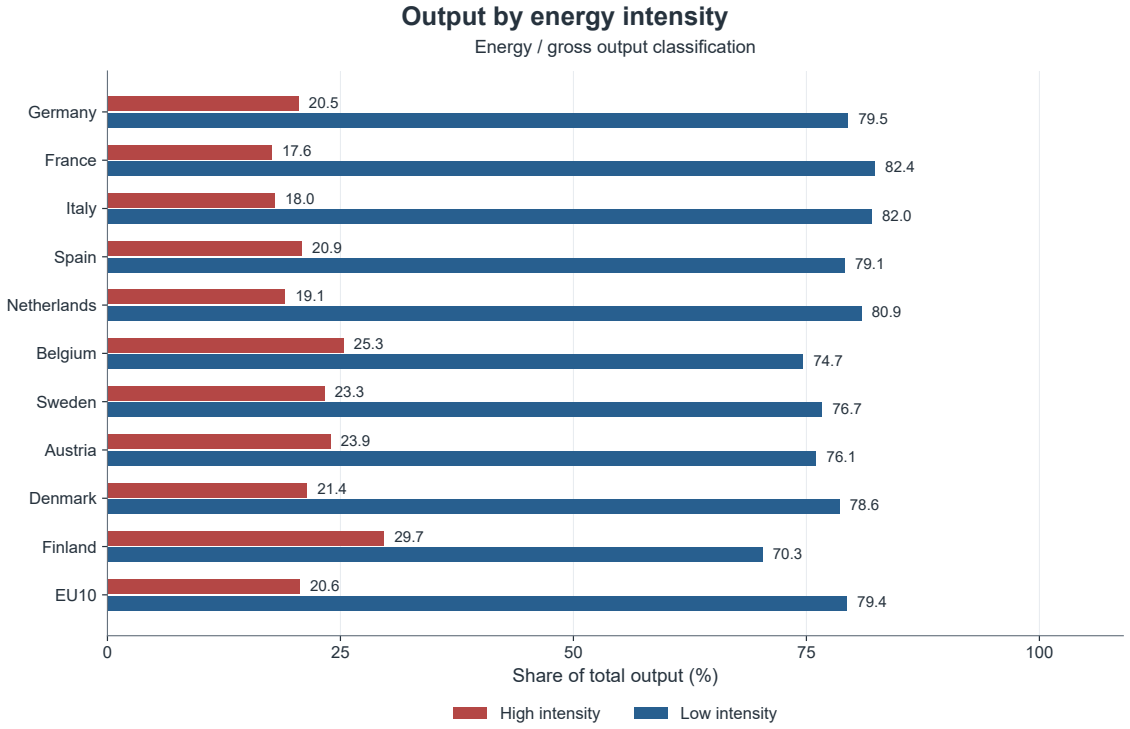


Figure 29: Gross-output shares of high- and low-energy-intensity groups, using the energy-purchases-to-gross-output classification.

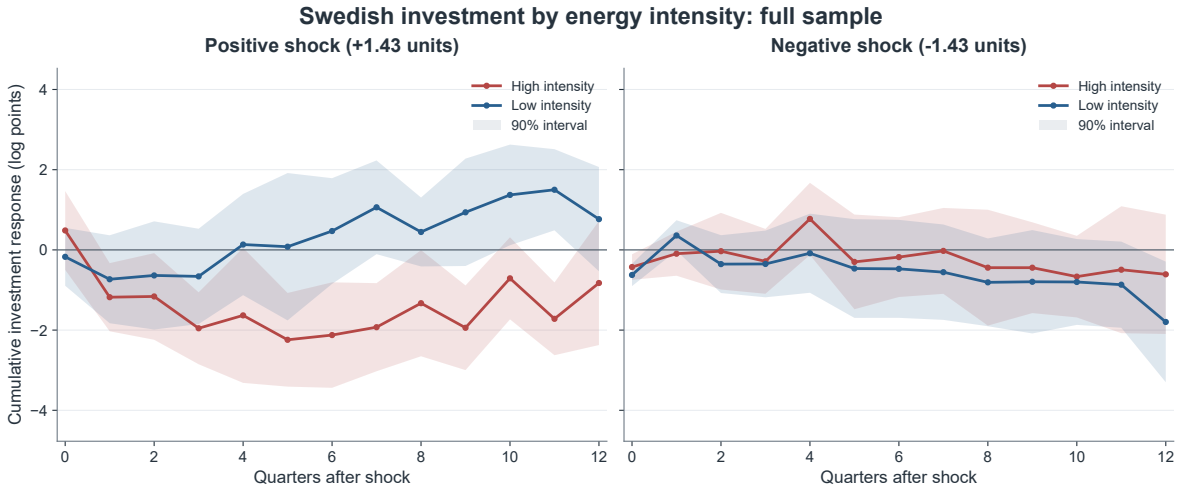


Figure 30: Swedish investment responses by energy intensity with data through 2026Q2. Groups and the reference shock magnitude are held fixed. Shading shows pointwise 90% intervals.

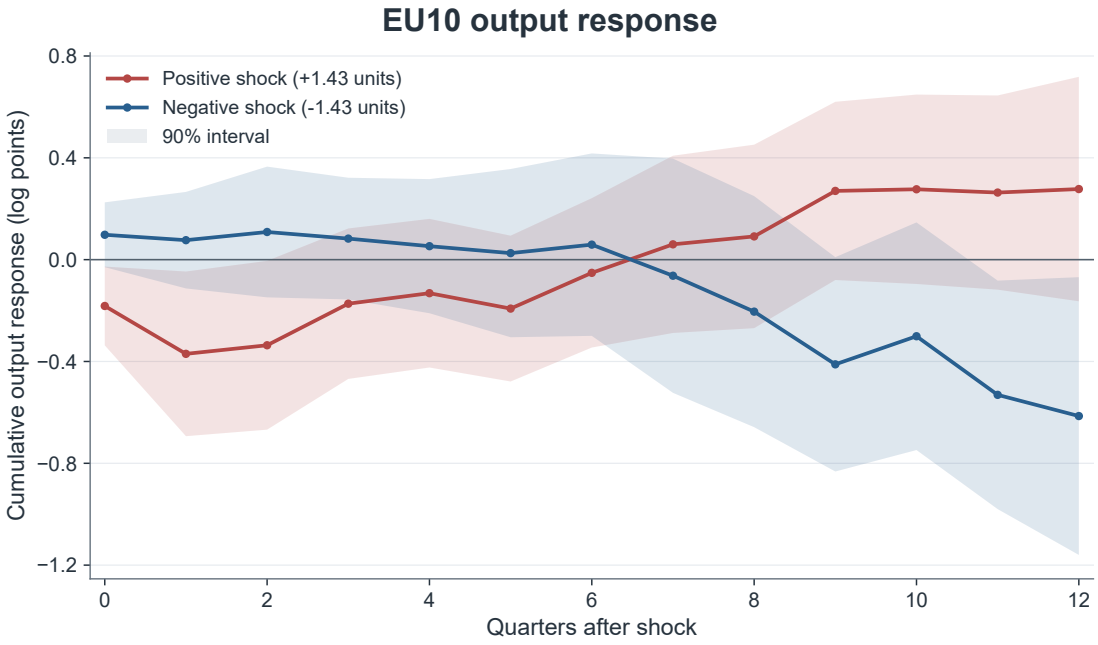


Figure 31: Cumulative EU10 real-GDP responses using the aggregate investment specification's controls and shock magnitude. Shading shows pointwise 90% intervals.

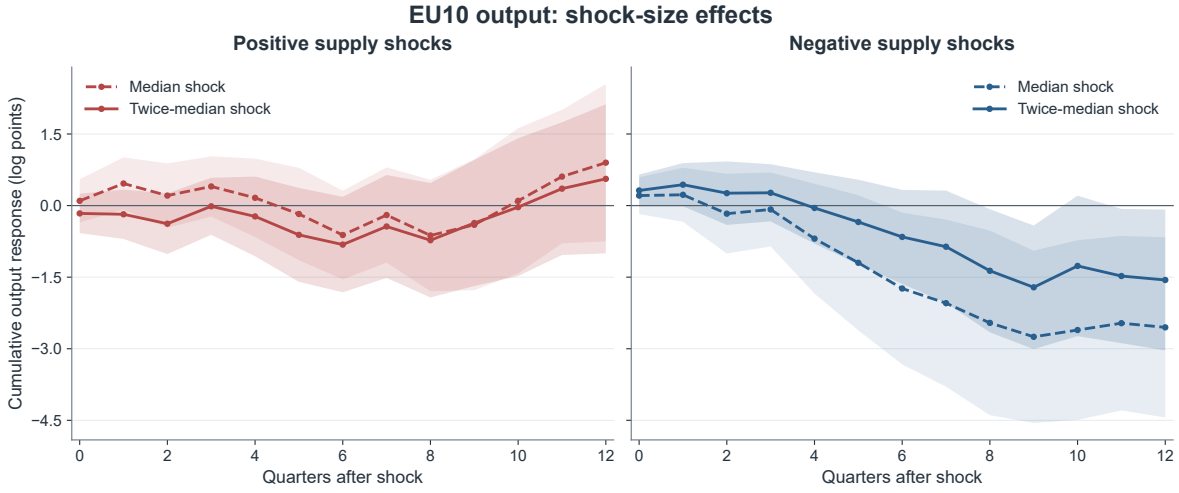


Figure 32: EU10 real-GDP responses at the median and twice-median shock magnitudes in a continuous threshold specification. Shading shows pointwise 90% intervals.

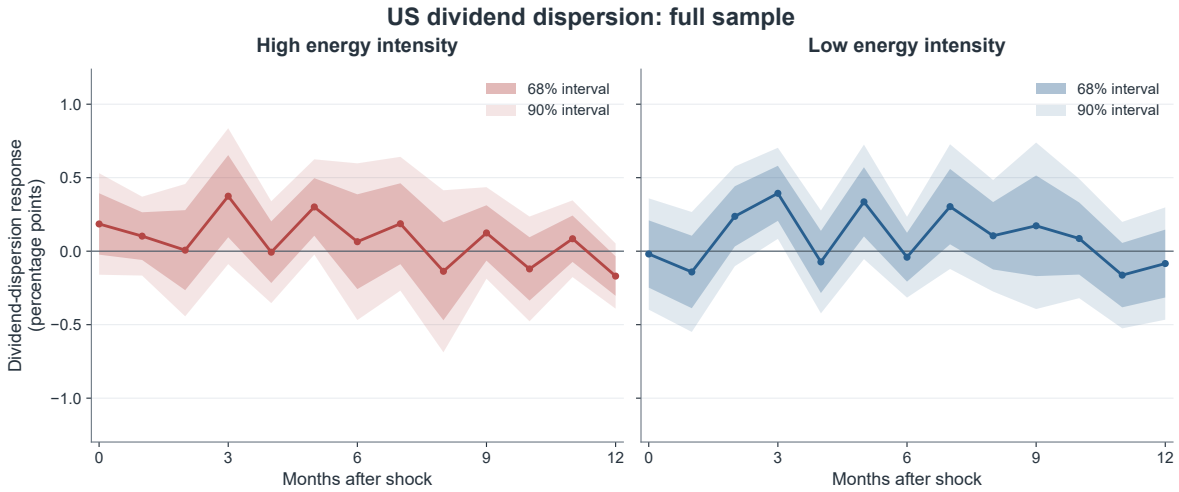


Figure 33: U.S. dividend-dispersion responses using the full sample, including 1998–2001 and 2020. Dark and light shading show pointwise 68% and 90% intervals.

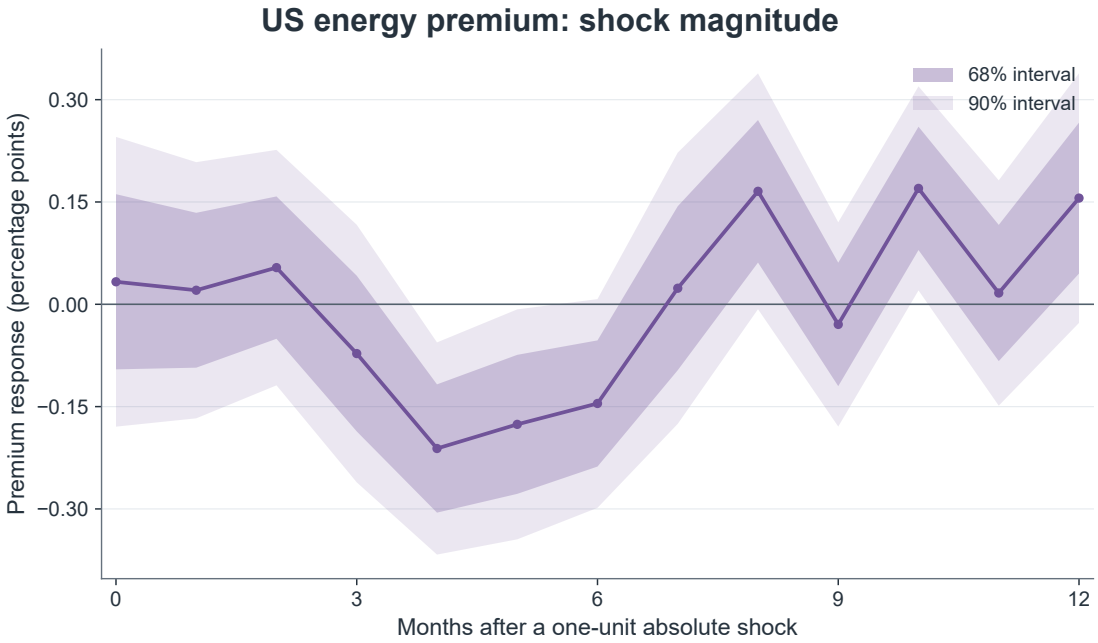


Figure 34: U.S. energy-intensity return-premium responses to a one-unit increase in absolute supply-shock magnitude. Dark and light shading show pointwise 68% and 90% intervals.

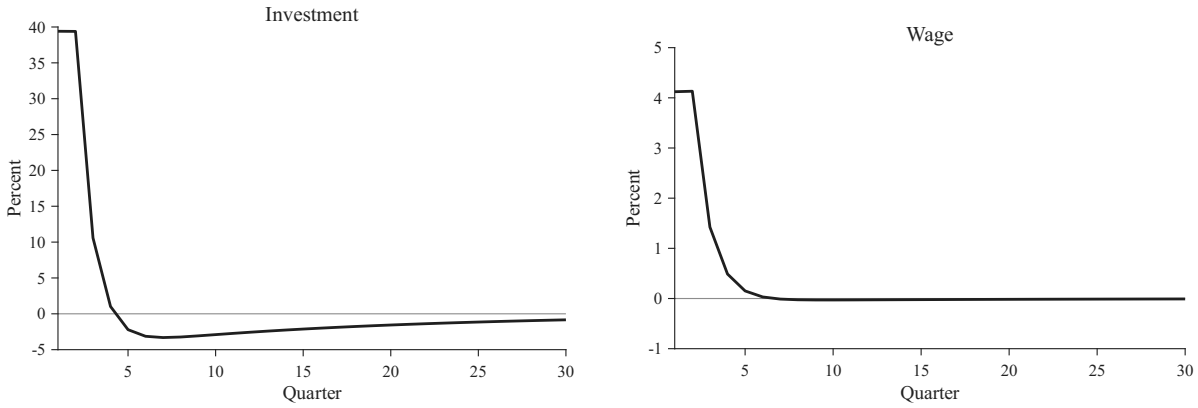
B Additional MIT Impulse Responses

Section 5 reports a subset of the series written by the MIT plotters. The figures below use the same folders and file names as `plot_HANC_MIT_results.m` and `plot_HANC_MIT_compare.m`: `oil_shock`, `gdp`, `total_capital`, `sectoral_capital`, `investment`, `wage`, `labor`, `returns`, `liquidation_rate`, and `idio_variance`. Paths remain `faculty macro mock/images/<folder>/`.

B.1 Remaining series for the main-text experiments

The main text shows the shock path, GDP, total capital, idiosyncratic variance, and sectoral capital for MIT1, MIT2, and MIT4, and the shock path, GDP, and total capital for the two comparisons. The remaining series appear here.

B.1.1 MIT1: Decrease in average prices



(a) Investment response

(b) Wage response

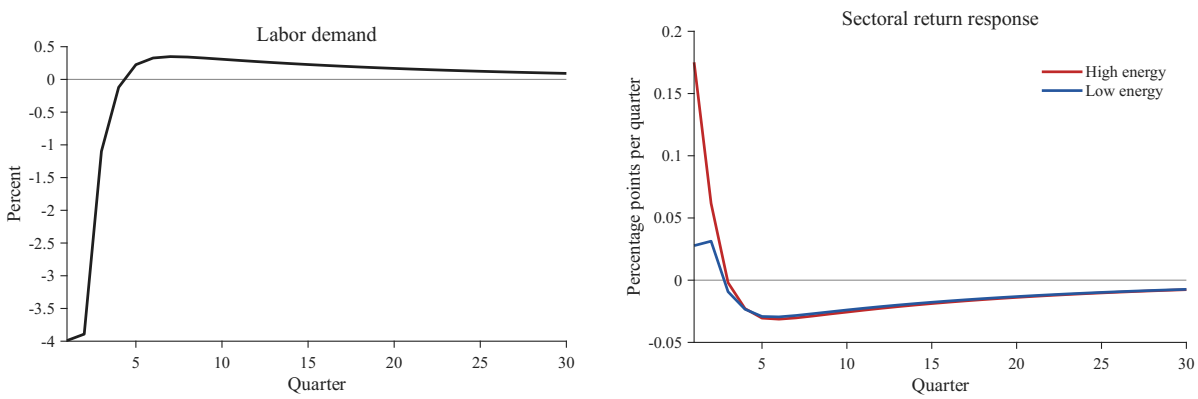
Figure 35: Investment and wage responses to a decrease in average oil price

B.1.2 MIT2: Increase in average prices

B.1.3 MIT4: Increase in volatility

B.1.4 MIT1 versus MIT9: Volatility in a price decline

B.1.5 MIT2 versus MIT10: Volatility in a price increase



(a) Labor response (b) Return response

Figure 36: Labor and return responses to a decrease in average oil price

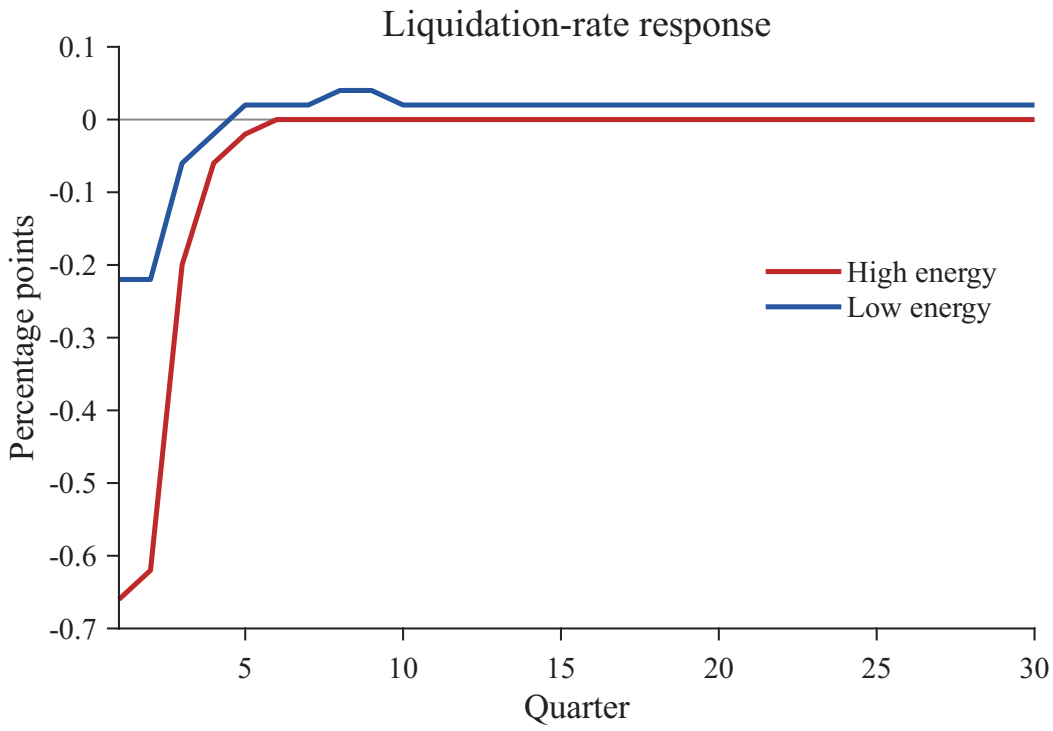
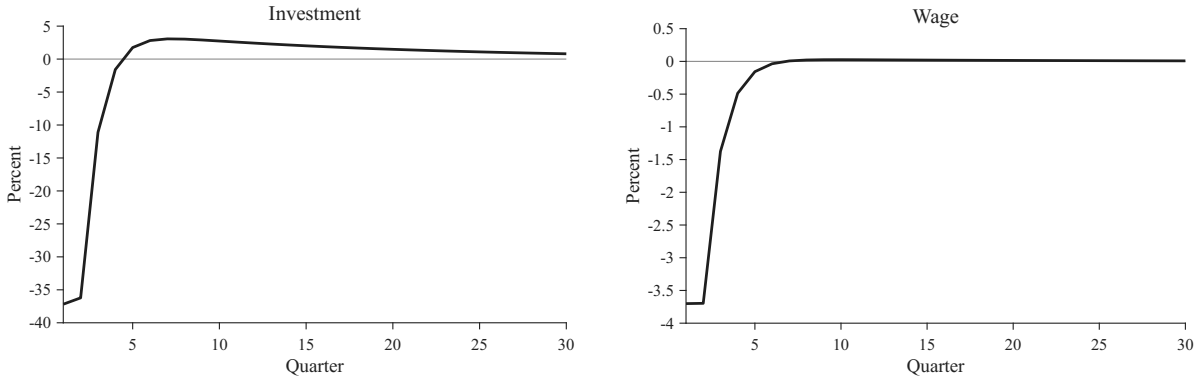
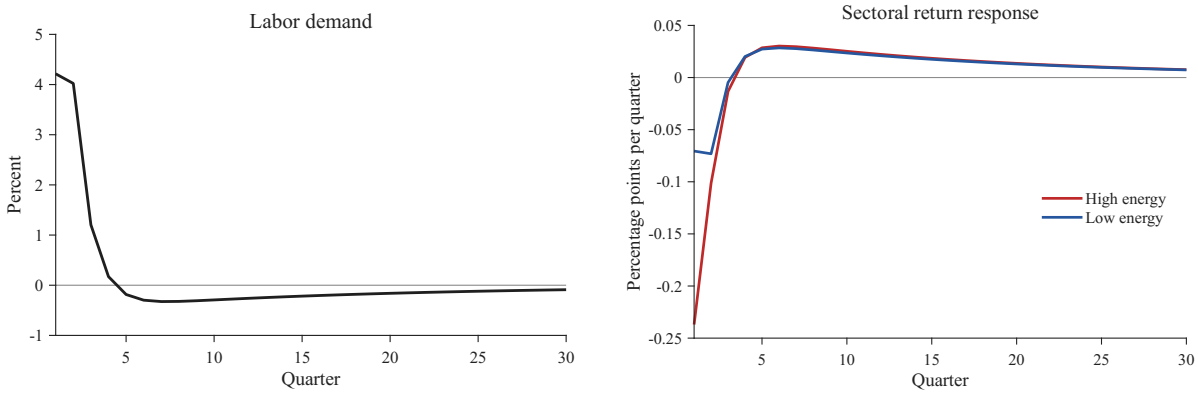


Figure 37: Liquidation-rate response to a decrease in average oil price



(a) Investment response (b) Wage response

Figure 38: Investment and wage responses to an increase in average oil price



(a) Labor response (b) Return response

Figure 39: Labor and return responses to an increase in average oil price

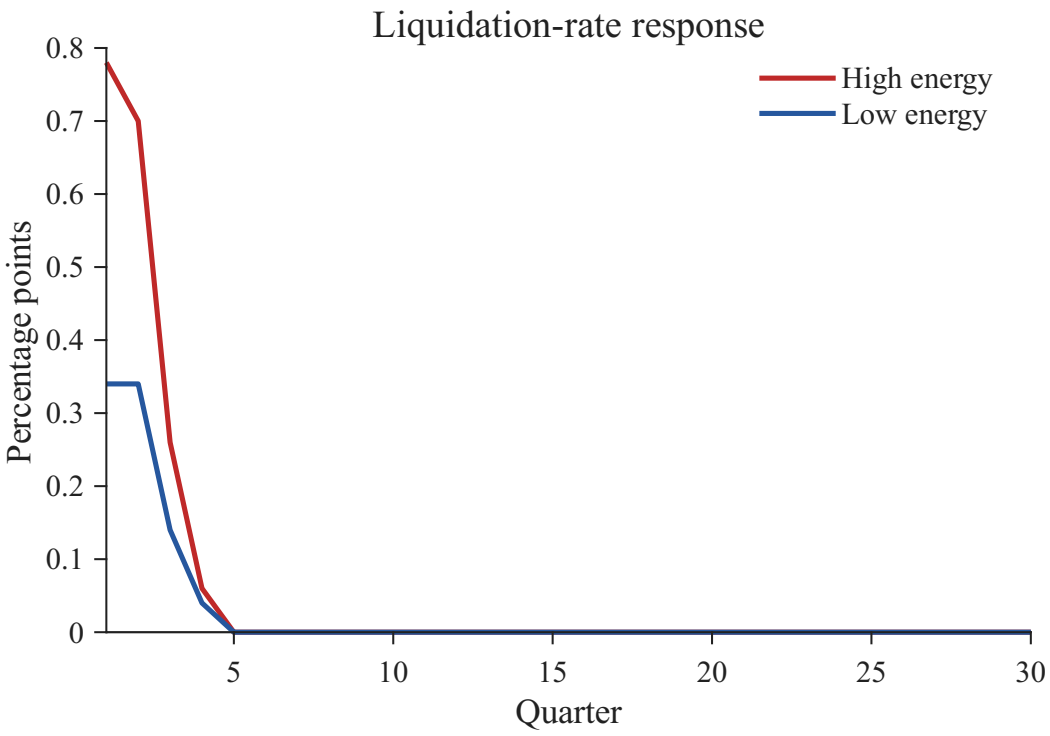
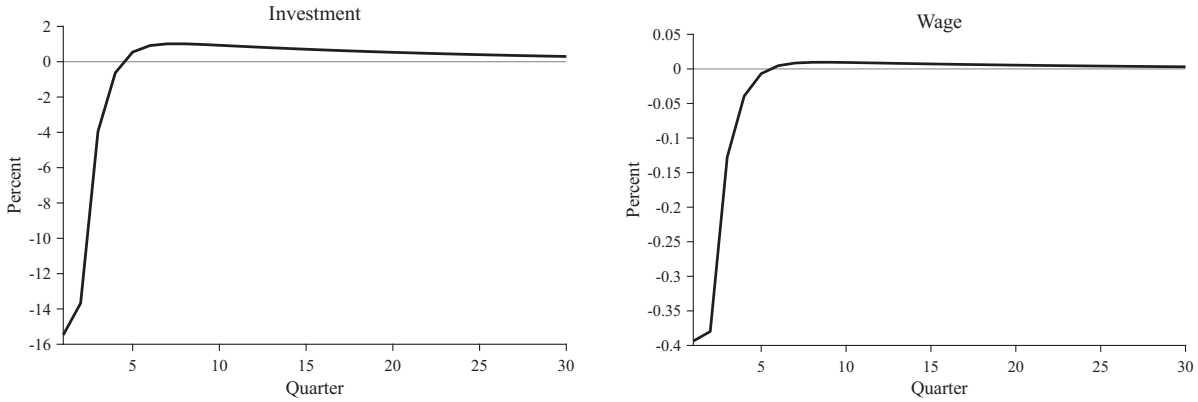


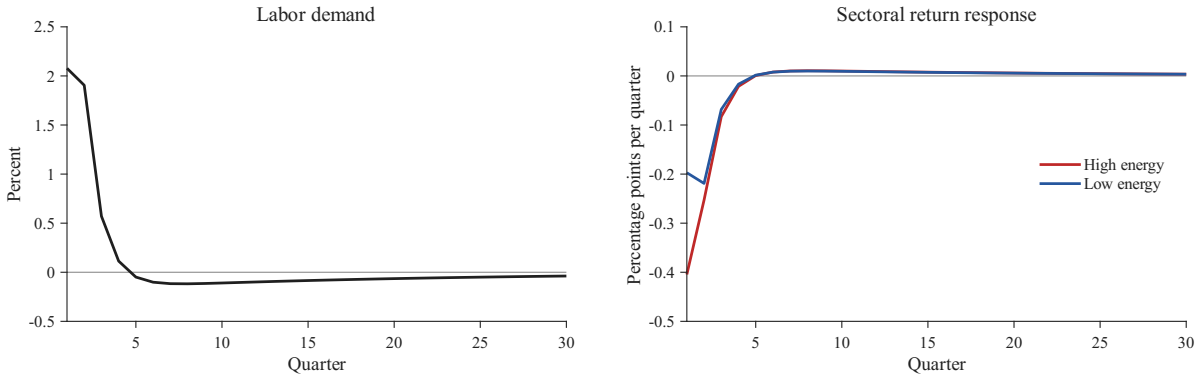
Figure 40: Liquidation-rate response to an increase in average oil price



(a) Investment response

(b) Wage response

Figure 41: Investment and wage responses to an increase in volatility



(a) Labor response (b) Return response

Figure 42: Labor and return responses to an increase in volatility

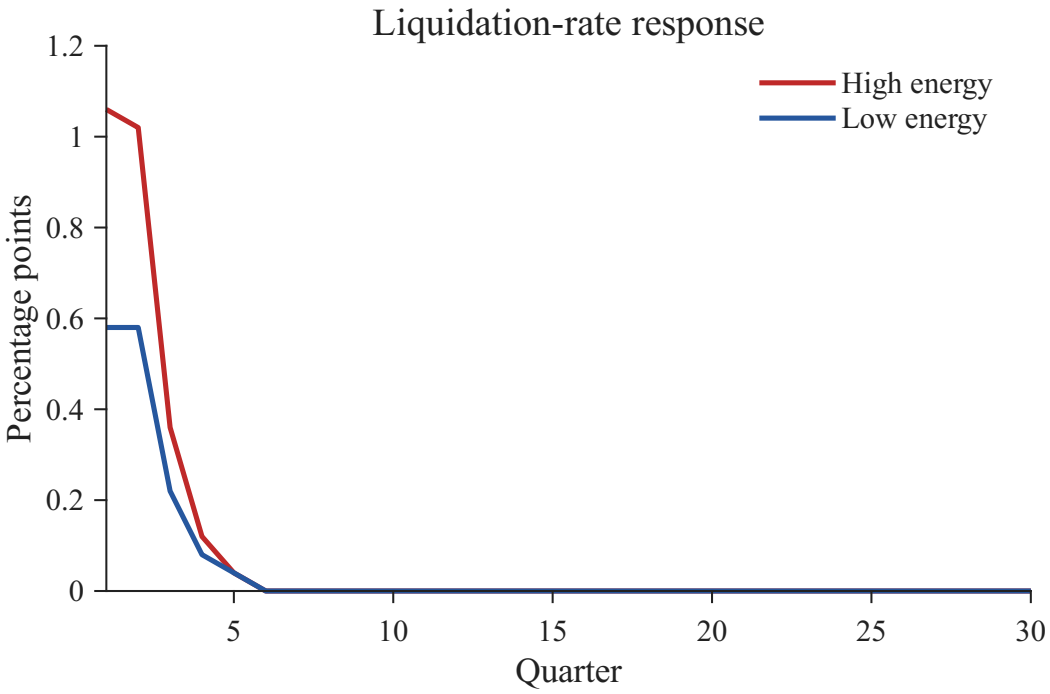
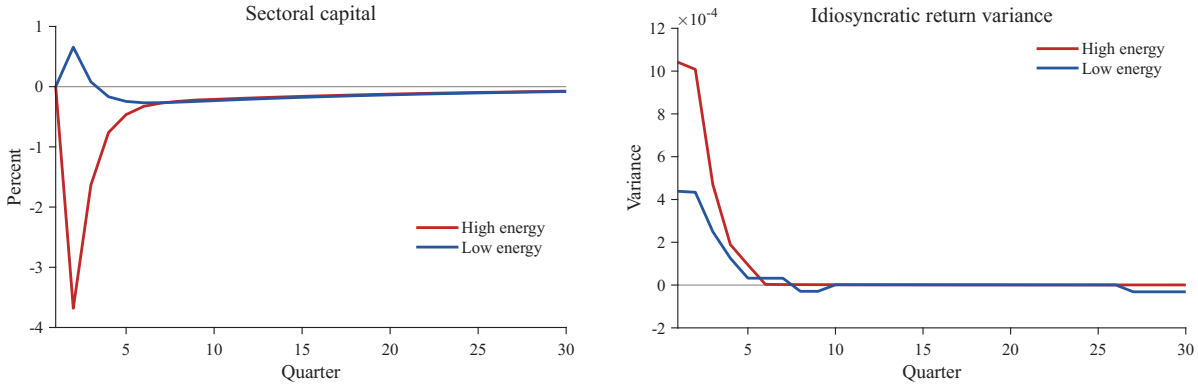
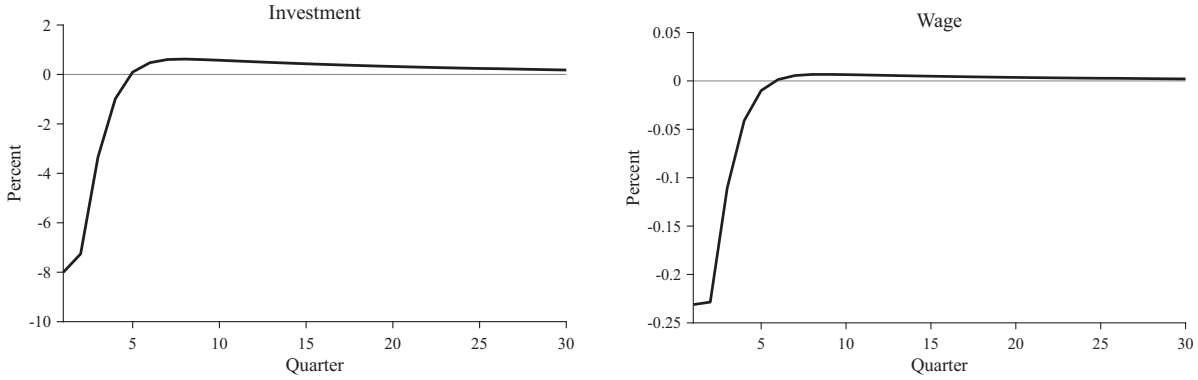


Figure 43: Liquidation-rate response to an increase in volatility



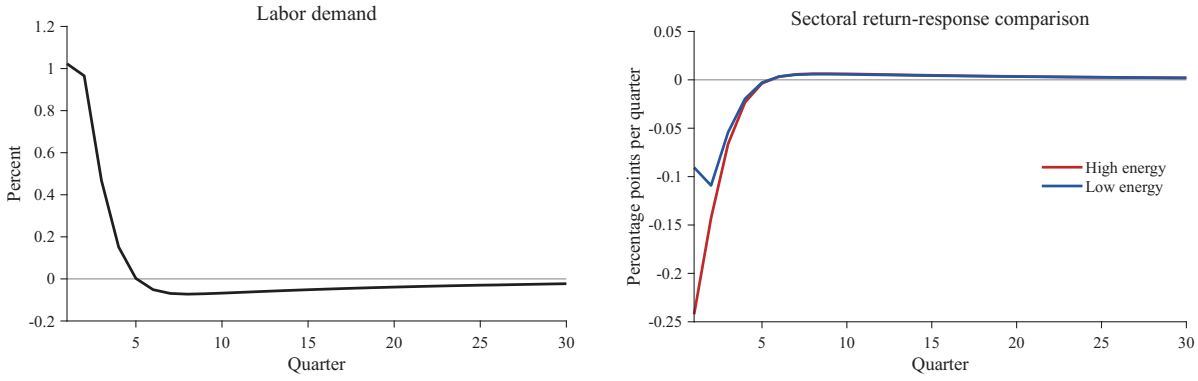
(a) Sectoral capital response (b) Variance response

Figure 44: Difference in sectoral responses to a price decline with and without a volatility shock



(a) Investment response (b) Wage response

Figure 45: Difference in investment and wage responses to a price decline with and without a volatility shock



(a) Labor response (b) Return response

Figure 46: Difference in labor and return responses to a price decline with and without a volatility shock

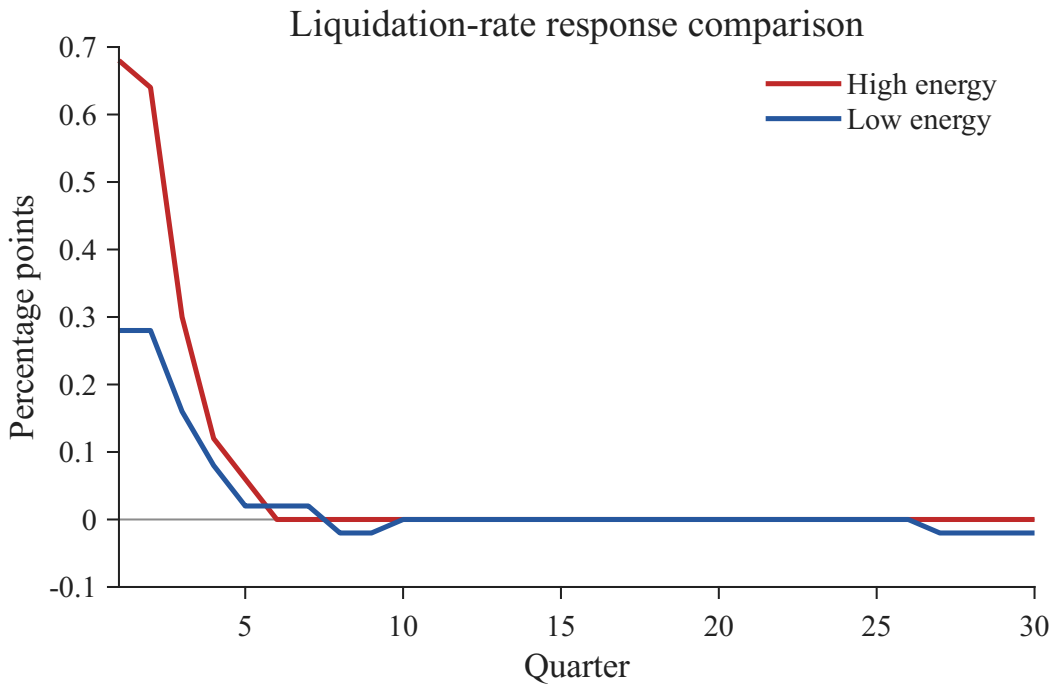
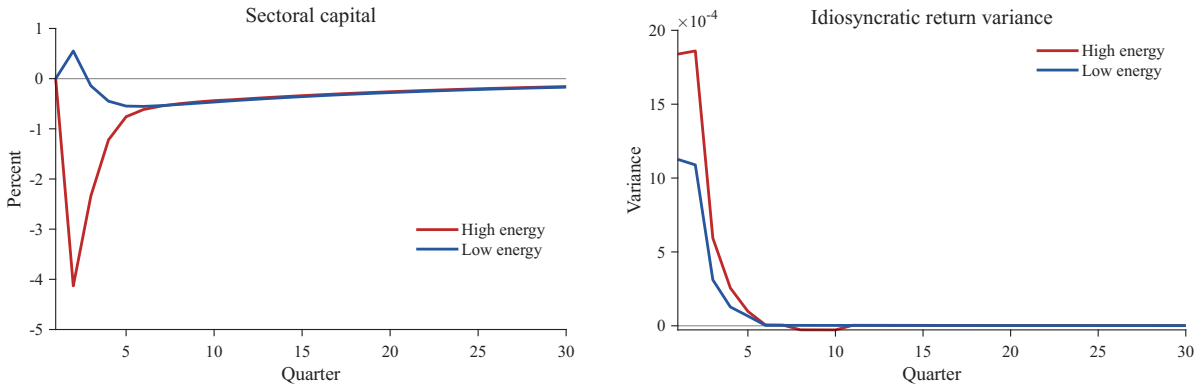


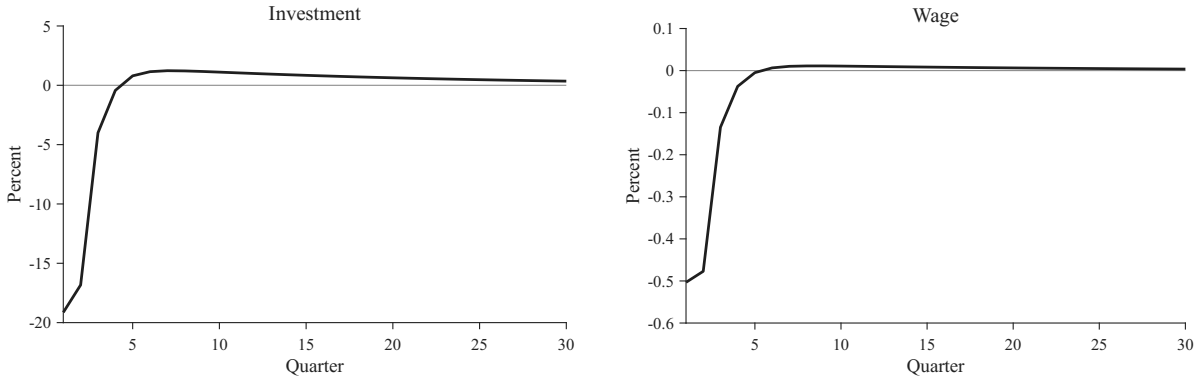
Figure 47: Difference in the liquidation-rate response to a price decline with and without a volatility shock



(a) Sectoral capital response

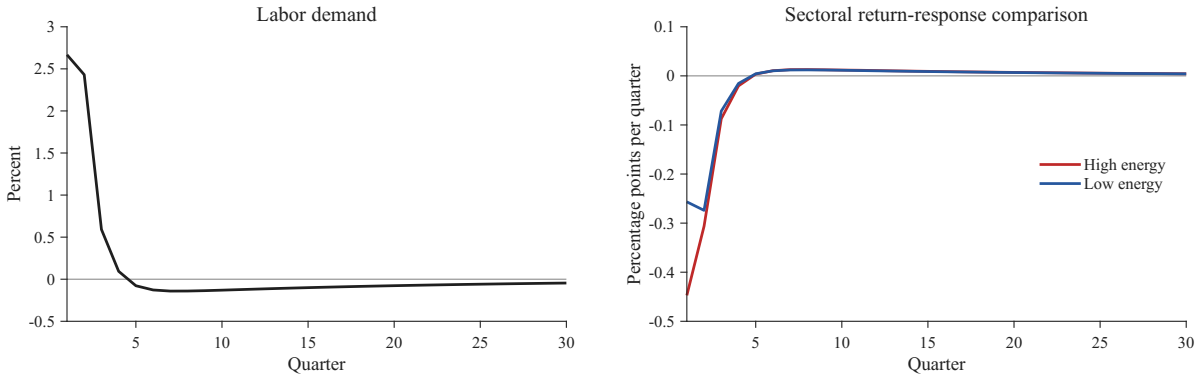
(b) Variance response

Figure 48: Difference in sectoral responses to a price increase with and without a volatility shock



(a) Investment response (b) Wage response

Figure 49: Difference in investment and wage responses to a price increase with and without a volatility shock



(a) Labor response (b) Return response

Figure 50: Difference in labor and return responses to a price increase with and without a volatility shock

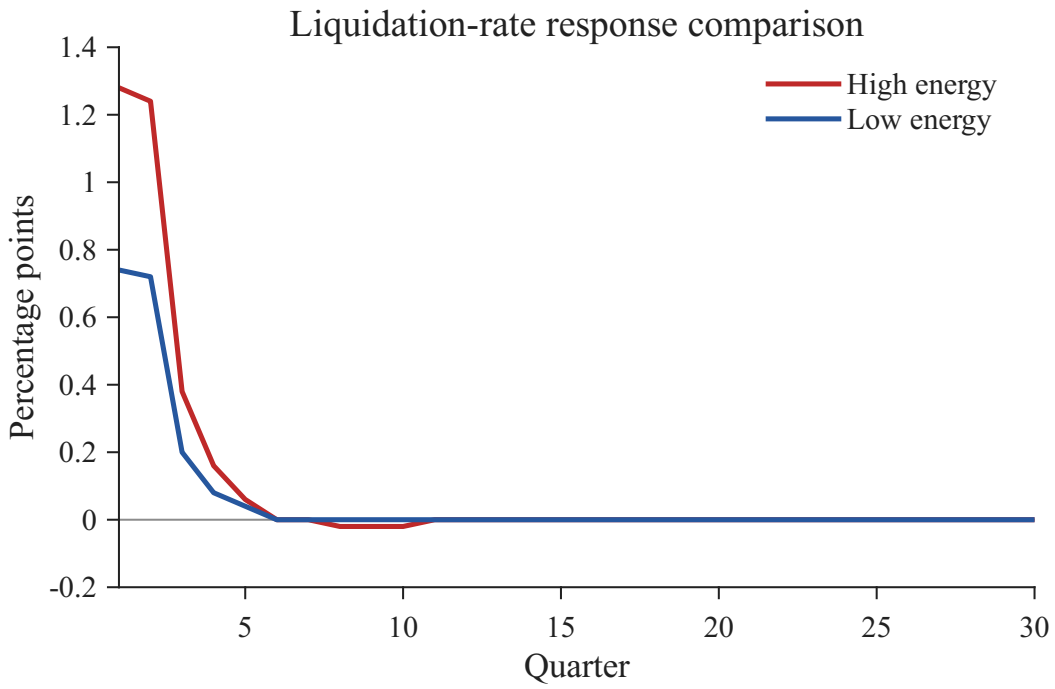


Figure 51: Difference in the liquidation-rate response to a price increase with and without a volatility shock

B.2 Additional MIT scenarios

The remaining MIT files are reported in full, using the scenario names and numbers from the experiment list.

B.3 MIT3: Large variance shock

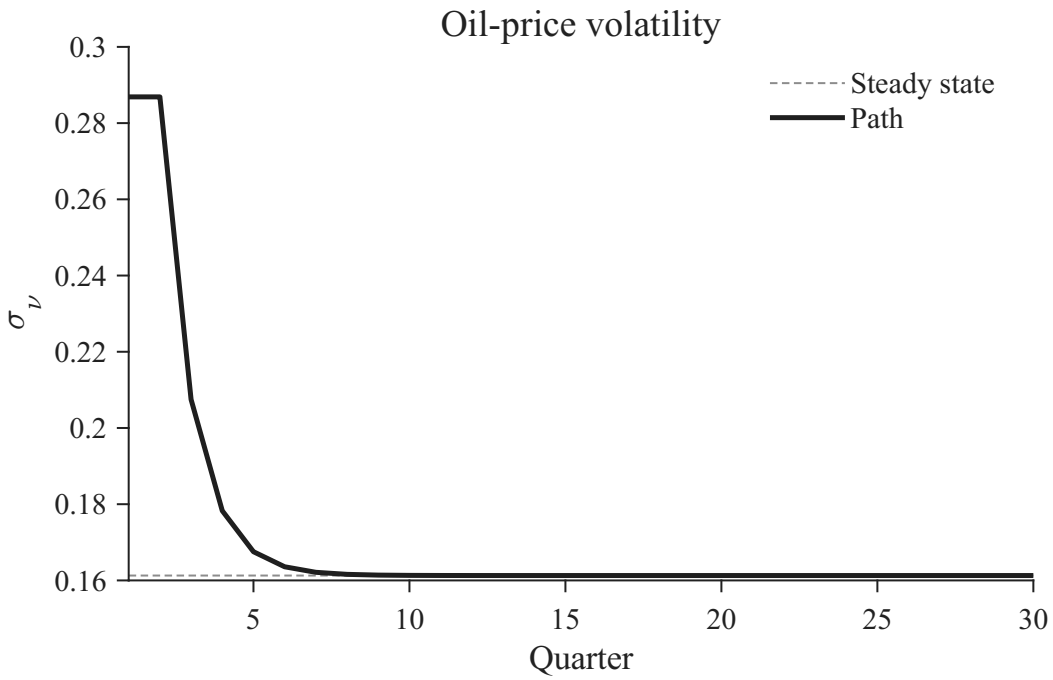
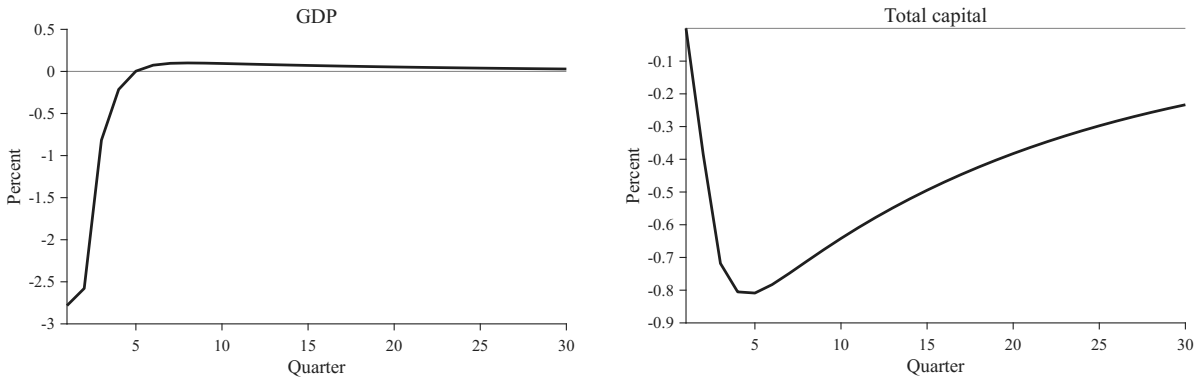


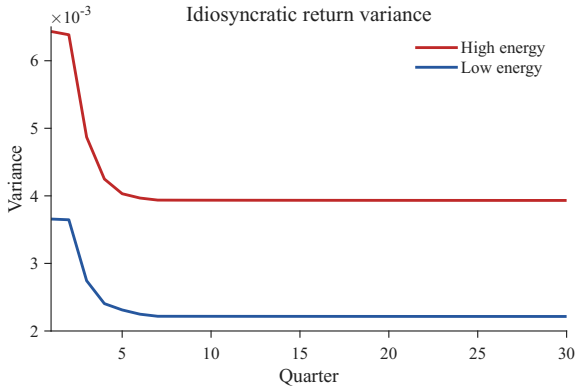
Figure 52: Shock path



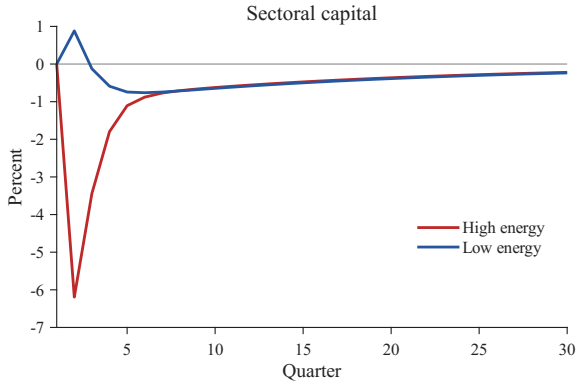
(a) GDP response

(b) Capital response

Figure 53: Aggregate responses

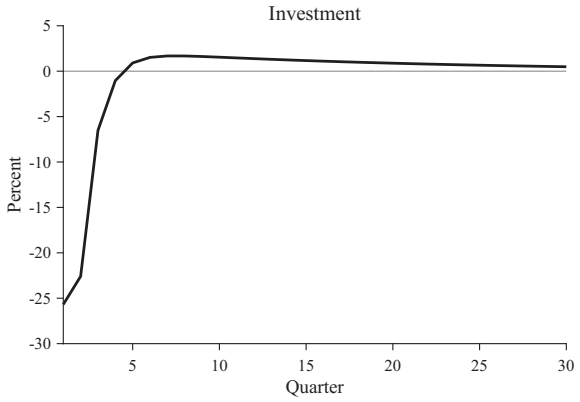


(a) Variance response

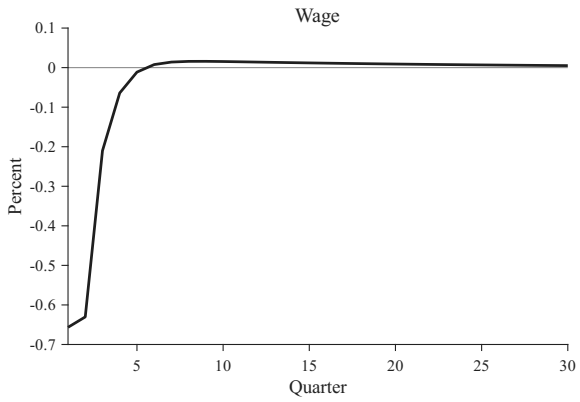


(b) Sectoral capital response

Figure 54: Sectoral responses

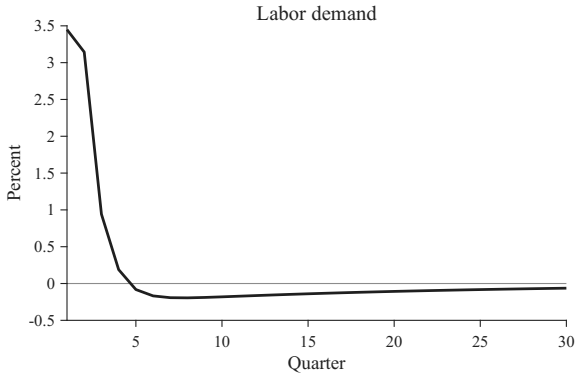


(a) Investment response

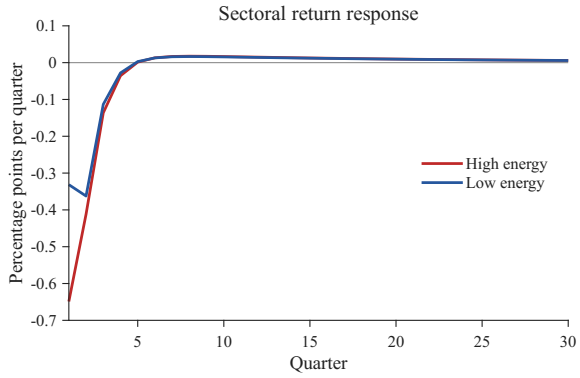


(b) Wage response

Figure 55: Investment and wage



(a) Labor response



(b) Return response

Figure 56: Labor and returns

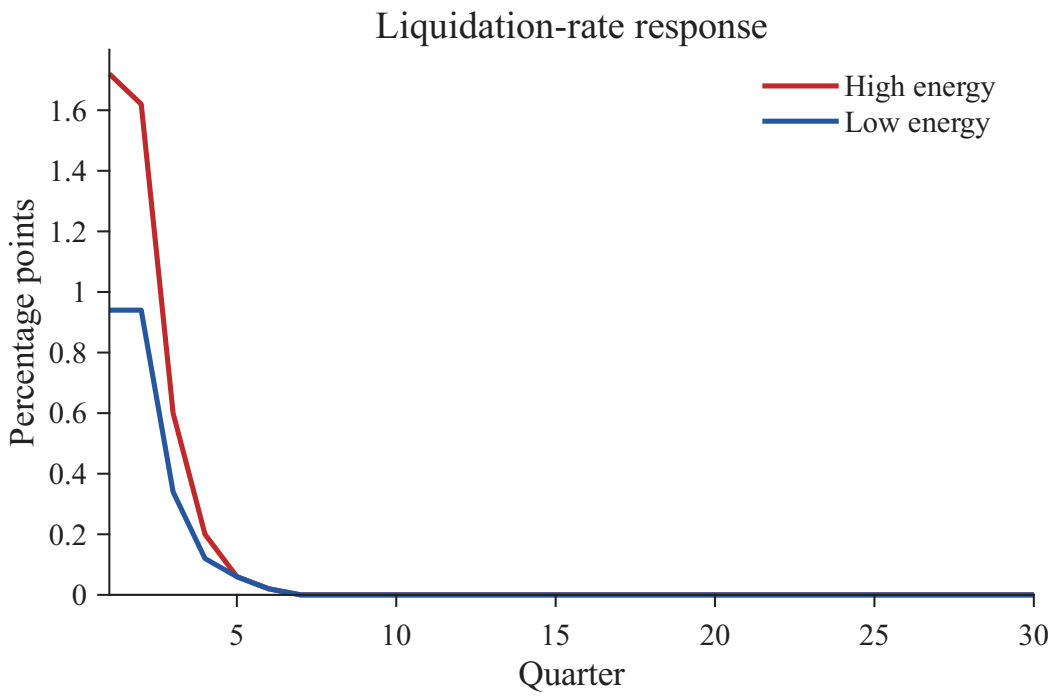


Figure 57: Liquidation-rate response

B.4 MIT5: Variance shock with medium duration

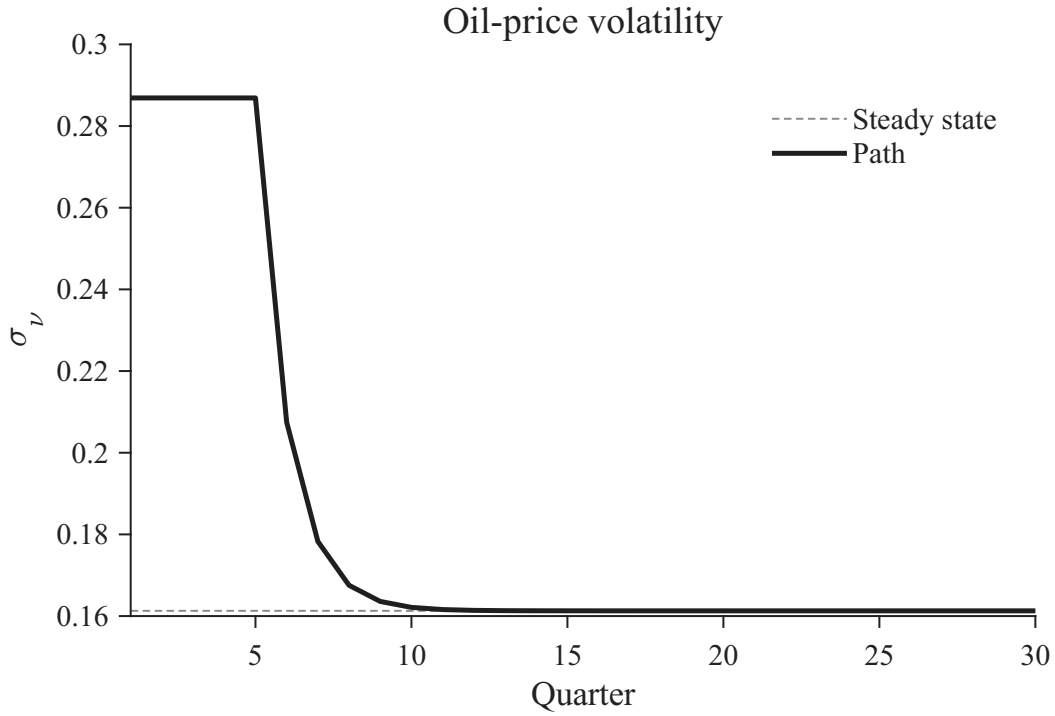
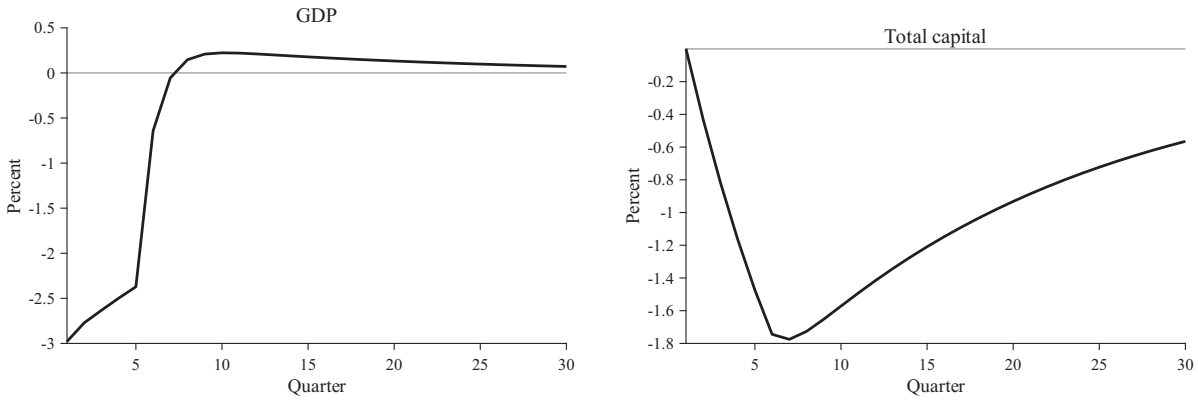


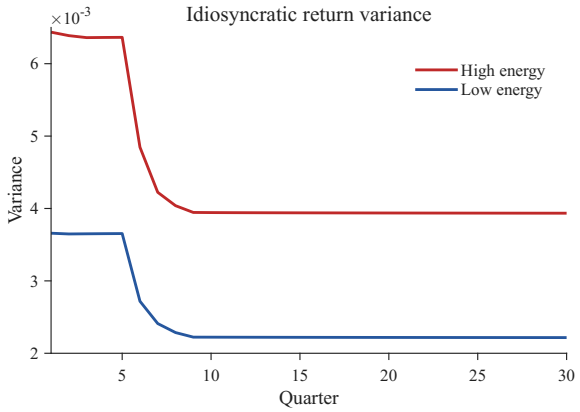
Figure 58: Shock path



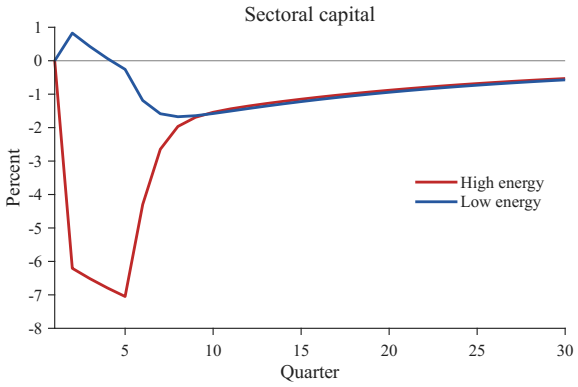
(a) GDP response

(b) Capital response

Figure 59: Aggregate responses

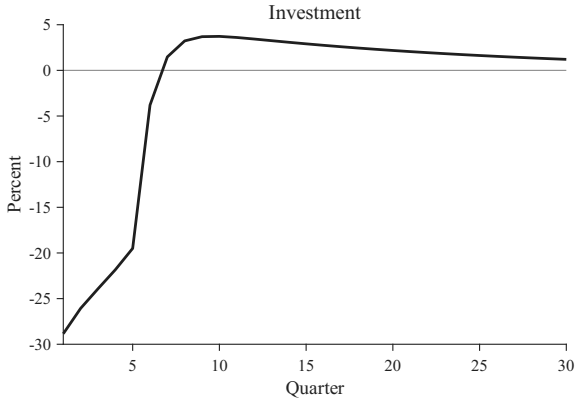


(a) Variance response



(b) Sectoral capital response

Figure 60: Sectoral responses

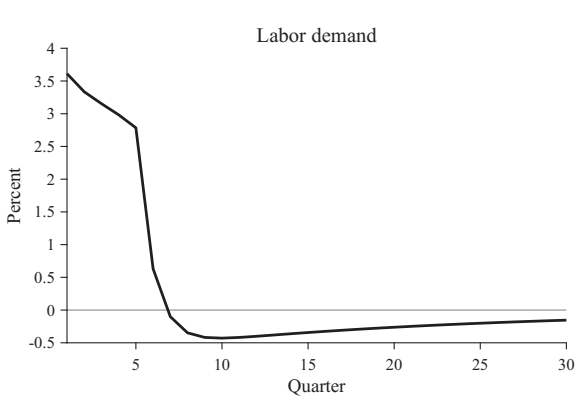


(a) Investment response

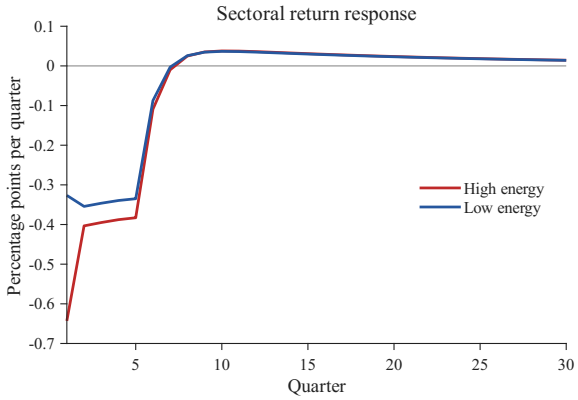


(b) Wage response

Figure 61: Investment and wage



(a) Labor response



(b) Return response

Figure 62: Labor and returns

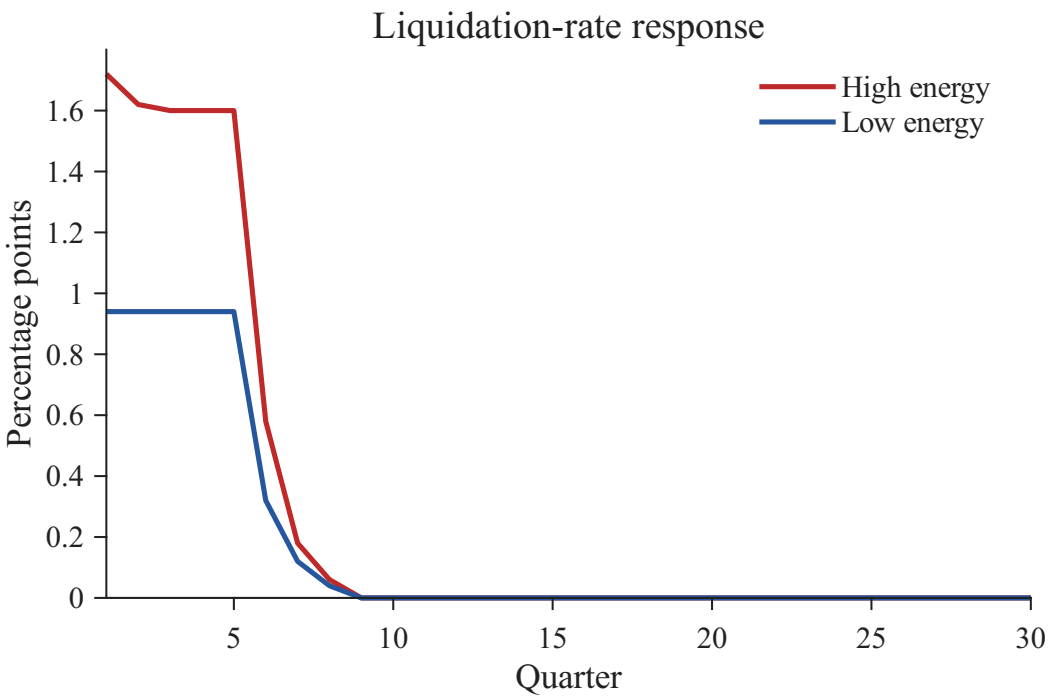


Figure 63: Liquidation-rate response

B.5 MIT6: Variance shock with high duration

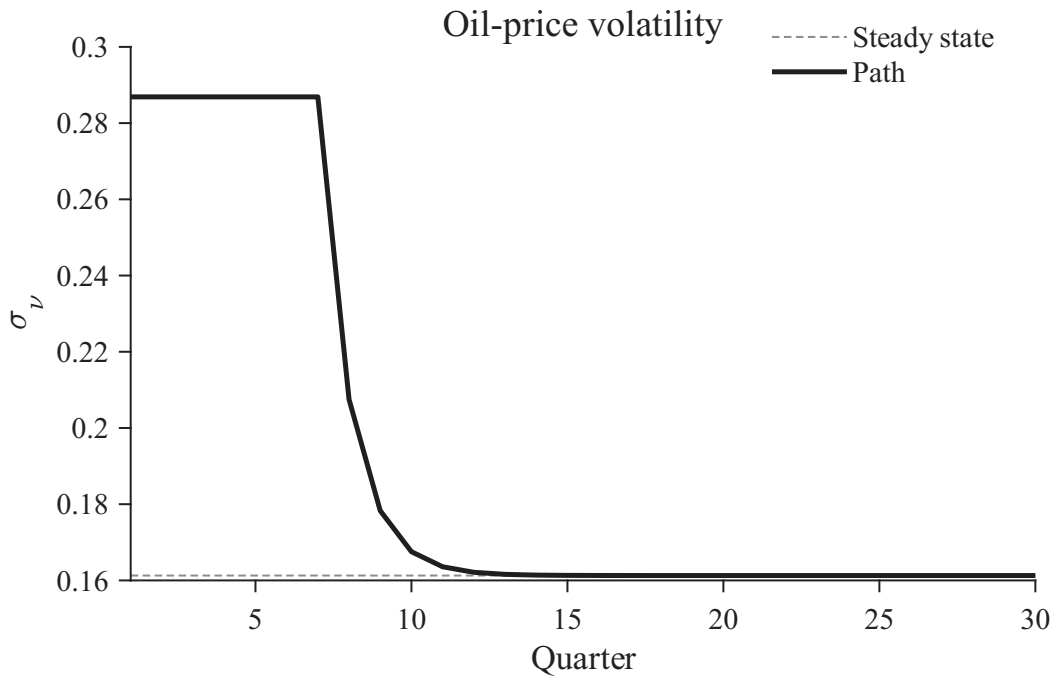
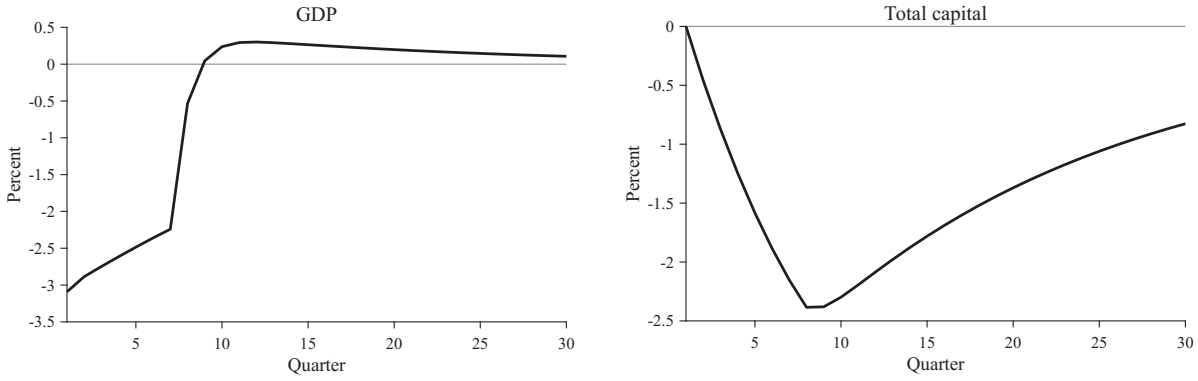


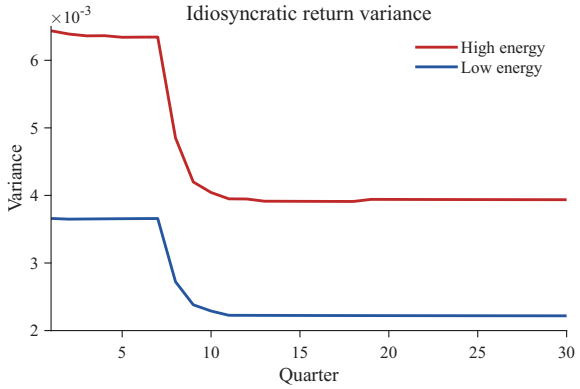
Figure 64: Shock path



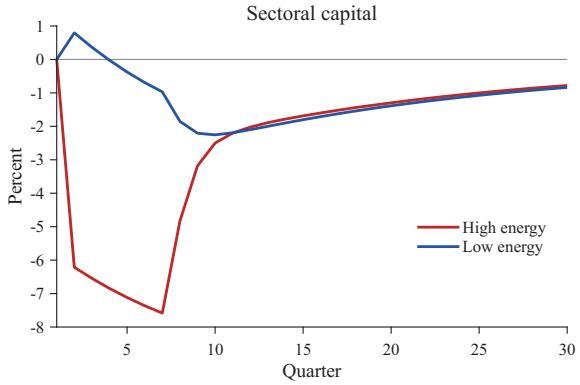
(a) GDP response

(b) Capital response

Figure 65: Aggregate responses

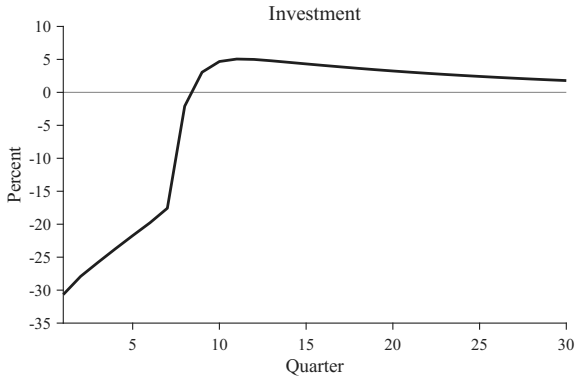


(a) Variance response



(b) Sectoral capital response

Figure 66: Sectoral responses

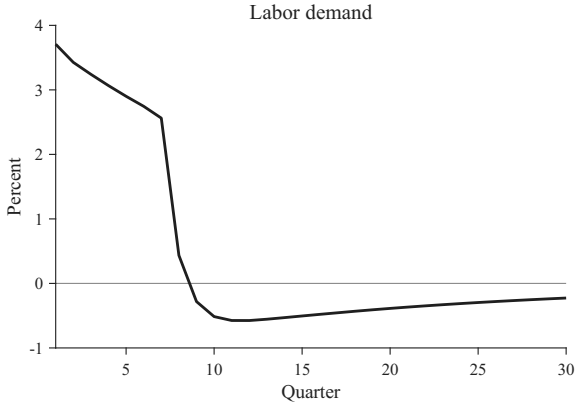


(a) Investment response

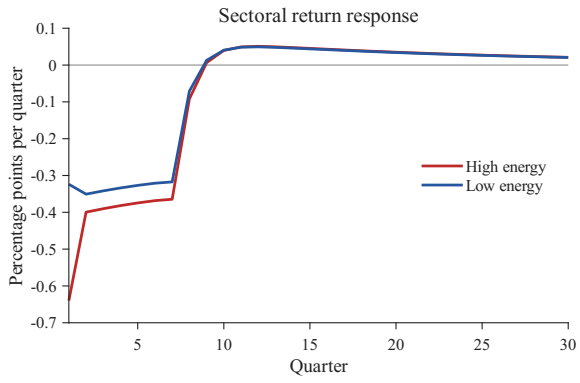


(b) Wage response

Figure 67: Investment and wage



(a) Labor response



(b) Return response

Figure 68: Labor and returns

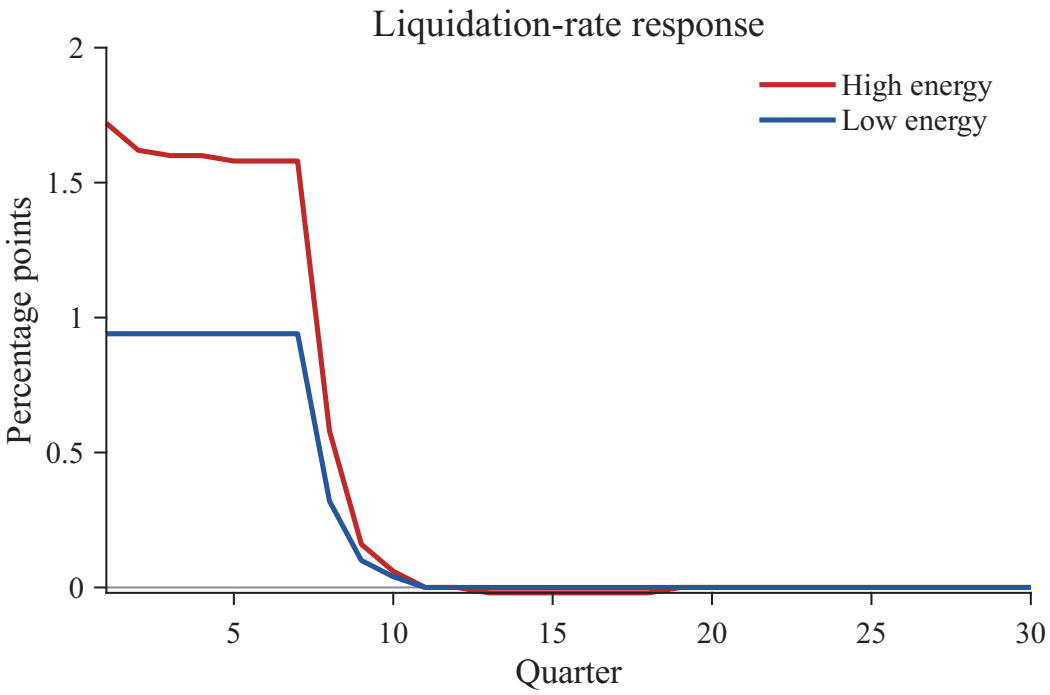


Figure 69: Liquidation-rate response

B.6 MIT7: Positive price shock with medium duration

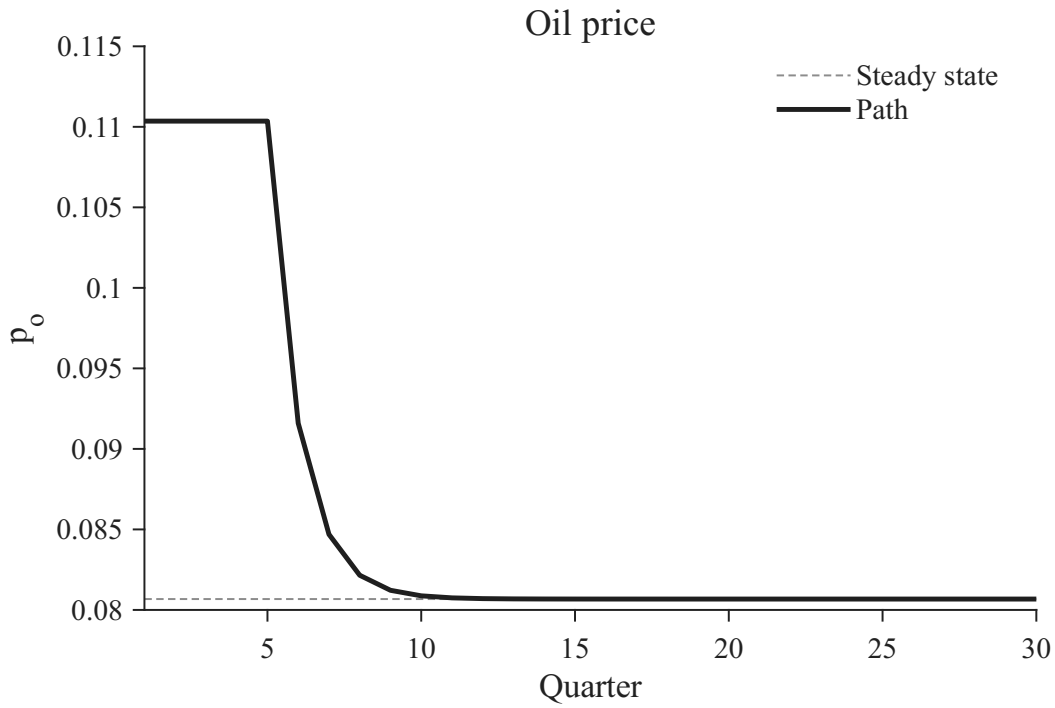
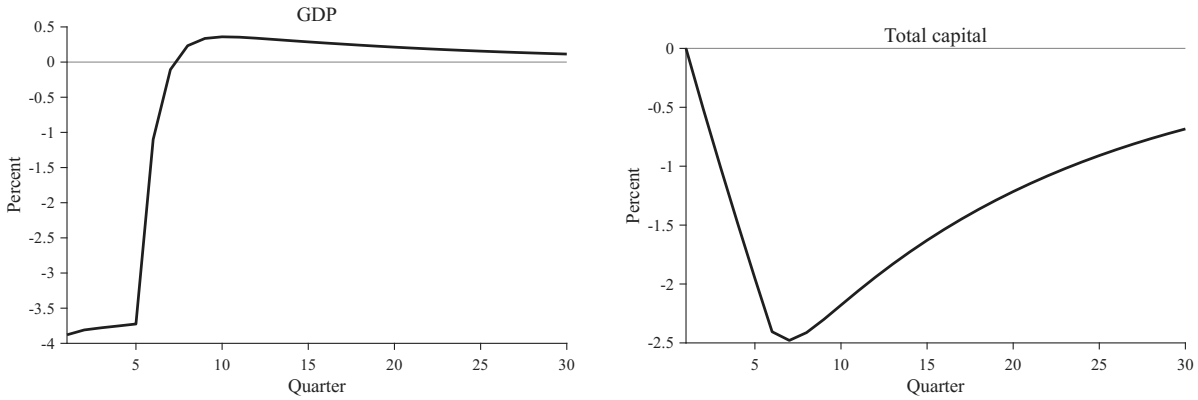


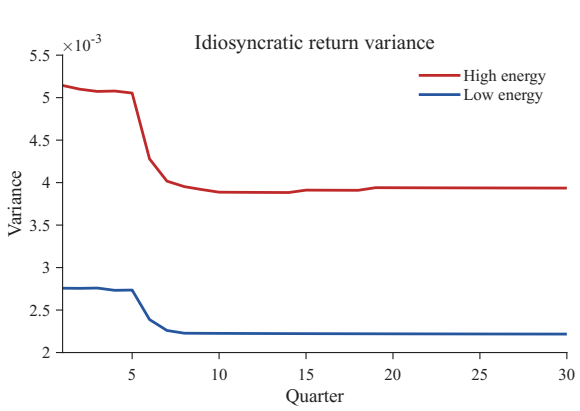
Figure 70: Shock path



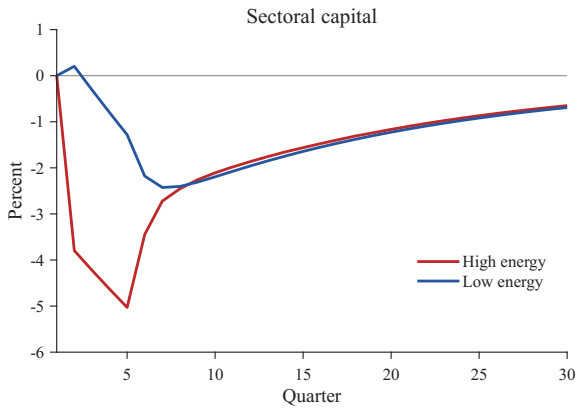
(a) GDP response

(b) Capital response

Figure 71: Aggregate responses

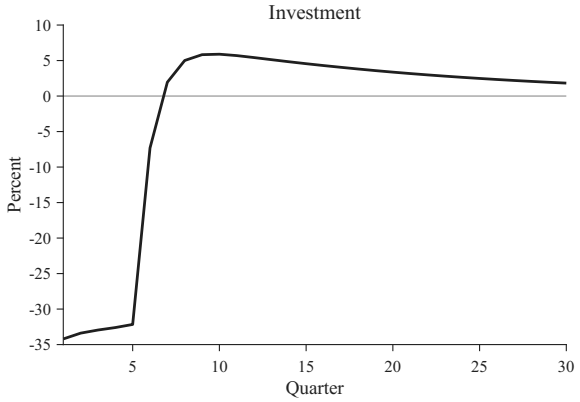


(a) Variance response

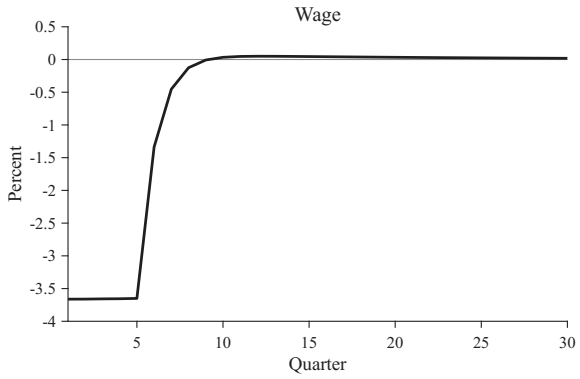


(b) Sectoral capital response

Figure 72: Sectoral responses

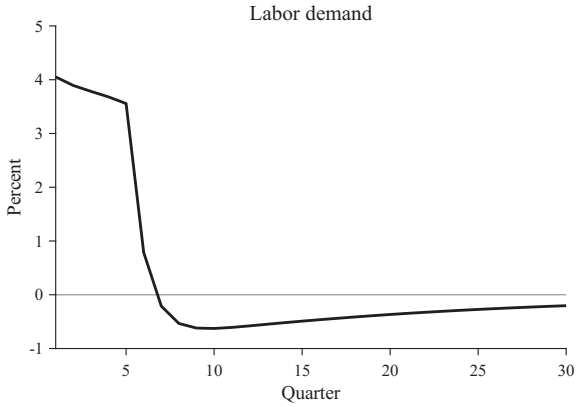


(a) Investment response

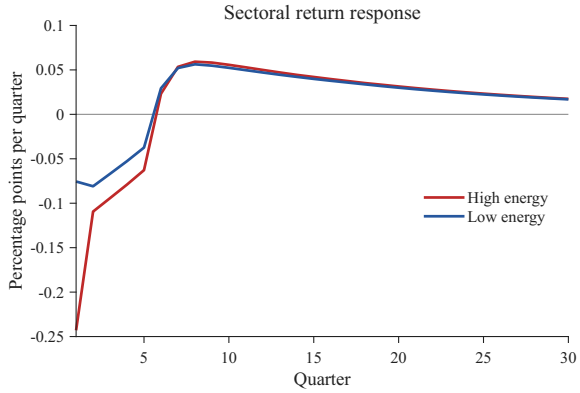


(b) Wage response

Figure 73: Investment and wage



(a) Labor response



(b) Return response

Figure 74: Labor and returns

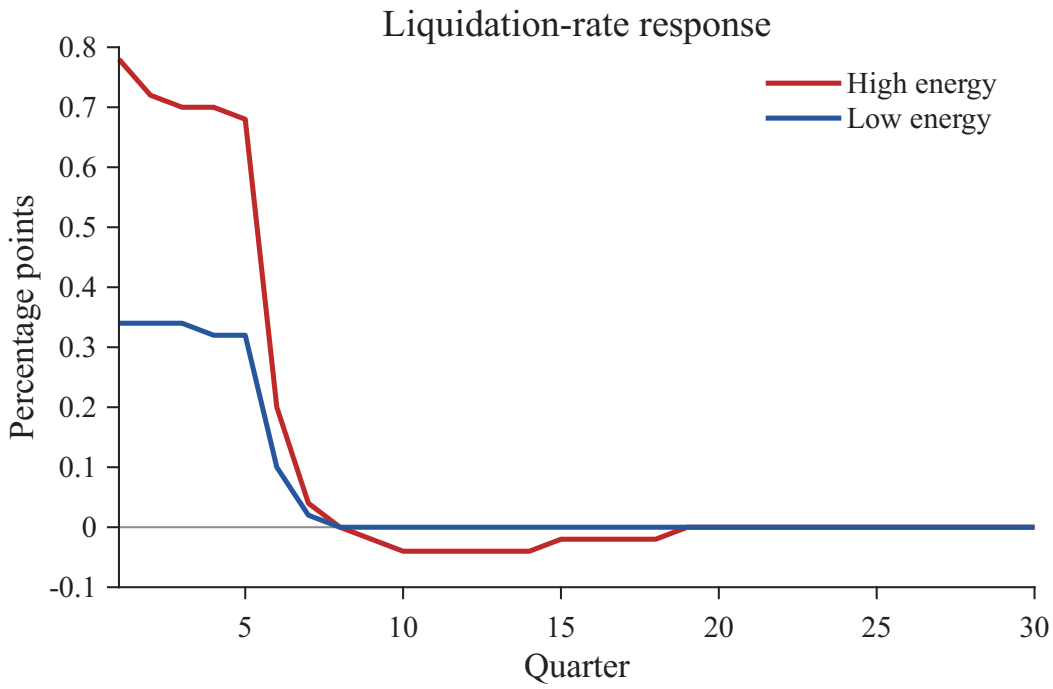


Figure 75: Liquidation-rate response

B.7 MIT8: Large positive price shock

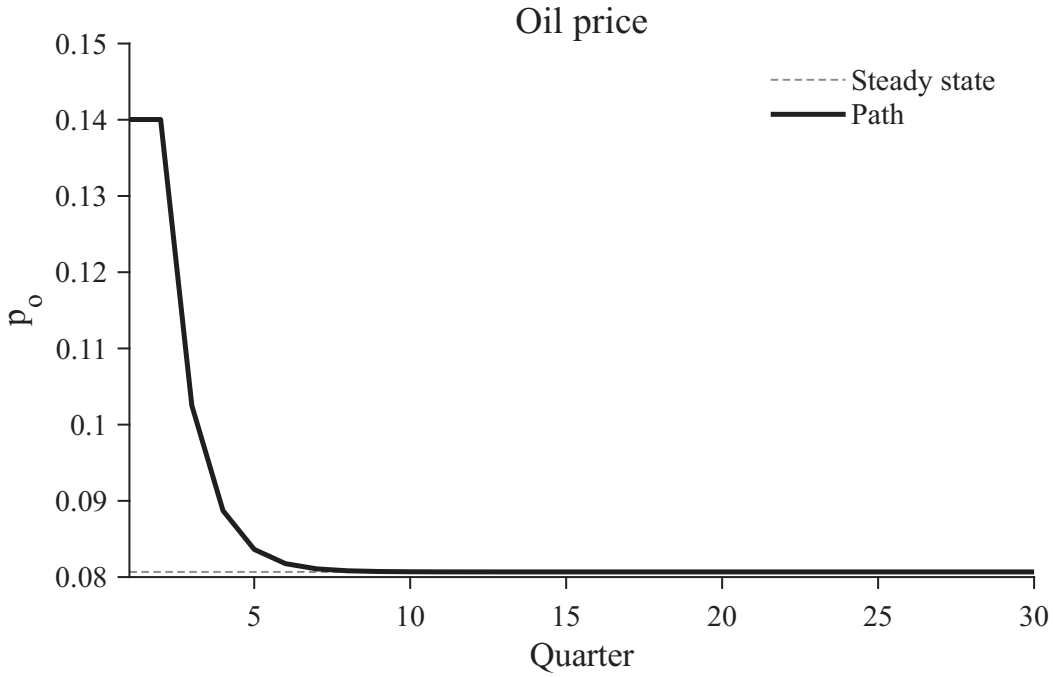
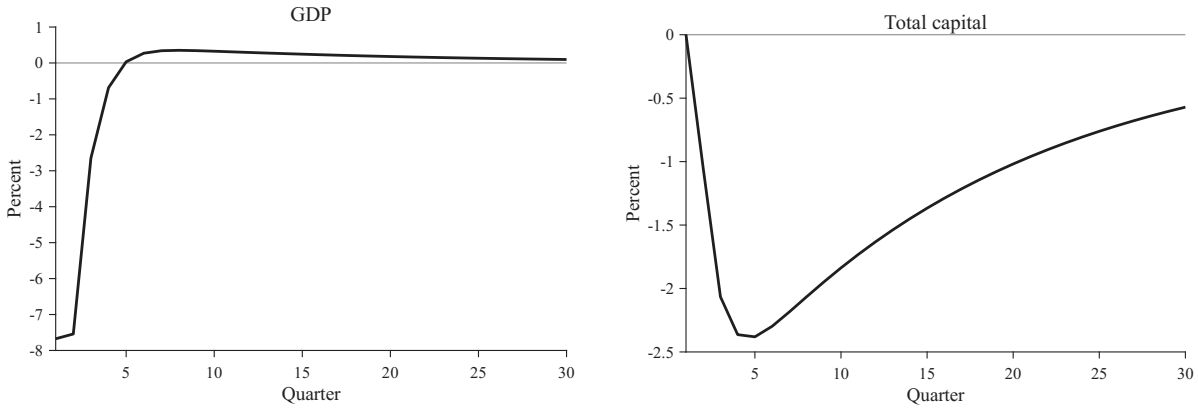


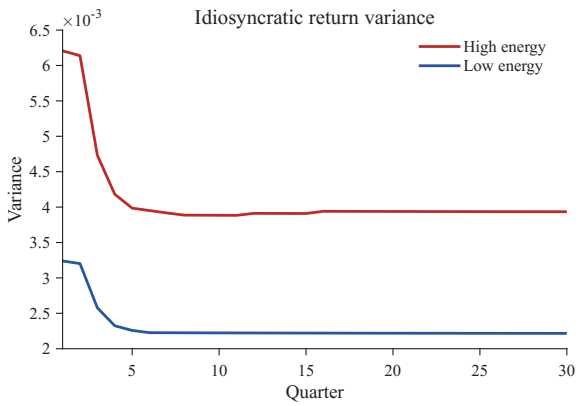
Figure 76: Shock path



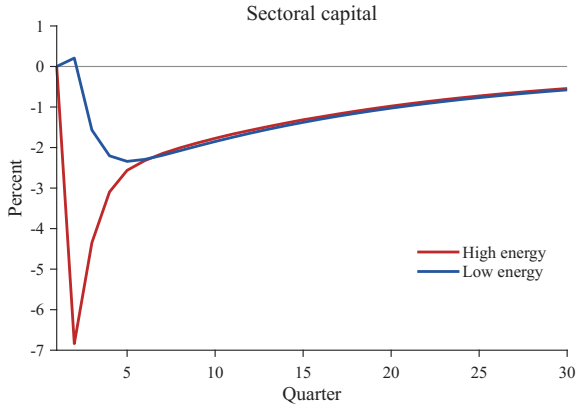
(a) GDP response

(b) Capital response

Figure 77: Aggregate responses

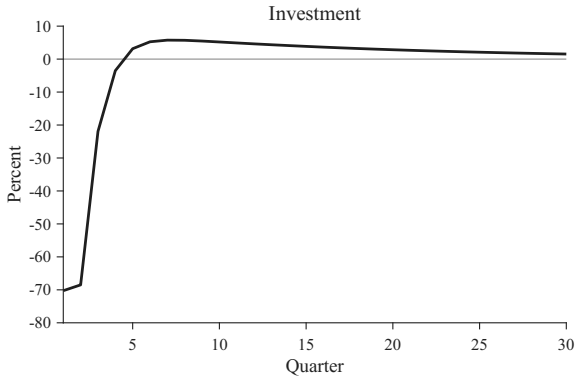


(a) Variance response

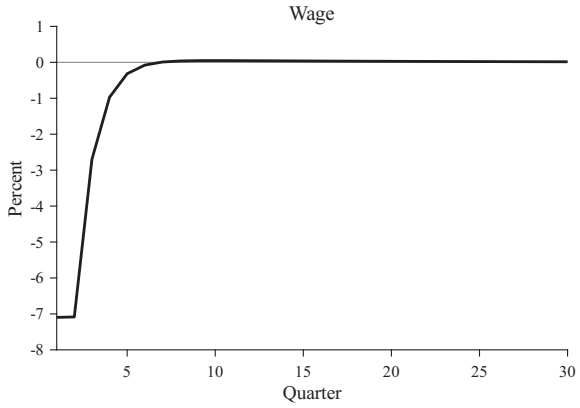


(b) Sectoral capital response

Figure 78: Sectoral responses



(a) Investment response

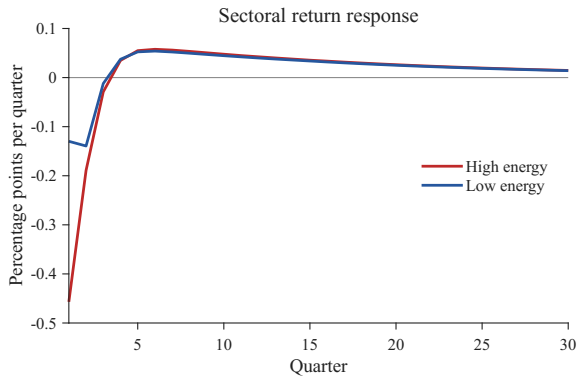


(b) Wage response

Figure 79: Investment and wage



(a) Labor response



(b) Return response

Figure 80: Labor and returns

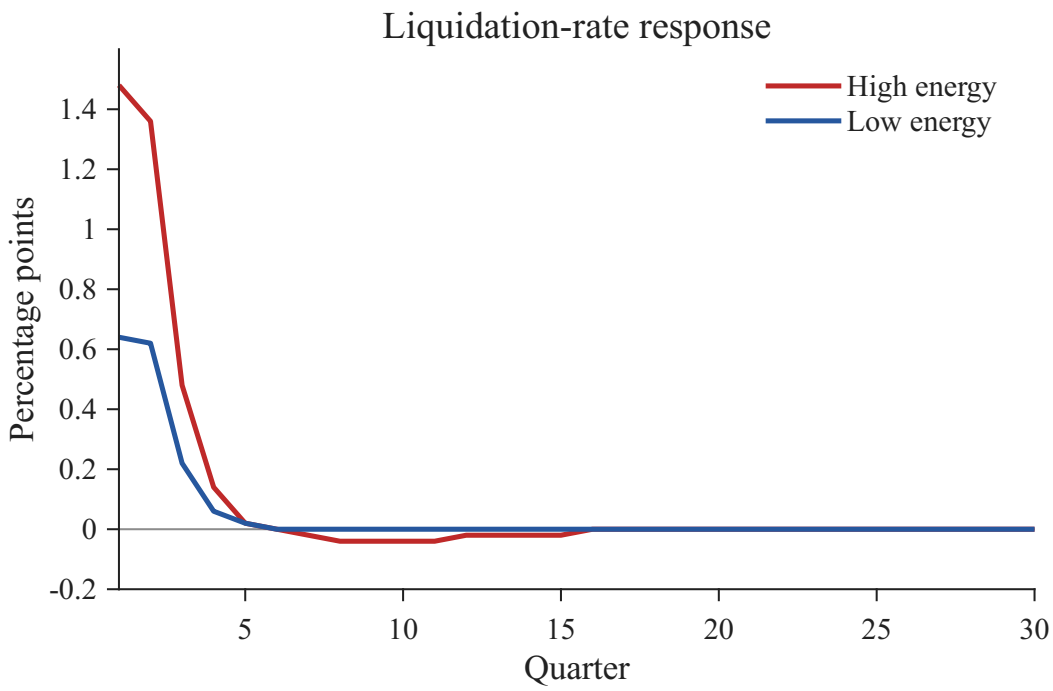


Figure 81: Liquidation-rate response

B.8 MIT9: Negative price shock with volatility

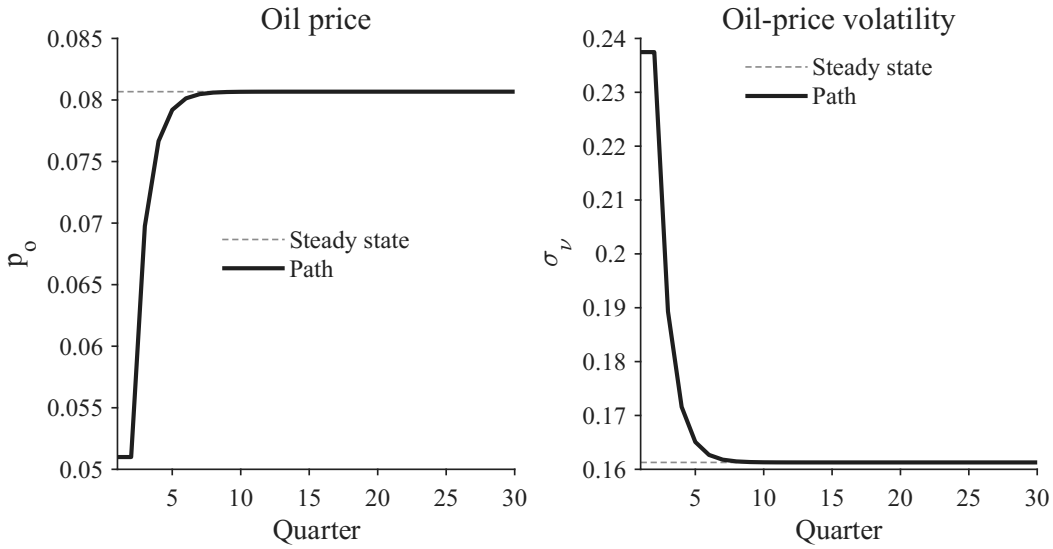
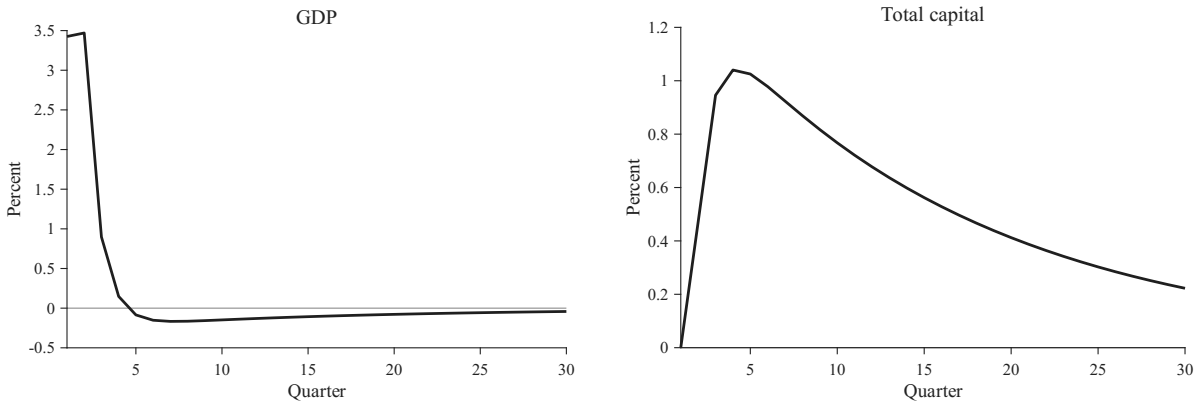


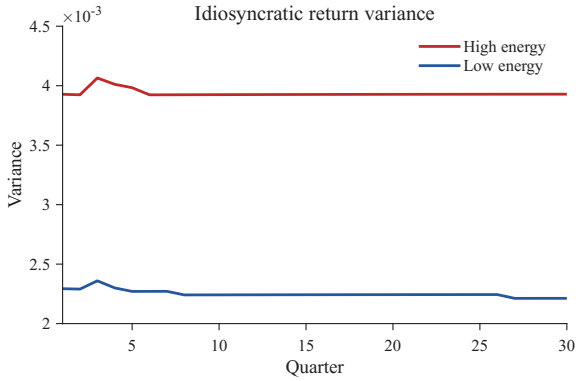
Figure 82: Shock path



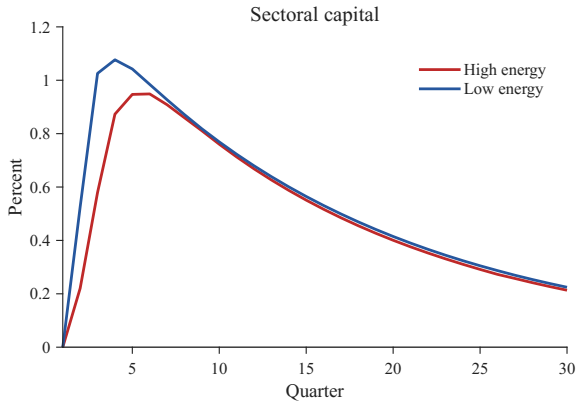
(a) GDP response

(b) Capital response

Figure 83: Aggregate responses

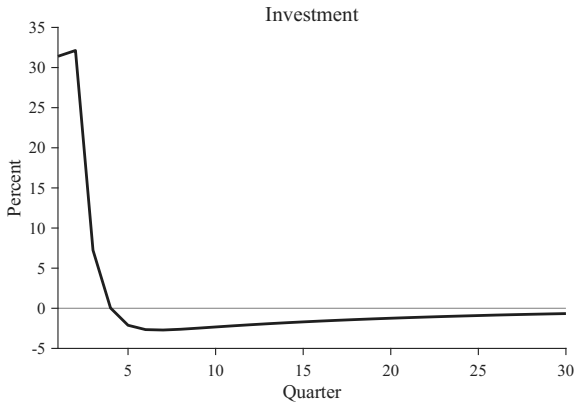


(a) Variance response



(b) Sectoral capital response

Figure 84: Sectoral responses

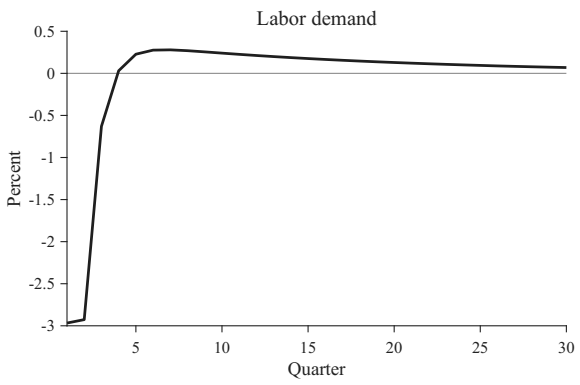


(a) Investment response

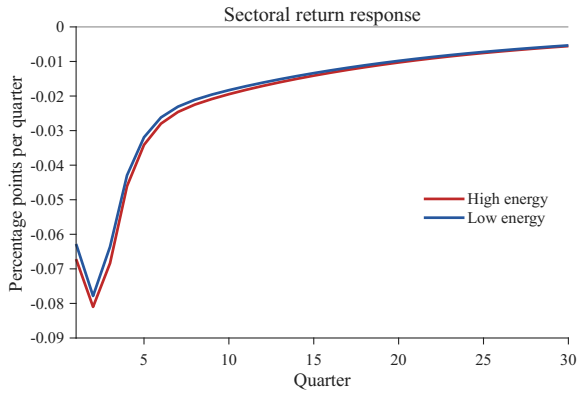


(b) Wage response

Figure 85: Investment and wage



(a) Labor response



(b) Return response

Figure 86: Labor and returns

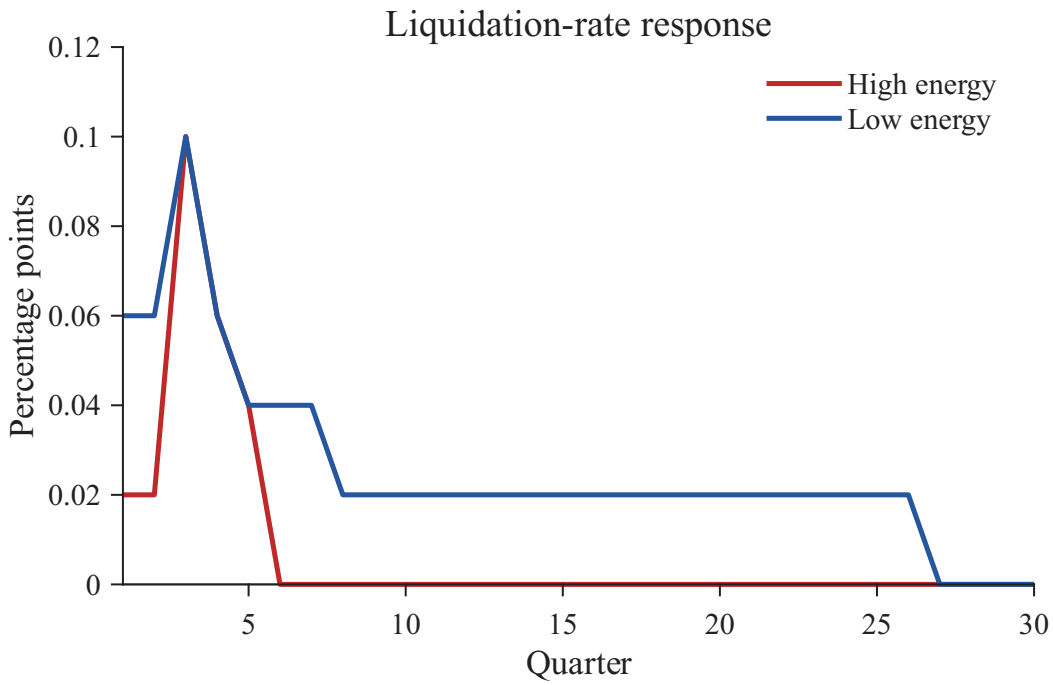


Figure 87: Liquidation-rate response

B.9 MIT10: Positive price shock with volatility

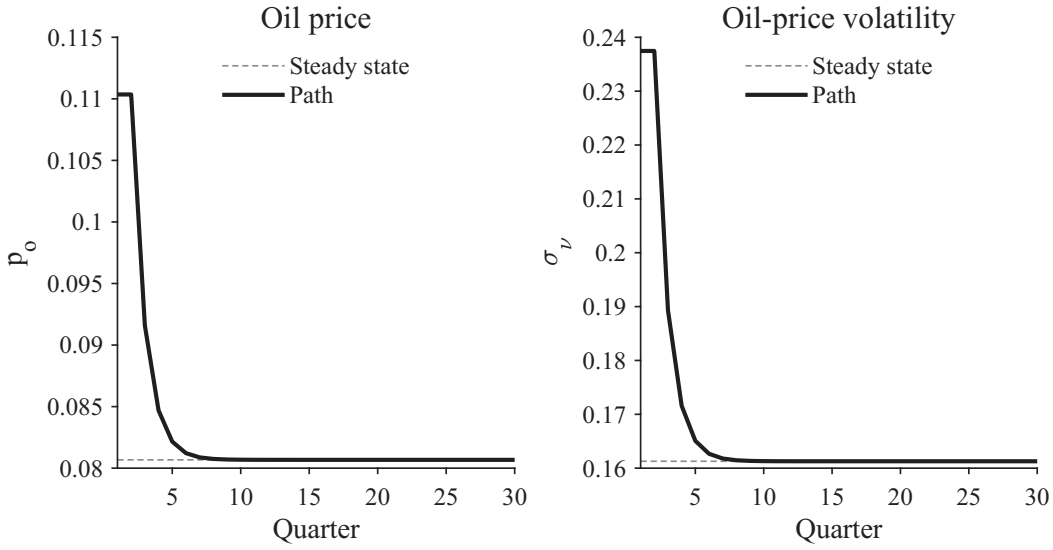
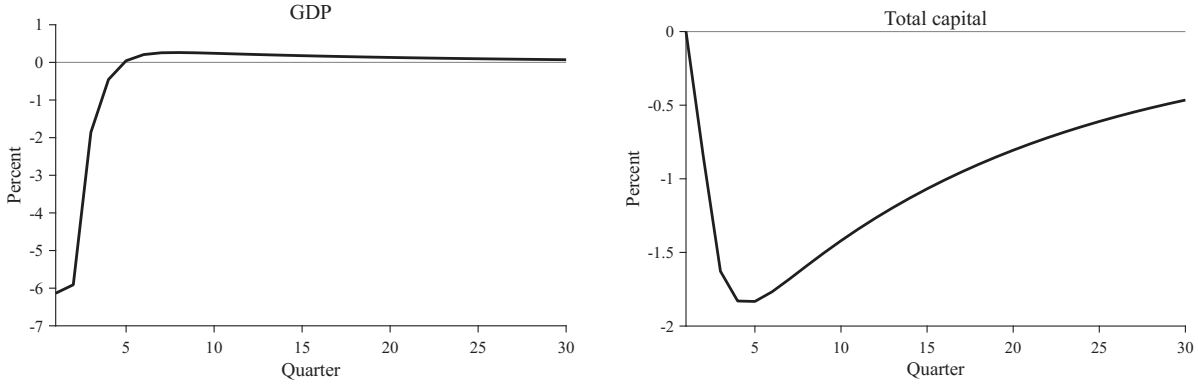


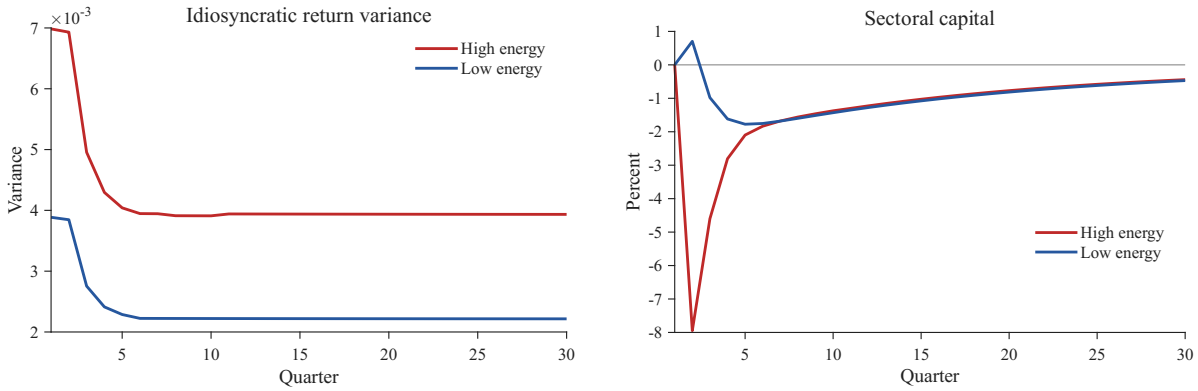
Figure 88: Shock path



(a) GDP response

(b) Capital response

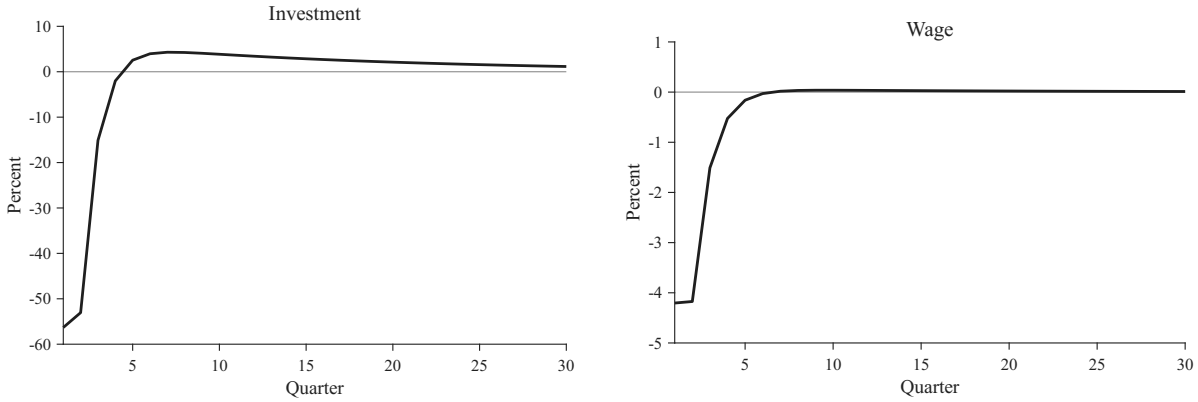
Figure 89: Aggregate responses



(a) Variance response

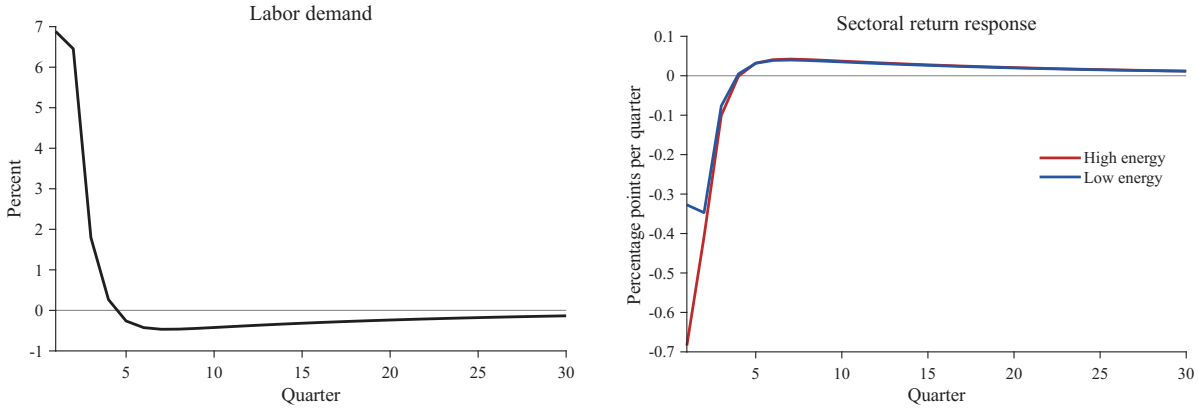
(b) Sectoral capital response

Figure 90: Sectoral responses



(a) Investment response (b) Wage response

Figure 91: Investment and wage



(a) Labor response (b) Return response

Figure 92: Labor and returns

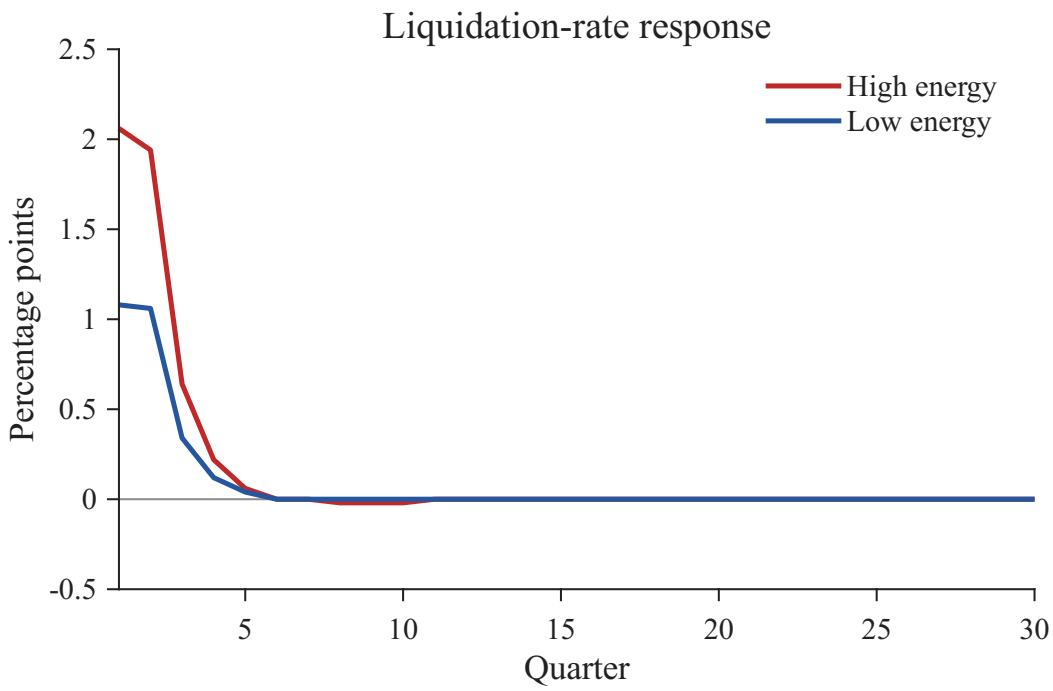


Figure 93: Liquidation-rate response

B.10 MIT11: Large negative price shock with volatility

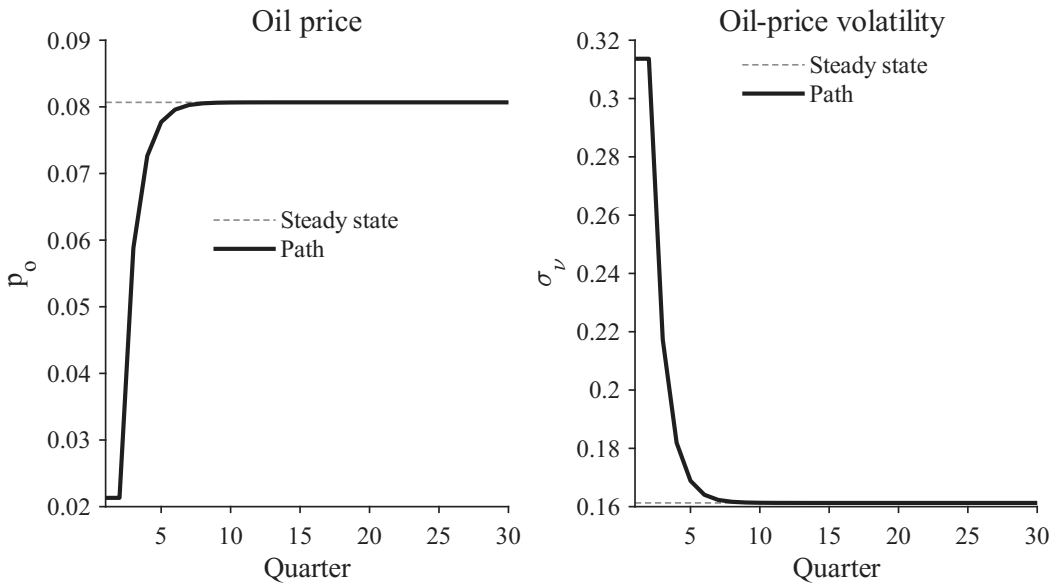
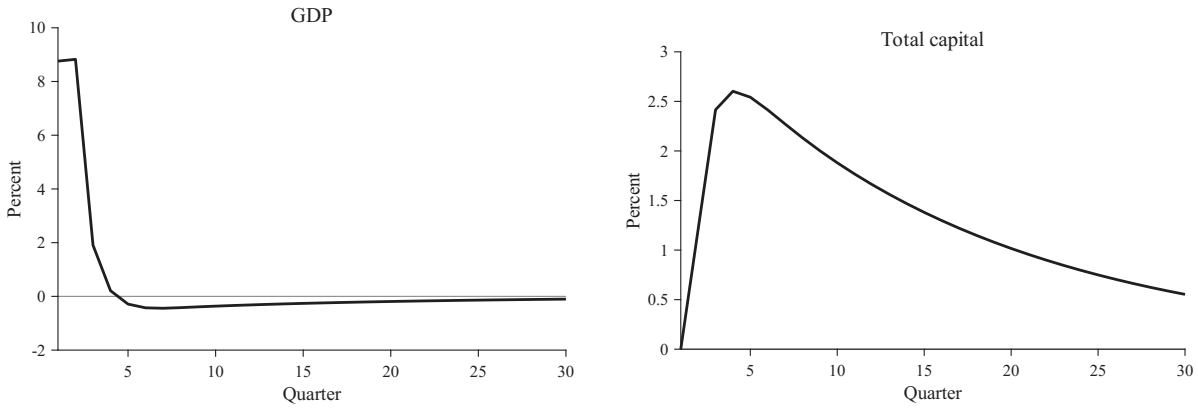


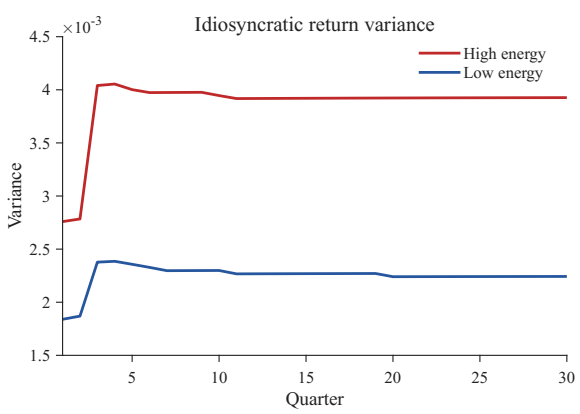
Figure 94: Shock path



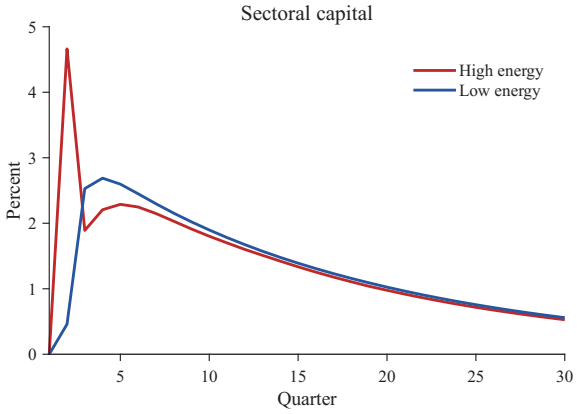
(a) GDP response

(b) Capital response

Figure 95: Aggregate responses

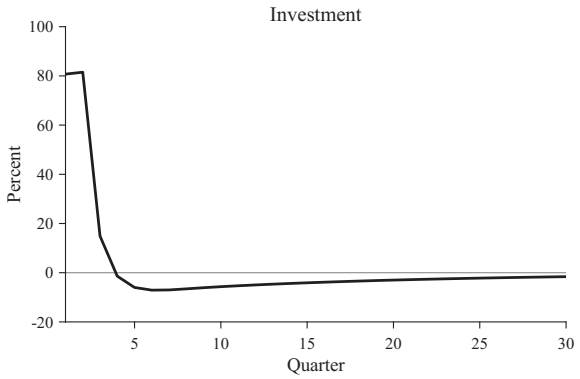


(a) Variance response

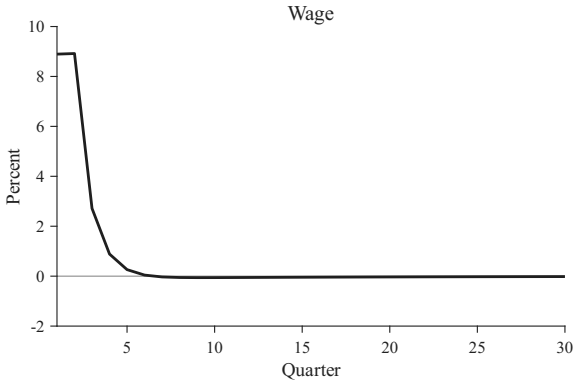


(b) Sectoral capital response

Figure 96: Sectoral responses

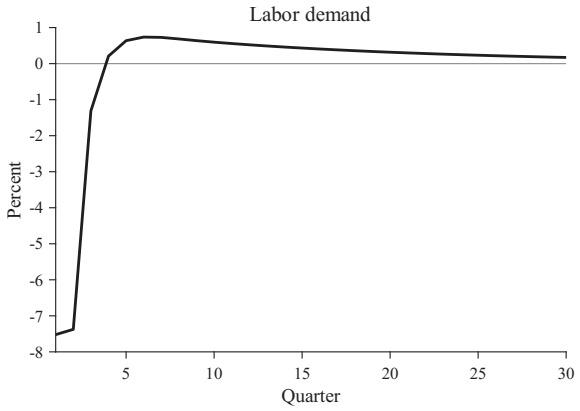


(a) Investment response

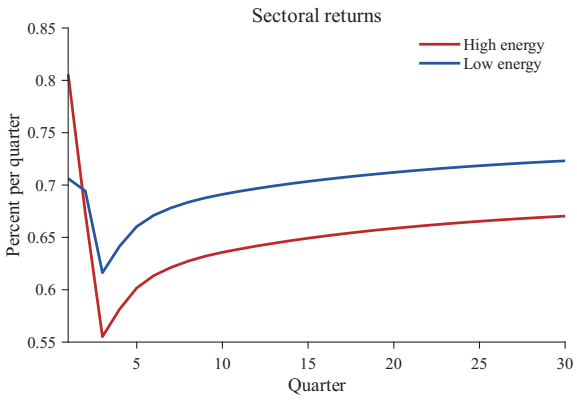


(b) Wage response

Figure 97: Investment and wage



(a) Labor response



(b) Return response

Figure 98: Labor and returns

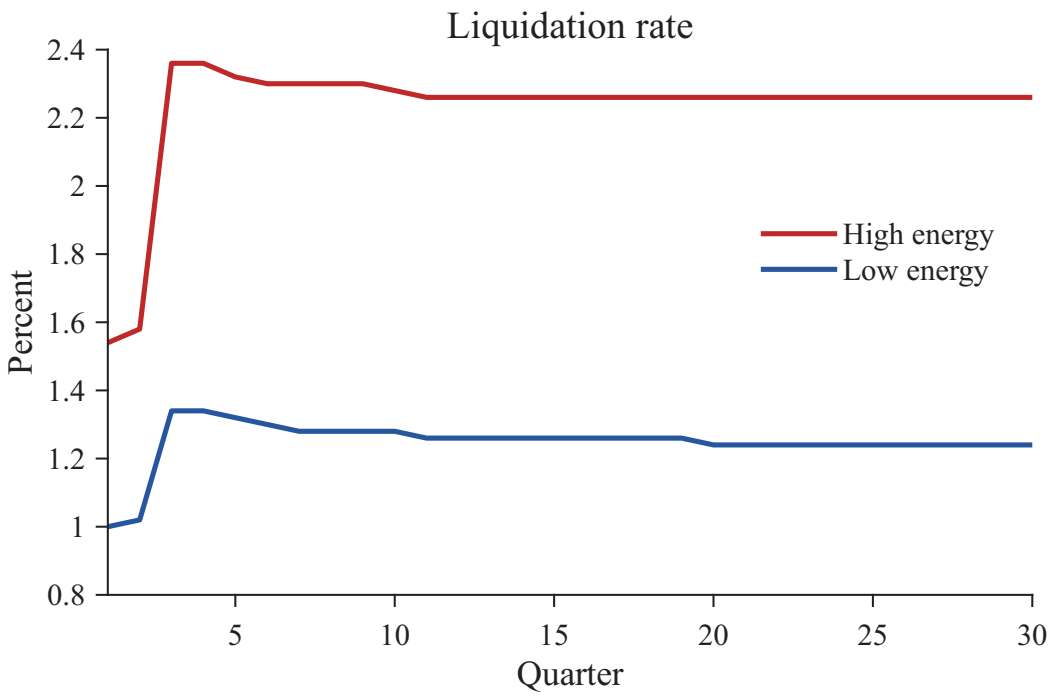


Figure 99: Liquidation-rate response

B.11 MIT12: Large positive price shock with volatility

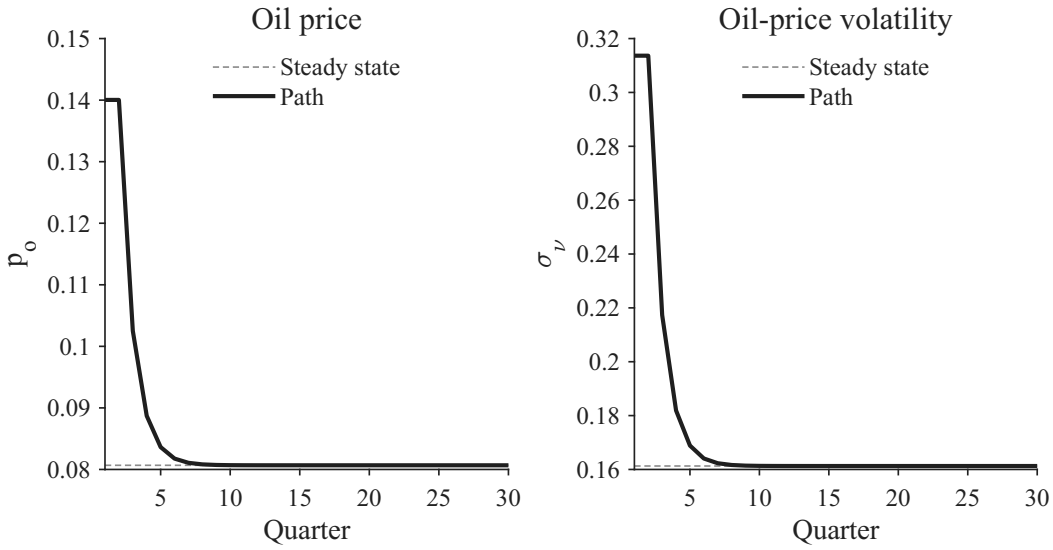
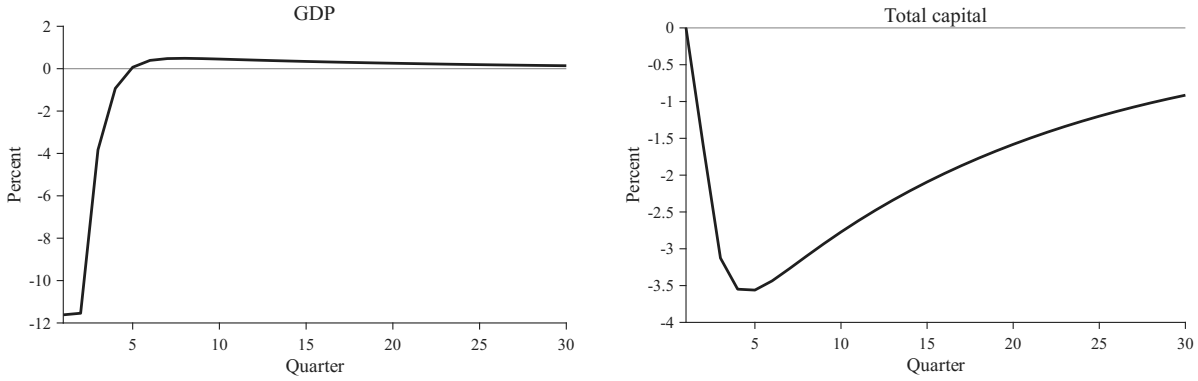


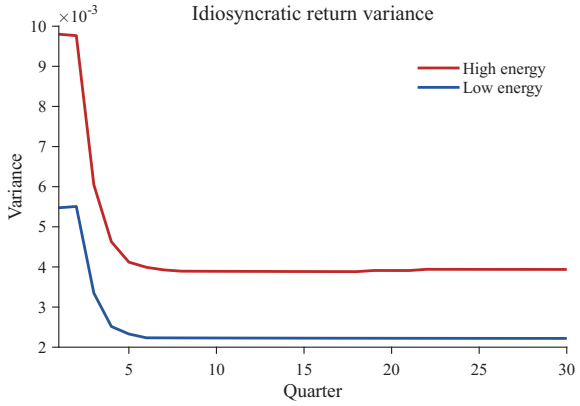
Figure 100: Shock path



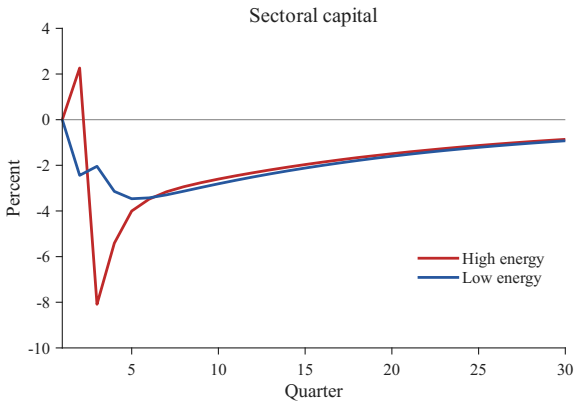
(a) GDP response

(b) Capital response

Figure 101: Aggregate responses

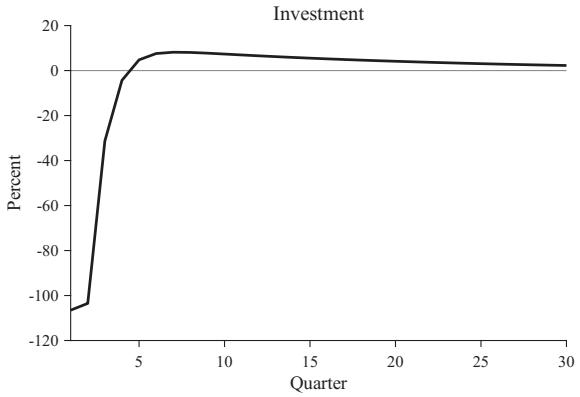


(a) Variance response

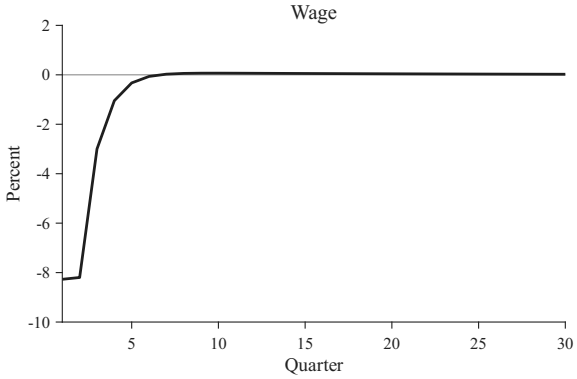


(b) Sectoral capital response

Figure 102: Sectoral responses

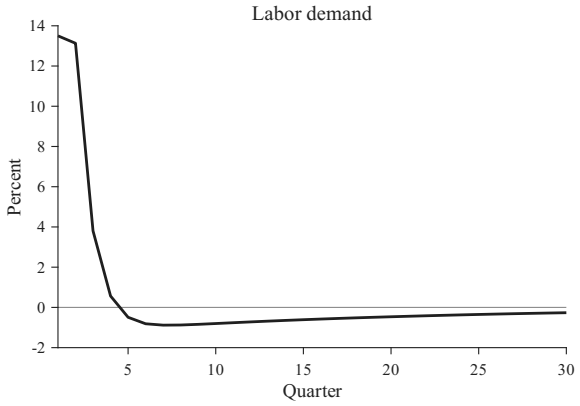


(a) Investment response

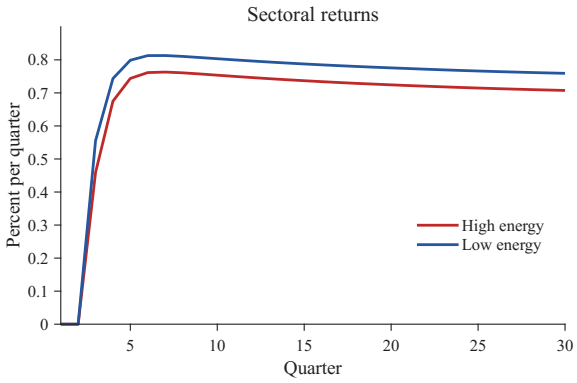


(b) Wage response

Figure 103: Investment and wage



(a) Labor response



(b) Return response

Figure 104: Labor and returns

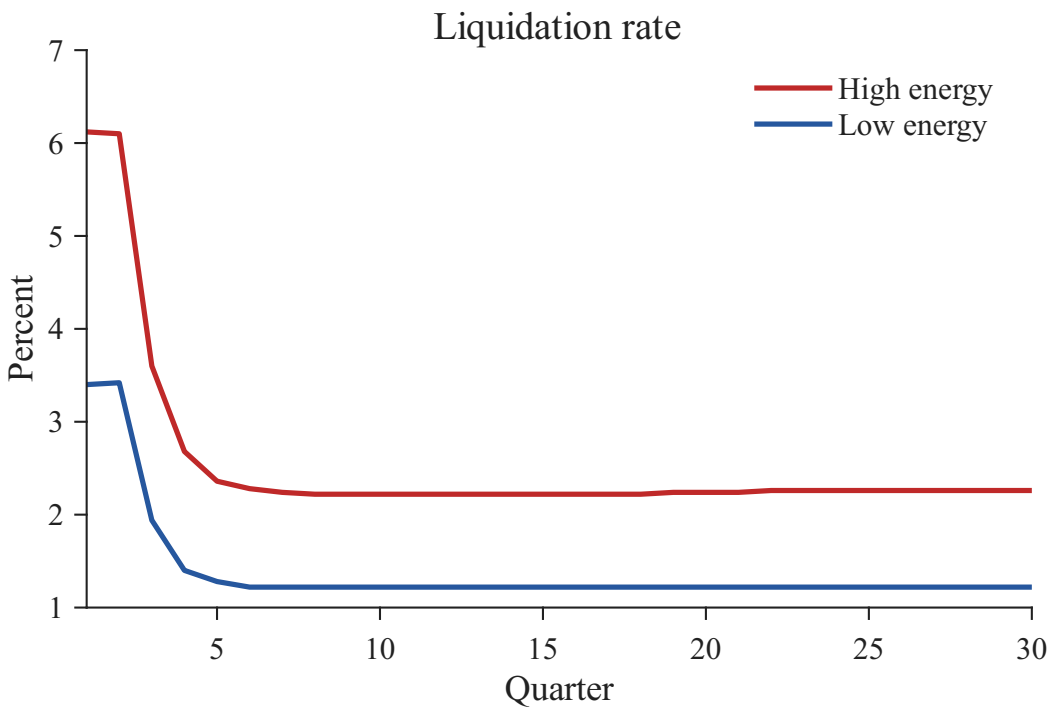


Figure 105: Liquidation-rate response

C Selected Firm First-Order Conditions

Let $\varrho_f = (\rho_f - 1)/\rho_f$ and define

$$Z_{js} = (1-\phi_s)\alpha_{0,s} O_{js}^{\varrho_f} + (1-\phi_s)\alpha_{LK,s} M_{js}^{\varrho_f} + \phi_s T_s^{\varrho_f}, \qquad Y_{js}^g = Z_{js}^{1/\varrho_f}.$$

For an active oil input and for land, the marginal products are

$$\frac{\partial Y_{js}^g}{\partial O_{js}} = (1-\phi_s)\alpha_{0,s}(Y_{js}^g)^{1/\rho_f} O_{js}^{-1/\rho_f}, \tag{26}$$

$$\frac{\partial Y_{js}^g}{\partial T_s} = \phi_s (Y_{js}^g)^{1/\rho_f} T_s^{-1/\rho_f}. \tag{27}$$

The labor and capital marginal products additionally contain the derivative of the inner capital–labor composite. Expected first-order conditions include the effect of each input on the liquidation threshold. Writing these wedges as μ_A for revenue and μ_B for obligations, the land condition is

$$\mathbb{E}_j\left[(1+\mu_{A,js}) p_{js} \frac{\partial Y_{js}^g}{\partial T_s} - (1+\mu_{B,js}) q_T\right] = 0. \tag{28}$$

D Liquidation Wedges

Let $\zeta_{js}^* = D_{js}/(p_{js} Y_{js}^g)$, with CDF F_ζ and density f_ζ. Expected liquidation losses are

$$\mathcal{L}_{js} = C_{\text{liq}}(1-\delta) K_s F_\zeta(\zeta_{js}^*). \tag{29}$$

The smooth density implies

$$\mu_{B,js} = \frac{C_{\text{liq}}(1-\delta) K_s \, f_\zeta(\zeta_{js}^*)}{p_{js} Y_{js}^g}, \qquad \mu_{A,js} = \zeta_{js}^* \mu_{B,js}. \tag{30}$$

Further derivation and the treatment of the collateral-coverage condition will be added in the final appendix.

E Numerical Accuracy

The final paper will report:

(i) steady-state goods, labor, and capital-market residuals;

(ii) transition-path residuals by market and date;
(iii) sensitivity to wealth-grid size and firm-return quadrature;
(iv) comparisons between four-point and full firm-return integration;
(v) sensitivity to transition damping and horizon length;
(vi) terminal-condition errors.