

Internet Appendix for

“Investment Under Upstream and Downstream Uncertainty”

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ABSTRACT

This Internet Appendix provides additional details, tables, and figures supporting the main text. This includes (i) a stylized model that shows the asymmetric effects of supply-chain uncertainty, (ii) variable description and construction, (iii) empirical connection between price uncertainty and the return volatility of trade partners, (iv) cleaning BEA Input-Output tables, (v) details on the solution method of the quantitative model, (vi) additional quantitative model results, (vii) additional micro-level empirical results, (viii) estimating the prices of risk of supply-chain uncertainty and (ix) additional macro-level empirical results.

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I. Stylized Model

A. Stylized Model: Setup

We present a stylized version of the quantitative model that is easy to analyze and allows the key economic intuition and insights to be characterized in closed form. Compared to the main model, the setup makes the following simplifications: (i) uncertainty over input or output prices lasts only one period; (ii) there are no assets in place — the firm is endowed with only one growth option that has a fixed size; (iii) the distribution of future input and output prices is discrete; (iv) there are no stochastic volatility shocks — the effects of input and output price uncertainty are analyzed via comparative statistics.

Model Description. A firm is deciding whether to invest in a capital input (for example, a machine or a stock of inventory) that is purchased from its supplier (denoted by s) to produce a flow of output products to sell to its customer (denoted by c). Time is discrete, and the firm can either invest in the project today (time 0) or wait until the next period (time 1). We assume the investment option expires at time 1.

Both the input price paid to the supplier and the output price received from the customer can change between time 0 and time 1. These price dynamics are outlined in Figure [IA1](#). The input price at time 0 is $P_{s,0} = P_s$, but the price at time 1 ($P_{s,1}$) either increases to $P_s + \sigma_s$ or decreases to $P_s - \sigma_s$ with equal probabilities. Thus, $P_{s,1}$ is a mean-preserving spread of $P_{s,0}$, with $E[P_{s,1}] = P_{s,0}$ and $Var[P_{s,1}] = \sigma_s^2$. This suggests that σ_s reflects upstream uncertainty. Likewise, the current output price is $P_{c,0} = P_c$. Letting h represent a constant greater than one, the output price at time 1 ($P_{c,1}$) will either (i) increase to $P_c + h\sigma_c$ (“very good” news); (ii) increase to $P_c + \sigma_c$ (“good” news); (iii) decrease to $P_c - \sigma_c$ (“bad” news); or (iv) decrease to $P_c - h\sigma_c$ (“very bad” news), with equal probabilities. Thus, $P_{c,1}$ is a mean-preserving spread of $P_{c,0}$, with $\partial Var[P_{c,1}]/\partial \sigma_c > 0$. Therefore, σ_c reflects downstream uncertainty. For simplicity, we assume that output price uncertainty only lasts between time 0 and time 1. This means that $P_{c,t} = P_{c,1}$ for all times $t > 1$. In what follows, $P_c(VG)$, $P_c(G)$, $P_c(B)$, $P_c(VB)$ denote the future output prices if “very good,” “good,” “bad,” and “very bad” news materializes, respectively.

To start the investment project at time t , the firm first needs to acquire the capital input for price $P_{s,t}$. Acquiring the capital input allows the firm to build up its production line and then produce one unit of output per period. No additional capital is required beyond the capital input purchased at t . The labor cost for each unit of output is constant over time and is given by $\omega > 0$. Therefore, the cash inflow in every period $\tau \geq t$ in which production takes place is $P_{c,\tau} - \omega$. For the purpose of illustration, we assume that $\sigma_c > P_{c,0} - \omega > 0$. This indicates that the project’s cash inflow is only positive if $P_{c,\tau \geq 1} \in \{P_c(G), P_c(VG)\}$.

The time discount factor of the firm’s owner is β . Given β , the project’s NPV at time 0 is positive (i.e., the real option is in the money). To make the dynamics nontrivial, we assume that the effect of input price uncertainty (σ_s) on the viability of the project depends on the

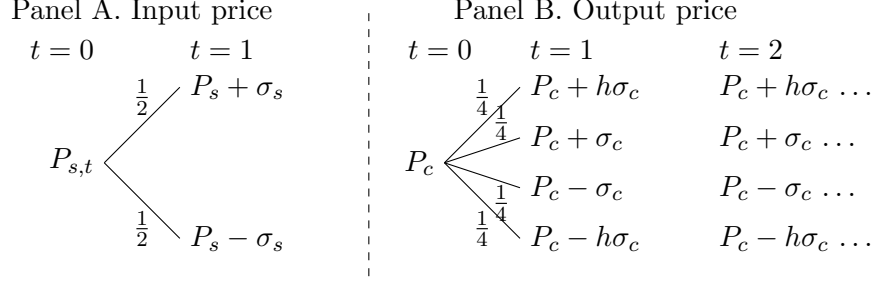


Figure IA1. Input- and output-price dynamics under the stylized model. This figure illustrates the dynamics of the input price from suppliers (Panel A) and output price to customers (Panel B) in the stylized model of Section I.A of the main article. P_s (P_c) denotes the unconditional price of the input (output). The term σ_s (σ_c) is positively related to upstream (downstream) uncertainty.

future output price. If the input price increases and the output price rises to $P_{c,1} = P_c(VG)$, then the project is still viable at time 1. However, if the input price increases and the output price only rises to $P_{c,1} = P_c(G)$, then the project has a negative NPV at time 1.

The investment is also partially reversible and the firm can abandon the project for a cost of $a > 0$ after production begins. We assume that $0 > P_c - \sigma_c - \omega + a(1 - \beta) > (h - 1)\sigma_c$, implying that the project is only abandoned in the “very bad” news case of $P_{c,1} = P_c(VB)$.¹

Lastly, we consider two separate assumptions for the production process.

Assumption 1: No time-to-build. The firm can immediately produce and sell output to the customer once the decision to invest is made and input good is purchased from the supplier. This instantaneous time-to-build assumption is standard in the real option literature (e.g., Dixit (1992) and Pindyck (1993)).

Assumption 2: Time-to-build. There is a one period interval between investing and receiving the project’s first revenue. This captures the time required to convert the input into an output stream (e.g., construction or R&D) before entering the product market.

¹We note the future input price in this stylized model only takes one of two possible realizations for parsimony and without loss of generality. If the future input price were to take one of four realizations similar to the output price dynamics (i.e., “very good”, “good”, “bad”, and “very bad”), then all of the model’s conclusions still hold. We need four output realizations of the output price in the model to induce a tradeoff between the benefits and the costs of waiting with respect to downstream uncertainty. With only two possible output-price states (e.g., “good” and “bad”) the abandonment option is either always exercised upon the realization of bad news realization (in that case, the benefit of waiting to invest does not depend on downstream uncertainty) or the abandonment option is too costly to exercise in any state (in that case, the cost of waiting to invest does not depend on downstream uncertainty).

B. Analysis Without Time-to-Build

We start by analyzing how upstream uncertainty (σ_s) and downstream uncertainty (σ_c) each affect a firm's decision to invest when there is no time-to-build. If the firm decides to invest at time 0, then the project will operate indefinitely unless “very bad” news about the output price arrives at time 1 and the project is abandoned. Alternatively, if the firm waits to invest, then the real option will only be exercised at time 1 if: (i) $P_c(G)$ materializes and the input price decreases; (ii) $P_c(VG)$ materializes and the input price decreases; or (iii) $P_c(VG)$ materializes and the input price increases. Each case occurs with probability $\frac{1}{8}$.

Given the NPV of investing now, denoted by $NPV_0^{\text{No TTB}}$, and the expected NPV of waiting to invest at time 1, denoted by $E_0[NPV_1^{\text{No TTB}}]$, the net benefit of waiting to invest in the model without time-to-build is given by $E_0[NPV_1^{\text{No TTB}}] - NPV_0^{\text{No TTB}}$, or

$$\begin{aligned} \text{NetBenefit}(\text{Wait, No TTB}) = & \underbrace{\left(-\frac{1}{4}NPV_{0[P_c(B)]} - \frac{1}{4}NPV_{0[P_c(VB)]} \right)}_{\text{(I)}} + \underbrace{\left(\frac{1}{2} - \frac{3}{8}\beta \right)P_s + \frac{1}{8}\beta\sigma_s}_{\text{(II)}} \\ & - \underbrace{\frac{1}{2}(P_c - \omega)}_{\text{(III)}} - \underbrace{\frac{1}{8}\frac{\beta}{1-\beta}(P_c + \sigma_c - \omega)}_{\text{(IV)}}. \end{aligned} \quad (\text{IA1})$$

Terms (I) and (II) capture the benefits of waiting, while terms (III) and (IV) capture the opportunity costs of waiting. We outline the intuition underlying each term below (the complete expressions for $NPV_0^{\text{No TTB}}$ and $E_0[NPV_1^{\text{No TTB}}]$ are in Section II below).

Term (I) is the benefit of waiting to avoid bad news about $P_{c,1}$ following the “bad news principle” (Bernanke, 1983). If $P_{c,1}$ falls in the $P_c(VB)$ and $P_c(B)$ cases, then the real option will not be exercised at time 1. Therefore, waiting to invest allows the firm to avoid the net loss of investing in an ex-post uneconomical project. Higher downstream uncertainty σ_c increases the potential loss from investing in the project immediately, as $NPV_{0[P_c(B)]}$ falls with σ_c . This implies that the benefit of waiting captured by term (I) increases in σ_c .²

Similar to downstream uncertainty, upstream uncertainty creates a benefit of waiting for new information to arrive before investing. Economically, term (II) captures the benefit of waiting to learn that the input price has fallen in the cases in which “good” news about $P_{c,1}$ is realized and the project remains viable at time 1.³ This term represents a “good news principle” associated with upstream uncertainty, as the benefit of waiting increases in σ_s .

Term (III) is the main opportunity cost of waiting and captures the forgone revenue during the inaction period if $P_c(G)$ or $P_c(VG)$ arise and the project is viable ex-post. As the

²In Section III.E below we discuss how the abandonment cost a interacts with both the cost and the benefit of waiting to invest.

³If “very good” news about the output price is realized, then there is no benefit in waiting for the input price to drop. This is because the project is viable at time 1 regardless of the input price.

firm can both invest and enter the product market at time 0 when there is no time-to-build, the foregone revenue from waiting to invest is the time 0 revenue. Thus, this opportunity cost of waiting to invest is not stochastic and does not depend on either σ_c or σ_s .

Finally, term (IV) is another cost of waiting to invest that arises due to upstream uncertainty. This term captures the potential loss of the future revenue stream in the case that the input price increases at time 1 but the output price only increases to $P_c(G)$. By assumption, σ_s is sufficiently large so that the project has negative NPV in this case. In this scenario, a waiting firm forgoes the positive profits it could have earned had it invested at time 0 before the input price increased and “good” news about the output price was realized. This term is independent of σ_s , but increases in σ_c .

Overall, upstream uncertainty has an unambiguous effect on investment: High σ_s delays investment at time 0 because the benefit of waiting increases in σ_s (term (II)) while the opportunity cost is independent of σ_s (terms (III) and (IV)). In contrast, downstream uncertainty has a more subtle effect on investment. This is because the benefit of waiting to invest increases in σ_c (term (I)) but the opportunity cost of waiting also depends on σ_c , provided that σ_s is large enough (term (IV)). While this creates some asymmetry between the effects of the two uncertainties, more downstream uncertainty also suppresses investment in the model without time-to-build. To see this, we collect the coefficients of σ_c in terms (I) and (IV) and obtain $\frac{1}{8} \frac{\beta}{1-\beta} \sigma_c$. Thus, the net benefit of waiting increases in σ_c .

C. Analysis with Time-to-Build

The analysis of the model with time-to-build is almost identical to that without time-to-build. The key difference is that if the firm invests at time 0 (waits to invest at time 1), then the first revenue is now only received at time 1 (time 2). Thus, the net benefit of waiting to invest with time-to-build has a similar form and intuition to equation (IA1) and is

$$\begin{aligned} \text{NetBenefit}(\text{Wait, TTB}) = & \underbrace{\left(-\frac{1}{4}NPV_{0[P_c(B)]} - \frac{1}{4}NPV_{0[P_c(VB)]} \right)}_{\text{(I)}} + \underbrace{\left(\frac{1}{2} - \frac{3}{8}\beta \right)P_s + \frac{1}{8}\beta\sigma_s}_{\text{(II)}} \\ & \underbrace{-\frac{1}{4}\beta(P_c + h\sigma_c - \omega) - \frac{1}{4}\beta(P_c + \sigma_c - \omega)}_{\text{(III)}} - \underbrace{\frac{1}{8} \frac{\beta^2}{1-\beta}(P_c + \sigma_c - \omega)}_{\text{(IV)}}. \end{aligned} \quad (\text{IA2})$$

Here, term (I) (term (II)) once again captures the benefit of waiting due to a “bad” (“good”) news principle about the output (input) price. These benefits rise with σ_c and σ_s , respectively. Similarly, and as explained in Section I.B of the main article, term (IV) captures an opportunity cost of not investing at time 0 provided that $\sigma_s > 0$.⁴

⁴For the purpose of brevity, we once again present the expressions for the NPV of exercising the option to

The key difference between equations (IA1) and (IA2) is related to term (III). This term captures an opportunity cost of waiting and represents the forgone profits from inaction. Without time-to-build, the firm could enter the product market in the same period it made its investment. As such, the foregone revenues from waiting arose at time 0 and were not stochastic. With time-to-build, these foregone revenues from waiting depend on the output price that is realized at time 1 *after* the time-to-build period ends. As such, these foregone profits become a stochastic function of the output price but do not depend on the input price. Moreover, these forgone profits are capped below by the abandonment option. This makes term (III) a convex function of $P_{c,1}$ that increases with σ_c . We refer to this as the “good news” principle associated with downstream uncertainty.

As in the case without time-to-build, more upstream uncertainty continues to unambiguously delay investment by increasing the benefit of waiting without affecting the opportunity cost. To understand the impact of downstream uncertainty with time-to-build, we differentiate equation (IA2) with respect to σ_c and obtain⁵

$$\frac{\partial \text{NetBenefit}(\text{Wait}, \text{TTB})}{\partial \sigma_c} = -\frac{1}{4}\beta h + \frac{1}{8} \frac{\beta^2}{1-\beta}. \quad (\text{IA3})$$

The first term above is negative due to the forgone profits over the inaction period and the second term is positive due to the “bad” news principle. Importantly, the net benefit of waiting can *decrease* in σ_c if $h > \frac{\beta}{2(1-\beta)}$. Intuitively, a sufficiently large value of h makes the foregone profits from the potential realization of $P_c(VG)$ dominate the benefits of waiting. This makes the firm *hasten* its investment in the face of more downstream uncertainty.

While the time-to-build lasts one period in this stylized model, the parameter h captures the effect of longer-time-to-build in reduced form. With a longer investment lag (higher h), “very good” news about $P_{c,1}$ can become more extreme. Thus, we expect downstream uncertainty to boost investment for longer time-to-build projects.

invest now, denoted NPV_0^{TTB} , and the NPV of delaying the option to invest, denoted $E_0[NPV_1^{\text{TTB}}]$, from the model with time-to-build in Section II below.

⁵The relevant parts of terms (I), (III), and (IV) are $-\frac{1}{4}\beta h \sigma_c - \frac{1}{4}\beta \sigma_c + \frac{1}{4} \frac{\beta}{1-\beta} \sigma_c - \frac{1}{8} \frac{\beta^2}{1-\beta} \sigma_c$.

II. Stylized Model Solution Details

A. Model Without Time-to-Build: Net Present Values

The NPV for exercising the option to invest at time 0 is

$$\begin{aligned}
 NPV_0^{\text{No TTB}} = & \frac{1}{4} \underbrace{\left\{ -P_s + P_c - \omega + \frac{\beta}{1-\beta}(P_c + h\sigma_c - \omega) \right\}}_{NPV_{0[P_c(VG)]} > 0} \\
 & + \frac{1}{4} \underbrace{\left\{ -P_s + P_c - \omega + \frac{\beta}{1-\beta}(P_c + \sigma_c - \omega) \right\}}_{NPV_{0[P_c(G)]} > 0} \\
 & + \frac{1}{4} \underbrace{\left\{ -P_s + P_c - \omega + \frac{\beta}{1-\beta}(P_c - \sigma_c - \omega) \right\}}_{NPV_{0[P_c(B)]} < 0} + \frac{1}{4} \underbrace{\{-P_s + P_c - \omega - \beta a\}}_{NPV_{0[P_c(VB)]} < 0},
 \end{aligned}$$

The NPV for waiting to invest at time 1 is

$$\begin{aligned}
 E_0[NPV_1^{\text{No TTB}}] = & \frac{\beta}{8} \underbrace{\left\{ -(P_s - \sigma_s) + \frac{1}{1-\beta}(P_c + h\sigma_c - \omega) \right\}}_{NPV_{1[P_c(VG), P_s(down)]} > 0} \\
 & + \frac{\beta}{8} \underbrace{\left\{ -(P_s - \sigma_s) + \frac{1}{1-\beta}(P_c + \sigma_c - \omega) \right\}}_{NPV_{1[P_c(G), P_s(down)]} > 0} \\
 & + \frac{\beta}{8} \underbrace{\left\{ -(P_s + \sigma_s) + \frac{1}{1-\beta}(P_c + h\sigma_c - \omega) \right\}}_{NPV_{1[P_c(VG), P_s(up)]} > 0}.
 \end{aligned}$$

B. Model with Time-to-Build: Net Present Values

$$NPV_0^{\text{TTB}} = \frac{1}{4} \underbrace{\left\{ -P_s + \frac{\beta}{1-\beta}(P_c + h\sigma_c - \omega) \right\}}_{NPV_{0[P_c(VG)]} > 0} + \frac{1}{4} \underbrace{\left\{ -P_s + \frac{\beta}{1-\beta}(P_c + \sigma_c - \omega) \right\}}_{NPV_{0[P_c(G)]} > 0}$$

$$\begin{aligned}
& + \frac{1}{4} \underbrace{\left\{ -P_s + \frac{\beta}{1-\beta}(P_c - \sigma_c - \omega) \right\}}_{NPV_0[P_c(B)] < 0} + \frac{1}{4} \underbrace{\{-P_s - \beta a\}}_{NPV_0[P_c(VB)] < 0}, \\
E_0[NPV_1^{\text{TTB}}] = & + \frac{1}{8} \beta \underbrace{\left\{ -(P_s - \sigma_s) + \frac{\beta}{1-\beta}(P_c + h\sigma_c - \omega) \right\}}_{NPV_1[P_c(VG), P_s(\text{down})] > 0} \\
& + \frac{1}{8} \beta \underbrace{\left\{ -(P_s - \sigma_s) + \frac{\beta}{1-\beta}(P_c + \sigma_c - \omega) \right\}}_{NPV_1[P_c(G), P_s(\text{down})] > 0} \\
& + \frac{1}{8} \beta \underbrace{\left\{ -(P_s + \sigma_s) + \frac{\beta}{1-\beta}(P_c + h\sigma_c - \omega) \right\}}_{NPV_1[P_c(VG), P_s(\text{up})] > 0}.
\end{aligned}$$

III. Variable Description and Construction

A. Micro-Level Variables

Book-to-market ratio. A firm's book-to-market ratio is constructed by following Daniel and Titman (2006). Book equity is defined as shareholders' equity minus the value of preferred stock. If available, shareholders' equity is set equal to stockholders' equity (Compustat Annual item SEQ). If stockholders' equity is missing, then common equity (Compustat Annual item CEQ) plus the par value of preferred stock (Compustat Annual item PSTK) is used instead. If neither of the two previous definitions of stockholders' equity can be constructed, then shareholders' equity is the difference between total assets (Compustat Annual item AT) and total liabilities (Compustat Annual item LT). For the value of preferred stock, we use the redemption value (Compustat Annual item PSTKRV), the liquidating value (Compustat Annual item PSTKL), or the carrying value (Compustat Annual item PSTK), in that order of preference. We also add the value of deferred taxes and investment tax credits (Compustat Annual item TXDITC) to and subtract the value of post-retirement benefits (Compustat Annual item PRBA) from, the value of book equity if either variable is available. Finally, the book value of equity in the fiscal year ending in calendar year $t - 1$ is divided by the market value of common equity from December of year $t - 1$.

Book leverage. Book leverage is defined as the sum of long-term debt (Compustat Annual item DLTT) and debt in current liabilities (Compustat Annual item DLC) divided by total assets (Compustat Annual item AT).

COGS growth. The real COGS growth rate of firm i at time t is computed as the change

in each firm’s real cost of goods sold (Compustat Annual item COGS) between fiscal years t and $t - 1$ divided by average COGS (expressed in real terms) in fiscal years t and $t - 1$. Here, we deflate the nominal value of each firm’s COGS using the consumer price index for all urban consumers constructed by the Bureau of Labor Statistics.

Depreciation rate. We define the depreciation rate of physical capital for firm i at time t , denoted by $\delta_{i,t}$ as the firm’s depreciation and amortization expense (Compustat Annual item DP) minus the firm’s amortization expense (Compustat Annual item AM), scaled by the firm’s net property, plant, and equipment (Compustat Annual item PPENT). We then proxy for the length of the firm’s time-to-build period using the inverse of this depreciation rate. That is, by using $\frac{1}{\delta_{i,t}}$.

Downstream uncertainty. We measure downstream uncertainty, the uncertainty of the customers of firm i at time t , using each one of three different proxies by following a three-step procedure. First, we identify the customers associated with firm i at time t using the procedure outlined in Section III.A of the main article. Second, we construct one of three different measures of uncertainty based on (i) realized stock return volatility, which is our baseline measure; (ii) idiosyncratic stock return volatility; or (iii) option-implied volatility. In regards to (i), our main variable of interest, we obtain the realized stock return volatility of each customer associated with firm i at time t by computing the standard deviation of the daily stock returns of each customer in the year preceding time t . When calculating these standard deviations we adjust daily stock returns for delisting events, and require that each customer firm has at least 200 nonmissing daily stock returns in the previous year. In regards to (ii), our first alternative proxy, we obtain the idiosyncratic volatility of the customers of firm i at time t by following Ang, Hodrick, Xing, and Zhang (2006). That is, we project each customer’s (de-listing adjusted) excess daily stock returns in the year preceding time t on the Fama and French (1993) factors, provided there are at least 200 valid daily returns in the previous year. We then compute the standard deviations of the residuals obtained from the aforementioned regression. In regards to (iii), our second alternative proxy, we obtain the option-implied volatility of each customer associated with firm i at time t using each customer firm’s at-the-money call options. Specifically, we compute the daily mean implied volatility of the firm by taking the equal-weighted average implied volatility across all call options with between 186 and 365 calendar days to maturity, and with moneyness between 0.95 and 1.05. We then compute the time-series average of this implied volatility over all days in the year preceding time t . We use option data from OptionMetrics to construct this proxy of customer-level uncertainty. The third and final step of this procedure is to calculate the equal-weighted average of each of the three uncertainty measures computed in the previous steps to arrive at proxies for downstream uncertainty based on the realized stock return volatility, idiosyncratic return volatility, and option-implied volatility of customer firms.

Employment growth. The employment growth rate is computed as the change in the number of employees (Compustat Annual item EMP) between fiscal years t and $t - 1$ divided

by the average number of employees in fiscal years t and $t - 1$.

Investment rate. Following Belo, Lin, and Bazdresch (2014), the investment rate is computed as capital expenditure (Compustat Annual item CAPX) minus the sales of property, planet, and equipment (Compustat Annual item SPPE, if not missing) scaled by the average net property, planet, and equipment in years t and $t - 1$ (Compustat Annual item PPENT).

Intangible growth. The real intangible investment growth rate of firm i at time t is computed following Peters and Taylor (2017) by first defining firm-level intangible investment as 30% the firm’s selling, general, and administrative expenses net of R&D (Compustat Annual item XSGA minus XRD, if not missing) plus 100% of the firm’s research and development expense (Compustat Annual item XRD, if not missing). We then deflate the nominal value of this quantity using the consumer price index for all urban consumers constructed by the Bureau of Labor Statistics. Finally, we define the firm’s real intangible growth rate as the growth rate in intangibles between fiscal years $t - 1$ and t .

Past return. A firm’s past return momentum in month t is defined as its cumulative return between months $t - 11$ and $t - 1$ Jagadeesh and Titman (1993). This measure is constructed using CRSP Monthly return data that is adjusted for de-listing events.

Own uncertainty. We measure the uncertainty of firm i at time t using each one of three different proxies for uncertainty based on (i) realized stock return volatility, which is our baseline measure; (ii) idiosyncratic stock return volatility; or (iii) option-implied volatility. In regards to (i), our main variable of interest, we obtain the realized stock return volatility of each firm i at each time t by computing the standard deviation of the daily stock returns of the firm in the year preceding time t . When calculating these standard deviations we adjust daily stock returns for delisting events, and require that each firm has at least 200 nonmissing daily stock returns in the previous year. In regards to (ii), our first alternative proxy, we obtain the idiosyncratic volatility of firm i at time t by following Ang et al. (2006). That is, we project each firm’s (de-listing adjusted) excess daily stock returns in the year preceding time t on the Fama and French (1993) factors, provided there are at least 200 valid daily returns in the previous year. We then compute the standard deviations of the residuals obtained from the aforementioned regression. In regards to (iii), our second alternative proxy, we obtain the option-implied volatility of each firm i at time t using each firm’s at-the-money call options. Specifically, we compute the daily mean implied volatility of the firm by taking the equal-weighted average implied volatility across all call options with between 186 and 365 calendar days to maturity, and with moneyness between 0.95 and 1.05. We then compute the time-series average of this implied volatility over all days in the year preceding time t . We use option data from OptionMetrics to construct this proxy of own uncertainty. The final step of this procedure is to calculate the equal-weighted average of each of the three uncertainty measures computed in the previous steps to arrive at proxies for firm-level uncertainty based on the realized stock return volatility, idiosyncratic return volatility, and option-implied volatility of each firm.

Profitability. A firm’s profitability, as measured by return on assets, is computed as

earnings before interest and tax expenses (Compustat Annual item EBIT) divided by the lagged value of total assets (Compustat Annual item AT).

R&D-to-assets. A firm’s research and development intensity is defined as the firm’s research and development expense (Compustat Annual item XRD) in fiscal year t divided by the firm’s total assets (Compustat Annual item AT) in fiscal year $t - 1$. In computing this variable, we do not impute missing values of Compustat Annual item XRD with zero.

Size. We calculate firm size as the natural logarithm of a firm’s total assets (Compustat Annual item AT).

Tangibility. Tangibility is defined as the ratio of a firm’s gross property, plant, and equipment (Compustat Annual item PPEGT) to the firm’s total assets (Compustat Annual item AT).

Tobin’s q . We define Tobin’s q as the book value of assets (Compustat Annual Item AT) minus the book value of common equity (Compustat Annual Item CEQ) plus the market value of common equity (Compustat Annual Item CSHO), divided by the book value of assets.

Upstream uncertainty. We measure upstream uncertainty, the uncertainty of the suppliers of firm i at time t , using each one of three different proxies by following a three-step procedure. First, we identify the suppliers associated with firm i at time t using the procedure outlined in Section III.A of the main article. Second, we construct one of three different measures of uncertainty based on (i) realized stock return volatility, which is our baseline measure; (ii) idiosyncratic stock return volatility; or (iii) option-implied volatility. In regards to (i), our main variable of interest, we obtain the realized stock return volatility of each supplier associated with firm i at time t by computing the standard deviation of the daily stock returns of each supplier in the year preceding time t . When calculating these standard deviations we adjust daily stock returns for delisting events, and require that each supplier firm has at least 200 nonmissing daily stock returns in the previous year. In regards to (ii), our first alternative proxy, we obtain the idiosyncratic volatility of the supplier of firm i at time t by following Ang et al. (2006). That is, we project each supplier’s (de-listing adjusted) excess daily stock returns in the year preceding time t on the Fama and French (1993) factors, provided there are at least 200 valid daily returns in the previous year. We then compute the standard deviations of the residuals obtained from the aforementioned regression. In regards to (iii), our second alternative proxy, we obtain the option-implied volatility of each supplier associated with firm i at time t using each supplier firm’s at-the-money call options. Specifically, we compute the daily mean implied volatility of the firm by taking the equal-weighted average implied volatility across all call options with between 186 and 365 calendar days to maturity, and with moneyness between 0.95 and 1.05. We then compute the time-series average of this implied volatility over all days in the year preceding time t . We use option data from OptionMetrics to construct this proxy of supplier-level uncertainty. Firms in our sample typically have multiple customers. To ensure a symmetric comparison between the uncertainty measures, we focus on firms with multiple suppliers as

well. The third and final step of this procedure is to calculate the equal-weighted average of each of the three uncertainty measures computed in the previous steps to arrive at proxies for downstream uncertainty based on the realized stock return volatility, idiosyncratic return volatility, and option-implied volatility of customer firms.

Working capital growth. The real working capital growth rate is computed by first defining the noncash working capital of firm i in year t as the firm’s current assets (Compustat Annual item ACT) minus the firm’s cash and cash equivalents (Compustat Annual item CHE). With working capital in hand, we deflate the nominal value of this quantity using the consumer price index for all urban consumers constructed by the Bureau of Labor Statistics. Finally, we compute the change in real working capital between fiscal years t and $t - 1$ divided by the average value of real working capital in fiscal years t and $t - 1$.

B. Macro-Level Variables

Default spread. The default spread at time t is defined as the difference between yields on AAA-rated corporate bonds and the yields on BAA-rated yields at the same point in time. We draw the default spread from the updated dataset corresponding to Welch and Goyal (2008), which is available on Amit Goyal’s website.

Downstream stock return volatility. Our primary measure of aggregate downstream uncertainty at time t , based on realized stock return volatility, is computed as follows. First, we calculate the vertical position of each industry at a given point in time following the procedure outlined in Section IV.A of the main article, and map these industry-level vertical position scores to the firm-level. Second, define downstream firms as those firms with a vertical position score that is below the 10th percentile of the cross-sectional distribution of vertical position scores at the given point in time. Third, we compute the realized stock return volatility of each firm assigned to the downstream portfolio in month t . When computing these monthly measures of realized stock return volatility we (i) adjust the CRSP daily stock return data for delisting events, and (ii) require that each firm has 15 valid returns in each month. Fourth, we then take the value-weighted average realized stock return volatility across all firms assigned to the downstream portfolio in month t . In applications that require a monthly measure of aggregate downstream uncertainty, we end the procedure here. In applications that require a quarterly measure of aggregate downstream uncertainty, we define downstream uncertainty in quarter t as the time-series average value of monthly aggregate downstream uncertainty over the three months in quarter t .

Excess market returns. We obtain the quarterly excess returns of the market portfolio using data on the market factor underlying the Fama and French (1993) three-factor model. Specifically, we compound the monthly returns associated with the excess market return factor to the quarterly frequency. We implement this calculation using factor return data drawn from Ken French’s data library.

Industrial production. We measure the quarterly growth rate of industry production at

time t using the logarithmic growth rate of the Board of Governors of the Federal Reserve System’s industrial production index. We obtain our data on the industrial production index from FRED and express the quarterly growth rate as a percentage.

Inflation rate. The inflation rate at time t is computed using the consumer price index for all urban consumers constructed by the Bureau of Labor Statistics. We draw this inflation rate date from the updated dataset corresponding to Welch and Goyal (2008), which is available on Amit Goyal’s website.

Investment-minus-consumption (IMC) spread. In line with Papanikolaou (2011), we proxy for investment-specific technology (IST) shocks using the value-weighted return spread on a portfolio of investment-related firms minus the return on a portfolio of consumption-related firms. We identify the set of investment- and consumption-related firms using the industry classification of Gomes, Kogan, and Yogo (2009).

Price-dividend ratio. We compute the price-dividend ratio of the S&P 500 index at time t by dividing the price index of the S&P 500 at time t by the twelve-month moving sum of dividends paid by the constituents of the S&P 500 index over the 12 months preceding time t . We obtain data on both components of the price-dividend ratio from the updated dataset corresponding to Welch and Goyal (2008), which is available on Amit Goyal’s website.

Public firm COGS growth. The aggregate growth rate of public firms’ cost of goods sold (COGS) is found by first summing COGS (Compustat Annual item COGS) across all firms in the CRSP/Compustat universe (excluding financial firms and utilities), then deflating the resulting aggregate quantities by the consumer price index for all urban consumers constructed by the Bureau of Labor Statistics, and finally computing the annual growth rate of the resulting time series of real aggregate COGS.

Public firm employment growth. The aggregate employment growth rate of public firms is measured by first summing the number of employees (Compustat Annual item EMP) across all firms in the CRSP/Compustat universe (excluding financial firms and utilities), and then computing the annual growth rate of the resulting number of employees.

Public firm intangible investment growth. The aggregate growth rate of public firms’ intangible investment is found by first constructing each firm’s intangible investment as 30% the firm’s selling, general, and administrative expenses net of R&D (Compustat Annual item XSGA minus XRD, if not missing) plus 100% of the firm’s research and development expense (Compustat Annual item XRD, if not missing). Next, we sum each firm’s intangible investment across all firms in the CRSP/Compustat universe (excluding financial firms and utilities), deflating the resulting aggregate quantities by the consumer price index for all urban consumers constructed by the Bureau of Labor Statistics. Finally, we compute the annual growth rate of the resulting time series of real aggregate intangible investment.

Public firm output growth. The aggregate growth rate of public firms’ output is found by first summing revenues (Compustat Annual item SALE) across all firms in the CRSP/Compustat universe (excluding financial firms and utilities), then deflating the resulting aggregate quantities by the consumer price index for all urban consumers constructed

by the Bureau of Labor Statistics, and finally computing the annual growth rate of the resulting time series of real aggregate revenues.

Public firm physical investment growth. The aggregate growth rate of public firms' physical investment is found by first summing net property, plant, and equipment (Compustat Annual item PPENT) across all firms in the CRSP/Compustat universe (excluding financial firms and utilities), then deflating the resulting aggregate by the consumer price index for all urban consumers constructed by the Bureau of Labor Statistics, and finally computing the annual growth rate of the resulting time series of real aggregate PPENT.

Public firm working capital growth. The aggregate growth rate of public firms' noncash working capital is found by first constructing each firm's noncash working capital as the difference between current assets (Compustat Annual item ACT) and cash and cash equivalents (Compustat Annual item CHE). Next, we sum each firm's noncash working capital across all firms in the CRSP/Compustat universe (excluding financial firms and utilities), deflating the resulting aggregate quantities by the consumer price index for all urban consumers constructed by the Bureau of Labor Statistics. Finally, we compute the annual growth rate of the resulting time series of real noncash working capital.

Real consumption growth. We construct the quarterly growth rate of real consumption at time t in four steps. First, we compute the sum of personal consumption expenditures on non-durable goods and personal consumption expenditures on services. Each of these components of personal consumption expenditure is constructed by the Bureau of Economic Analysis and is expressed in nominal terms in units of billions of dollars. Second, we deflate the nominal values of personal consumption expenditures by the consumer price index deflator to express consumption expenditures in real terms. Specifically, we use the deflator associated with the consumer price index for all urban consumers constructed by the Bureau of Labor Statistics. Third, we scale real personal consumption expenditures at each point in time by the size of the U.S. population, as reported by the Bureau of Economic Analysis. Finally, to compute the quarterly growth rate of real consumption expenditures, we begin by aggregating consumption expenditures from the monthly frequency to the quarterly frequency. This is done by computing the average value of real consumption expenditures per capita per quarter. We then compute the logarithmic growth rate of this quarterly real consumption expenditures per capita series. We obtain each of the aforementioned series from FRED and express the quarterly growth rate of real consumption as a percentage.

Real equipment investment. We construct the quarterly growth rate of real equipment investment at time t in three steps. First, we obtain the nominal level of equipment investment from the Bureau of Economic Analysis (BEA) National Income and Product Accounts (NIPA) data. Specifically, we obtain this quantity from Line 11 of Table 1.1.5. Second, we deflate the nominal value of this series using the price index for the same item available in Table 1.1.4 of the NIPA data. Finally, we compute the logarithmic quarterly growth rate of this real series and express the quarterly growth rate of real private investment as a percentage.

Real fixed investment. We construct the quarterly growth rate of real fixed investment (i.e., the sum of nonresidential and residential investment) at time t in three steps. First, we obtain the nominal level of private fixed investment from the Bureau of Economic Analysis (BEA) National Income and Product Accounts (NIPA) data. Specifically, we obtain this quantity from Line 8 of Table 1.1.5. Second, we deflate the nominal value of this series using the price index for the same item available in Table 1.1.4 of the NIPA data. Finally, we compute the logarithmic quarterly growth rate of this real series and express the quarterly growth rate of real private investment as a percentage.

Real gross domestic product. We construct the quarterly growth rate of real gross domestic production (GDP) at time t by computing the logarithmic growth rate of real gross domestic product per capita, as constructed and reported by the Bureau of Economic Analysis. We obtain our data on real GDP per capita from FRED and express the quarterly growth rate as a percentage.

Real intellectual property products investment. We construct the quarterly growth rate of real intellectual property products (IPP) investment at time t in three steps. First, we obtain the nominal level of intellectual property product investment from the Bureau of Economic Analysis (BEA) National Income and Product Accounts (NIPA) data. Specifically, we obtain this quantity from Line 12 of Table 1.1.5. Second, we deflate the nominal value of this series using the price index for the same item available in Table 1.1.4 of the NIPA data. Finally, we compute the logarithmic quarterly growth rate of this real series and express the quarterly growth rate of real private investment as a percentage.

Real nonresidential investment. We construct the quarterly growth rate of real nonresidential investment at time t in three steps. First, we obtain the nominal level of nonresidential investment from the Bureau of Economic Analysis (BEA) National Income and Product Accounts (NIPA) data. Specifically, we obtain this quantity from Line 9 of Table 1.1.5. Second, we deflate the nominal value of this series using the price index for the same item available in Table 1.1.4 of the NIPA data. Finally, we compute the logarithmic quarterly growth rate of this real series and express the quarterly growth rate of real private investment as a percentage.

Real residential investment. We construct the quarterly growth rate of real residential investment at time t in three steps. First, we obtain the nominal level of residential investment from the Bureau of Economic Analysis (BEA) National Income and Product Accounts (NIPA) data. Specifically, we obtain this quantity from Line 13 of Table 1.1.5. Second, we deflate the nominal value of this series using the price index for the same item available in Table 1.1.4 of the NIPA data. Finally, we compute the logarithmic quarterly growth rate of this real series and express the quarterly growth rate of real private investment as a percentage.

Real structures investment. We construct the quarterly growth rate of real structures investment at time t in three steps. First, we obtain the nominal level of structures investment from the Bureau of Economic Analysis (BEA) National Income and Product Accounts

(NIPA) data. Specifically, we obtain this quantity from Line 10 of Table 1.1.5. Second, we deflate the nominal value of this series using the price index for the same item available in Table 1.1.4 of the NIPA data. Finally, we compute the logarithmic quarterly growth rate of this real series and express the quarterly growth rate of real private investment as a percentage.

Risk-free rate. We use the Treasury bill rate as our proxy for the risk-free rate at time t . We obtain data on the risk-free rate from the updated dataset corresponding to Welch and Goyal (2008), which is available on Amit Goyal’s website.

Term spread. The term spread at time t is defined as the difference between the yield on long-term Treasury bonds and the Treasury bill rate. We draw the term spread from the updated dataset corresponding to Welch and Goyal (2008), which is available on Amit Goyal’s website.

Upstream stock return volatility. Our primary measure of aggregate upstream uncertainty at time t , based on realized stock return volatility, is computed as follows. First, we calculate the vertical position of each industry at a given point in time following the procedure outlined in Section IV.A of the main article, and map these industry-level vertical position scores to the firm-level. Second, define upstream firms as those firms with a vertical position score that exceeds the 90th percentile of the cross-sectional distribution of vertical position scores at the given point in time. Third, we compute the realized stock return volatility of each firm assigned to the upstream portfolio in month t . When computing these monthly measures of realized stock return volatility we (i) adjust the CRSP daily stock return data for delisting events, and (ii) require that each firm has 15 valid returns in each month. Fourth, we then take the value-weighted average realized stock return volatility across all firms assigned to the upstream portfolio in month t . In applications that require a monthly measure of aggregate upstream uncertainty, we end the procedure here. In applications that require a quarterly measure of aggregate upstream uncertainty, we define upstream uncertainty in quarter t as the time-series average value of monthly aggregate upstream uncertainty over the three months in quarter t .

IV. Input/Output Price Uncertainty versus Supplier/Customer Return Volatility

In this section, we provide empirical evidence to support the assumption that input (output) price uncertainty is positively related to uncertainty over the valuations of a firm’s suppliers (customers). We obtain annual time series for output prices (PISHIP) and input prices (PIINV) that are specific to a cross-section of 473 manufacturing industries covered by the NBER-CES Manufacturing Industry Database (using the 1997 NAICS industry classification). These time-series span year $\tau \in \{1958, \dots, 2018\}$. For each industry i , we model

the annual log growth in PISHIP and PIINV using a GARCH(1,1) model to obtain the output and input price uncertainty, denoted by $\hat{\sigma}_{P(\text{Output}),i,\tau}$ and $\hat{\sigma}_{P(\text{Input}),i,\tau}$, respectively.

For each industry i we use the 1997 BEA Make and Use Tables, described in Section V, to compute the flow-weighted stock returns of the industry's customers and suppliers. Below, we let N (C) denote the number of industries (commodities) that exist within the BEA Make and Use tables. In line with the notation in Section V, we refer to the Make matrix as $M_{N \times C}$ and the Use matrix as $U_{C \times N}$. The flow of inputs from industry i to industry j is then recorded in element

$$A(i, j) = \sum_{c=1}^C M(i, c) \left(\frac{U(c, j)}{\sum_{k=1}^N U(c, k)} \right)$$

of matrix $A_{N \times N}$. Given $A_{N \times N}$, we construct the monthly time series of the returns of industry i 's customers as

$$r_{i,t}^{\text{Customer}} = \sum_{j=1}^N w_j^{c,i} r_{j,t}, \quad \text{where } w_j^{c,i} = A(i, j) / \sum_k A(i, k).$$

Similarly, the monthly time-series of the returns of industry i 's suppliers is

$$r_{i,t}^{\text{Supplier}} = \sum_{j=1}^N w_j^{s,i} r_{j,t}, \quad \text{where } w_j^{s,i} = A(j, i) / \sum_k A(k, i).$$

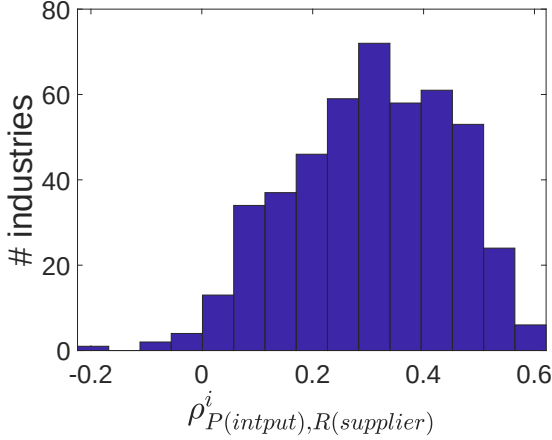
Next, in December of each year τ we construct the realized return volatility of $r_{i,t}^{\text{Customer}}$ and $r_{i,t}^{\text{Supplier}}$ over the last M months, denoted by $RV_{\text{Customer},i,\tau}$ and $RV_{\text{Supplier},i,\tau}$. In the benchmark case, we set $M = 3$ to encompass the latest quarter, but we obtain very similar results for $M = 6$ and $M = 12$.

We then focus on industries in our sample that overlap with the NBER-CES database, represented by N_{CES} . For each $i \in N_{CES}$ we compute two time-series correlations: (i) the correlation between the industry's output price uncertainty and the industry's customer return volatility, $\rho_{P(\text{Output}),R(\text{Customer})}^i = \rho(\hat{\sigma}_{P(\text{Output}),i,\tau}, RV_{\text{Customer},i,\tau})$, and (ii) the correlation between the industry's input price uncertainty and the industry's supplier return volatility, $\rho_{P(\text{Input}),R(\text{Supplier})}^i = \rho(\hat{\sigma}_{P(\text{Input}),i,\tau}, RV_{\text{Supplier},i,\tau})$. We only compute this correlation for industries for which there are at least ten overlapping years of price uncertainty and return volatility data.

Panel A of Figure IA2 shows the histogram of $\rho_{P(\text{Output}),R(\text{Customer})}^i$ while Panel B shows the histogram of $\rho_{P(\text{Input}),R(\text{Supplier})}^i$. Consistent with assumption posited in the empirical analysis, both $\rho_{P(\text{Output}),R(\text{Customer})}^i$ and $\rho_{P(\text{Input}),R(\text{Supplier})}^i$ are positive and sizable for almost all industries. Both distributions are right-skewed. The cross-sectional average of

$\rho_{P(\text{Input}),R(\text{Supplier})}^i$ is 0.31 with a t -statistic of 45.41. Likewise, the cross-sectional average of $\rho_{P(\text{Output}),R(\text{Customer})}^i$ is 0.21 with a t -statistic of 28.27.⁶

Panel A. Input price and supplier return correlations



Panel B. Output price and customer return correlations

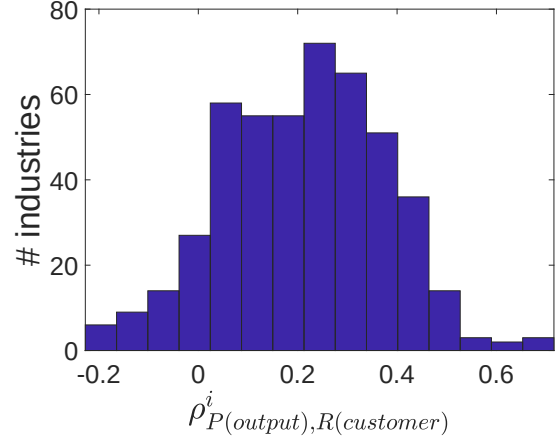


Figure IA3. Cross-sectional correlation: price versus return uncertainty. Panel A shows the histogram of $\rho_{P(\text{Input}),R(\text{Supplier})}^i$ and Panel B the histogram of $\rho_{P(\text{Output}),R(\text{Customer})}^i$. $\rho_{P(\text{Output}),R(\text{Customer})}^i$ is the correlation between industry i 's output price uncertainty and the industry's customer return volatility. $\rho_{P(\text{Input}),R(\text{Supplier})}^i$ is the correlation between industry i 's input price uncertainty and the industry's supplier return volatility. The sample period ranges from 1958 to 2018.

V. Cleaning BEA Input-Output Tables

We closely follow Gofman, Segal, and Wu (2020), by using the BEA Make and Use tables for years 2012, 2007, 2002, 1997, 1992, 1987, 1982, and 1977 to measure industry-level vertical position using equation (12). For each set of tables, we define N_t (C_t) as the number of industries (commodities) that exist within the BEA tables in year t . The dimensions of the Make table, which we denote by M_t , are $N_t \times C_t$. Similarly, the dimensions of the Use table, which we denote by U_t , are $C_t \times (N_t + 1)$. The first N_t columns of U_t contain the dollar flow of a commodity into each industry (i.e., record the value of the commodity used

⁶As mentioned above, we obtain similar results for other choices of M . For example, if $M = 6$, then $\rho_{P(\text{Input}),R(\text{Supplier})}^i$ averages 0.18, with a t -statistic of 30.43, while $\rho_{P(\text{Input}),R(\text{Supplier})}^i$ averages 0.14, with a t -statistic of 18.73.

by the industry as an input), while the last column of U_t contains the dollar value of the commodity used for final consumption.

Next, we normalize the Make and Use tables so that the sum of each row is one. Specifically, we define the matrices $\tilde{M}_t$ and $\tilde{U}_t$ such that

$$\begin{aligned}\tilde{M}_{j,i,t} &= M_{j,i,t} \bigg/ \left(\sum_{z=1}^{C_t} M_{j,z,t} \right), \quad \forall i \in \{1, \dots, N_t\} \text{ and } j \in \{1, \dots, C_t\} \\ \tilde{U}_{i,j,t} &= U_{i,j,t} \bigg/ \left(\sum_{z=1}^{N_t+1} U_{i,z,t} \right), \quad \forall i \in \{1, \dots, N_t\} \text{ and } j \in \{1, \dots, C_t\}.\end{aligned}$$

Here, element (j, i) in $\tilde{M}$ captures the share of commodity i produced by industry j , and element (i, j) in $\tilde{U}_t$ represents the share of commodity i used by industry j . When computing these shares we take the possibility that some of the commodity may be used for final consumption into account. We remove industries related to the state, local, and Federal government (denoted by entries S001-S007) and Other Services (denoted by NAICS code 81). The final consumption use of each commodity (i.e., the final column of each Use table) is drawn from the Personal Consumption Expenditure columns of the BEA USe files (denoted by F01000 or 910000).

If the sum of a particular row of the Use table, denoted by the matrix U_t , is zero, then we set the respective rows of the normalized Use table, denoted by $\tilde{U}_t$, to zero also. Likewise, when we compute the normalized Use matrix $\tilde{U}_t$ we remove industries that supply for than 90% of their output to themselves. That is, we exclude any industries for which $\tilde{U}_{t,(i,i)} > 0.90$. We apply this filter because these industries are essentially disconnected from the broader economy, yet have extremely high vertical position scores. If we were to include these few but extreme industries in our calculations of vertical position, then the vertical positions of the relatively few industries that supply to these disconnected industries, either directly or indirectly, would become elevated. Also note that equation (12) features a $N_t \times N_t$ matrix $T_t \equiv \tilde{M}_{N_t \times C_t} \times \tilde{U}_{C_t \times N_t}$, where element (i, j) of matrix T_t contains the amount transferred from industry i to industry j . For each row i in T_t , if the element (i, j) is less than 1%, we set this element equal to zero and distribute this small amount among the non-negligible elements of row i . This filter allows us to minimize any noise in the Make and Use tables and allows us to focus on the most economically important inter-industry transfers. We then use these definitions of $\tilde{M}_t$ and $\tilde{U}_t$ to compute the vertical position scores using equation (12).

In order to link the BEA-implied vertical position measures to the CRSP/Compustat universe of firms we make use of data provided by the BEA to map industry codes in the Make and Use tables to NAICS codes (for the 1997, 2002, 2007, and 2012 tables) and to SIC codes (for the 1977, 1982, 1987, and 1992 tables). For the NAICS-based tables in the post-1997 period, we map NAICS codes to the CRSP/Compustat universe as follows. First, we

try to match each firm's six-digit NAICS code to the six-digit NAICS codes of the available industries. If no matches are found, we then try to match each firm's five-digit NAICS code to the five-digit NAICS codes of the available industries. If no matches are found, we then apply this same process to four-digit, three-digit, and two-digit NAICS codes (in that order). Likewise, for the pre-1997 period, we first try to match each firm to an industry using four-digit SIC codes. For the firms that remain unmatched, we then try to match each firm to an industry based on three-digit, or two-digit SIC codes (in that order).

VI. Model Solution and Simulation

We first discretize each of σ^{In} and σ^{Out} , the conditional volatility of input and output prices from equation (3) of the main article, respectively, using a Markov chain. For each process, we use an equally spaced grid with extreme points that are 2.5 standard deviations above and below the unconditional mean. We obtain the transition matrix associated with each of the Markov chains using the method of Tauchen (1986). For $j \in \{\text{In}, \text{Out}\}$, we denote the resulting grid as $g_\sigma^j = [\sigma_1^j, \dots, \sigma_{N_\sigma^j}^j]$, and we denote Π_σ^j as the $N_\sigma^j \times N_\sigma^j$ transition matrix of the process.

Next, to discretize the process associated with the level of each log-price p^j , for $j \in \{\text{In}, \text{Out}\}$, from equation (2) of the main article, we proceed in two steps. First, we select the grid points $g_p^j = [p_1^j, \dots, p_{N_p^j}^j]$ such that the extreme points p_1^j and $p_{N_p^j}^j$ are 2.5 standard deviations above and below the mean price (of zero), where the standard deviation is determined by the average level of price volatility σ_0 , which is the mid point of g_σ^j . Next, after solving the model using a set of sparse grids that have a minimum of $N_p^{j, \text{Min}}$ points (using the procedure outlined below) and obtaining an approximate solution to the unconditional investment threshold, we make the grid dense around the free boundary, as needed, with a minimum of $N_p^{j, \text{Bound}}$ additional grid points, to ensure the accuracy of the solution. The transition matrix associated with the Markov chain of the price process is a three-dimensional matrix with dimensions $N_\sigma^j \times N_p^j \times N_p^j$. Specifically, we denote $\Pi_p^j(\sigma_k^j)$ as the $N_p^j \times N_p^j$ price transition matrix of price p_j whenever the current state of the conditional volatility process is $\sigma_k^j \in g_\sigma^j$. We populate $\Pi_p^j(\sigma_k^j)$ via the method of Tauchen (1986) using the grid g_p^j and the conditional volatility σ_k^j .

The grid for the stock of installed inputs k is denoted by g_k and is endogenously selected as follows. First, we set a coarse grid for k and solve the model to obtain an approximate level for the stochastic steady-state of capital, which we denoted by $\tilde{k}_{ss}$. We then reconstruct the grid for k using a minimum of N_k grid points that are centered around the value of $\tilde{k}_{ss}$, with half of the grid points spaced above (below) $\tilde{k}_{ss}$. These grid points are unequally spaced, such that most of the mass of the refined grid for k is in the region around $\tilde{k}_{ss}$. We ensure that the minimum and maximum points on g_k are not selected in model simulations, such

that the investment policy is always an interior point on the grid.

With the grids for each of capital, price, and conditional volatility processes in place, we solve the model by first conjecturing initial values for V and V^{Build} from equations 4 and 5, respectively. The value function iteration proceeds as follows. Let the valuation functions in iteration i be denoted by V^i and $V^{i,\text{Build}}$, respectively. Given these value functions, we begin by finding the optimal policy $k^{',i+1}$ and update V^{i+1} . We then update $V_0^{i+1,\text{Build}} = V^{i+1}$, where the subscript here refers to the elapsed time-to-build. Given $V_{\tau}^{i+1,\text{Build}}$, we can forward update $V_{\tau+1}^{i+1,\text{Build}}$. We stop the iteration algorithm when both $\|V^{i+1} - V^i\|$ and $\|V^{i+1,\text{Build}} - V^{i,\text{Build}}\|$ are less than a tolerance level ε .

To compute the unconditional moments, we allow the output price, its uncertainty, and the focal firm's capital to vary over a path of $N_{\text{Population}}$ quarterly observations, and compound every four non-overlapping quarterly observations to form annual paths. To ensure the model is independent of the initial states, we discard the first N_{Burn} observations from the simulation. To obtain the investment thresholds associated with the output price that are a function of downstream uncertainty, we first fix capital at the stochastic steady state, as well as the input price and its uncertainty, and proceed by simulating a path of N_{Sim} periods, allowing the output price and its uncertainty to vary, while keeping track of the output-price thresholds and the contemporaneous realized return of the customer. As the model does not include leverage, we scale the realized volatility of the customer's returns to align with the data. As described in the body of the paper, we then collect all unique investment thresholds, and for numerical accuracy (that is, to be able to compute credible confidence intervals for the return volatilities that are associated with each critical value of the price), we keep only critical values that appear at least N_{Conf} times in the simulation. For each unique threshold in the sample, we then construct a set of all realized return volatilities associated with that threshold in the path, and compute the 90% confidence interval of the set. Obtaining input-price investment thresholds as a function of upstream uncertainty follows a parallel procedure, replacing the output price with the input price and its associated uncertainty.

We fine-tune the methodology parameters as follows: $N_{\sigma}^{\text{In}} = 5$, $N_{\sigma}^{\text{Out}} = 5$, $N_p^{\text{In},\text{Min}} = 7$, $N_p^{\text{Out},\text{Min}} = 7$, $N_p^{\text{In},\text{Bound}} = 14$, $N_p^{\text{Out},\text{Bound}} = 14$, $N_k = 121$, $N_{\text{Burn}} = 1000$, $N_{\text{Population}} = 10,000$, $N_{\text{Sim}} = 10,000$.

VII. Additional Model Results

A. Effect of Higher Upstream Uncertainty

The benchmark calibration of the model features symmetric laws of motions for the levels and uncertainties of input and output prices (recall equations (2) and (3)). Furthermore, we set the volatility parameters governing input and output price uncertainty to be the same. This is done for a constructive reason, as we want to rule out any mechanical sources of

asymmetry between the exogenous driving processes for input and output prices that could, in turn, hard-wire the asymmetry between the effects of upstream and downstream uncertainty on investment. Here, we relax this assumption and set the unconditional volatility of the input prices (and consequently, of suppliers' returns) to be 15% higher than the volatility of output prices (and consequently, customers' returns), in line with the data.

Figure IA4 shows that the results are materially invariant to this heterogeneity: input price (or upstream) uncertainty still raises the investment thresholds and delays investment. We also confirm that the relation between downstream uncertainty and investment is identical to the benchmark, despite one facet of uncertainty becoming more volatile.

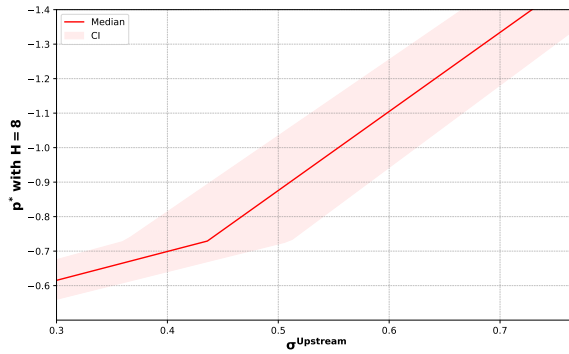


Figure IA4. Investment thresholds: Higher upstream volatility. This figure shows the investment thresholds, p^* , in order of increasing (absolute) magnitude as a function of upstream uncertainty σ^{Upstream} at the model's steady state. Accordingly, the thresholds p^* reflect free boundaries based on critical values of the log input price, p^{In} . The horizontal shaded region shows the model-implied 90% confidence interval of the effects of upstream uncertainty on the investment threshold, displayed on the vertical axis. The red line shows the median value of each confidence interval (i.e., median upstream uncertainty). Upstream uncertainty is defined in equation (9) of the main article and reflects the suppliers' realized stock return volatility over the previous year, where the average realized volatilities in the model are set to match their empirical counterpart. In solving the model, we set the length of the time-to-build period H to eight periods and calibrate the volatility of input prices in equation (2) of the main article such that input price uncertainty is 15 percentage points higher than its value in the baseline calibration.

B. Effect of Back-Loaded Investment

The baseline calibration of the model sets $w_1 = 1$, so that all investment costs are paid upfront. Here we consider an alternative calibration of the model in which $w_H = 1$, so that all investment costs are paid at the end of time-to-build period. The results are shown in Figure IA5, where we contrast the effects of back-loaded investment (displayed by the blue curves and confidence intervals) to the intermediate case of sequential investment that is discussed in Section III.F of the main article (displayed by the red curves and confidence intervals).

If investment is completely back-loaded, then upstream uncertainty still suppresses investment. Qualitatively, the slope of the dashed blue curve is visibly lower compared to the case of equally-spaced investment, depicted by the solid red curve. This lower slope with back-loaded investment corresponds to a weaker association between uncertainty and the propensity to invest. Quantitatively, however, the effect of back-loaded investment is relatively negligible, as the confidence intervals of the blue and red curves largely overlap.

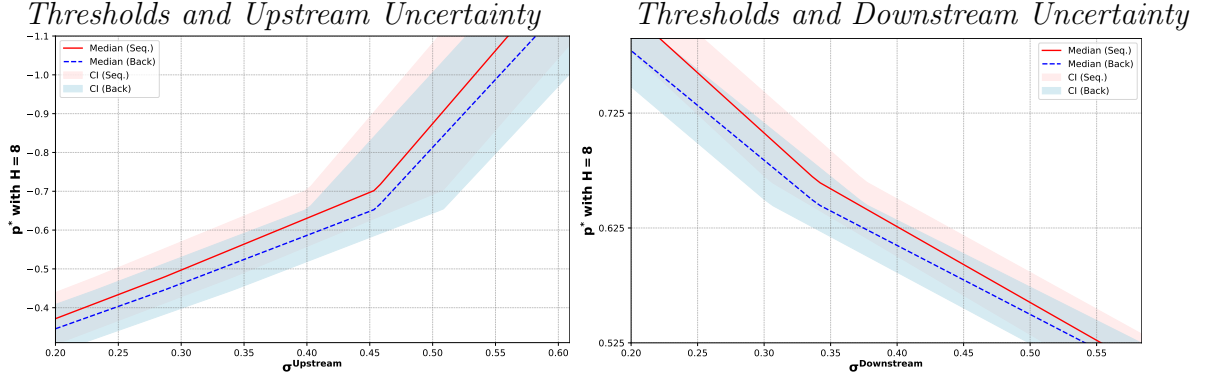


Figure IA5. Investment thresholds: Sequential versus back-loaded investment. This figure shows the investment thresholds p^* in order of increasing (absolute) value as a function of upstream uncertainty σ^{Upstream} (left) and downstream uncertainty $\sigma^{\text{Downstream}}$ (right), using an identical procedure to that outlined in Figure 3 of the main article, but for two different assumptions of when the investment is paid for during the time-to-build period. First, we assume that the investment is paid for sequentially over the time-to-build period so that $w_\tau = 1/8$ for $\tau \in [1, 8]$. This is referred to as the case of sequential investment, or “Seq.” Second, we assume that the investment is paid at the end of the time-to-build period so that $w_\tau = 0$ for $\tau \leq 7$ and $w_8 = 1$. This is referred to as the case of back-loaded investment, or “Back.” In the left (right) column, the thresholds p^* reflect free boundaries based on critical values of the log input (output) price, p^{In} (p^{Out}). The thresholds associated with the median investment threshold in the sequential (back-loaded) case are presented in the solid red (dashed blue) lines, and the red and blue shaded regions represent 90% confidence intervals for each set of thresholds.

C. Effect of Price-Uncertainty Correlation

The baseline calibration of our model, which we refer to as “Case 1,” assumes that shocks to the level and uncertainty of input and output prices in equations (2) and (3) of the main article are orthogonal. Here, we consider two alternative calibrations of the model in which we set a negative correlation between the level and volatility of input and output prices, respectively. These negative correlations are obtained via the discretization of the state variables. In our first alternative calibration, which we refer to as “Case 2,” we set the correlation between the level of input prices and input price uncertainty to be equal to -0.20 . We choose this value of the correlation coefficient to be empirically consistent with the correlation between the level of suppliers’ stock returns and the volatility of suppliers’

stock returns. In our second calibration, which we refer to as “Case 3,” we set this correlation coefficient to a counterfactually high (in absolute magnitude) value of -0.50.

The results associated with upstream uncertainty are shown in the left panel of Figure IA6. The results from the baseline model are displayed by the solid red line. Recalling the discussion from Section II.C.2 of the main article, the baseline result demonstrates that with a long time-to-build period, upstream uncertainty raises the investment thresholds, thereby suppressing investment. The results of Case 2, which are shown in the same figure using the dashed blue curve, indicate that with a realistic correlation, upstream uncertainty still raises the investment threshold (i.e., this facet of uncertainty still suppresses investment), although the relation between upstream uncertainty and the investment threshold is attenuated (i.e., the slope of the curve is somewhat lower). Finally, the results of Case 3, which are shown in the same figure using the dash-dotted green curve and the green confidence interval, show that if the magnitude of the correlation is too large, then the negative effect of upstream uncertainty on investment effectively vanishes. That is, when taking the confidence interval into account, the investment threshold does not materially change with σ^{Upstream} (i.e., the relation between upstream uncertainty and investment is statistically flat in Case 3).

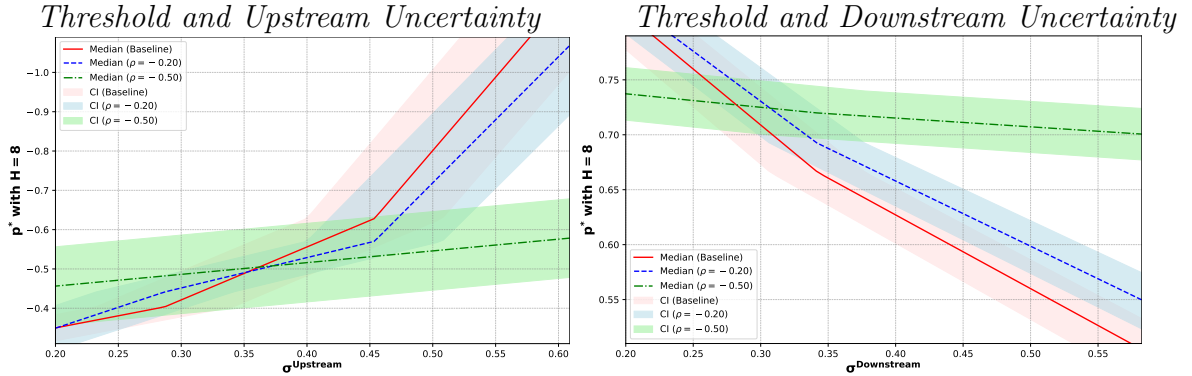


Figure IA6. Investment thresholds: Correlated prices. This figure shows the investment thresholds, p^* , in order of increasing (absolute) magnitude as a function of upstream uncertainty σ^{Upstream} (left panel) and downstream uncertainty $\sigma^{\text{Downstream}}$ (right panel) at the model’s steady state in three cases: (a) the baseline case, in which the level and volatility of prices are uncorrelated; (b) an alternative case, in which the level and volatility of prices have a modest negative correlation of $\rho = -0.20$; and (c) a more extreme alternative case, in which the level and volatility of prices have a moderate negative correlation of $\rho = -0.50$. Accordingly, in the left (right) panel, the thresholds P^* reflect free boundaries based on critical values of the log input (output) price, p^{In} (p^{Out}). The thresholds associated with the median investment threshold in the baseline case of $\rho = 0$, an alternative case of $\rho = -0.20$, and the more extreme alternative case of $\rho = -0.50$ are presented in the solid red, dashed blue, and dash-dotted green lines, respectively, and the red, blue, and green shaded regions represent 90% confidence intervals for each set of thresholds. Here, the time-to-build period H is set to eight quarters.

We repeat an equivalent analysis for downstream uncertainty in the right panel of Figure IA6, where we allow the level and volatility of output prices to become increasingly correlated

(in absolute magnitude). Specifically, we report the baseline results from Section [II.C.2](#) of the main article in the red curve, and also report the results of Case 2 ($\rho = -0.20$) and Case 3 ($\rho = -0.50$) using the blue and green curves, respectively. With a long time-to-build period, the baseline investment thresholds decrease as downstream uncertainty (i.e., customers' stock return volatility) rises. This suggests that higher downstream uncertainty spurs or hastens investment. The blue curve shows that a similar result is maintained, albeit with a slight attenuation in the magnitude of the effect (i.e., a slightly lower slope is absolute value), when the correlation between the price level and uncertainty is realistic, as in Case 2. Finally, the green curve shows that if this correlation is set to a counterfactually large value, as in Case 3, then the relation between downstream uncertainty and the investment effectively goes away.

D. Effect of Operating Leverage

Figure [IA7](#) shows the investment thresholds as a function of upstream and downstream uncertainty in both the baseline model where $\omega = 0$, which is displayed by the red curves and confidence intervals, and in an alternative calibration of the model where $\omega = 0.005$, which is displayed by the blue curves and confidence intervals. The curves for the investment threshold are nearly identical in both cases. This outcome is broadly consistent with the closed-form model examined in Section [I.A](#) that shows that the net benefit of waiting to invest does not depend on the degree of fixed operating costs (see equation [\(IA3\)](#)).

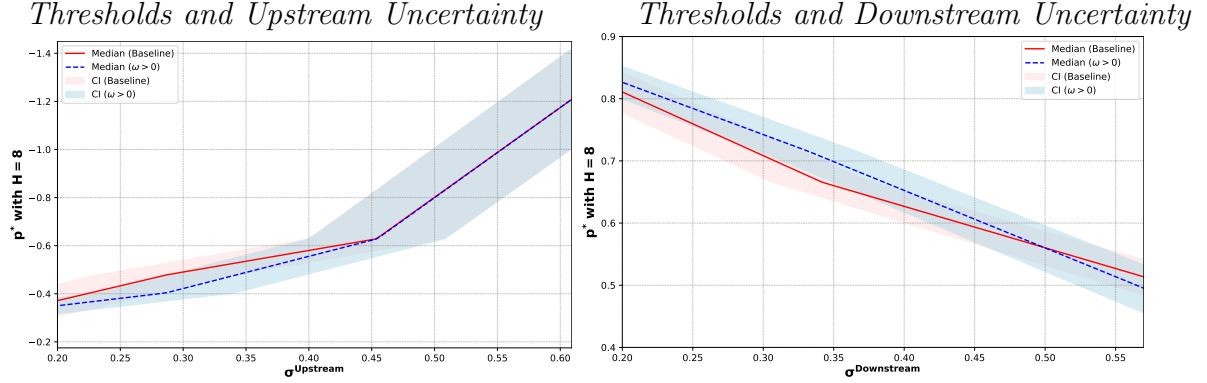


Figure IA7. Investment thresholds: Operating leverage. This figure shows the investment thresholds, p^* , in order of increasing (absolute) magnitude as a function of upstream uncertainty σ^{Upstream} (left panel) and downstream uncertainty $\sigma^{\text{Downstream}}$ (right panel) at the model's steady state in both the baseline case (i.e., $\omega = 0$) and an alternative calibration in which the firm is subject to operating leverage of $\omega = 0.005$. Accordingly, in the left (right) panel, the thresholds p^* reflect free boundaries based on critical values of the log input (output) price, p^{In} (p^{Out}). The thresholds associated with the median investment threshold in the baseline ($\omega = 0$) and operating leverage ($\omega > 0$) cases are presented in the solid red and dashed blue lines, respectively, and the red and blue shaded regions represent 90% confidence intervals for each set of thresholds. Upstream and downstream uncertainty are defined in equation (9) of the main article and reflect either the suppliers' or the customers' realized stock return volatility over the previous year, where the average realized volatilities in the model are set to match their empirical counterparts. Here, the time-to-build period H is set to eight quarters.

E. Aggregate Calibration

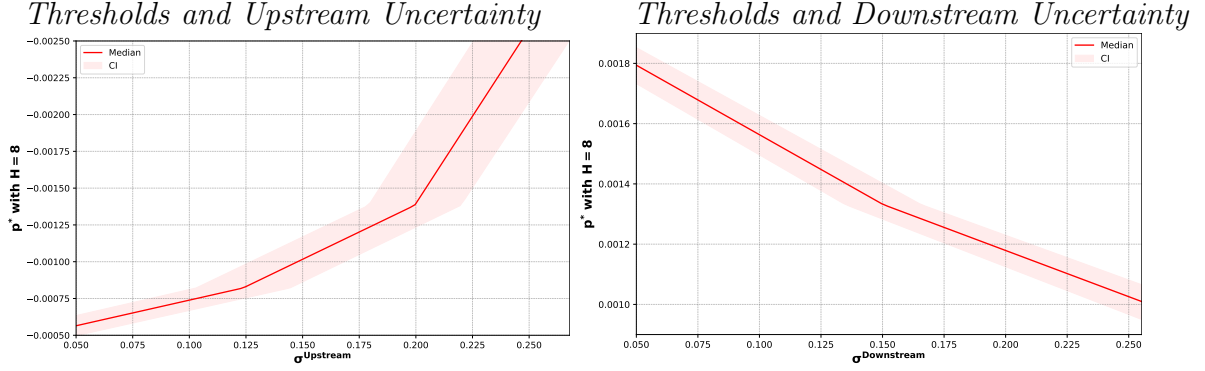


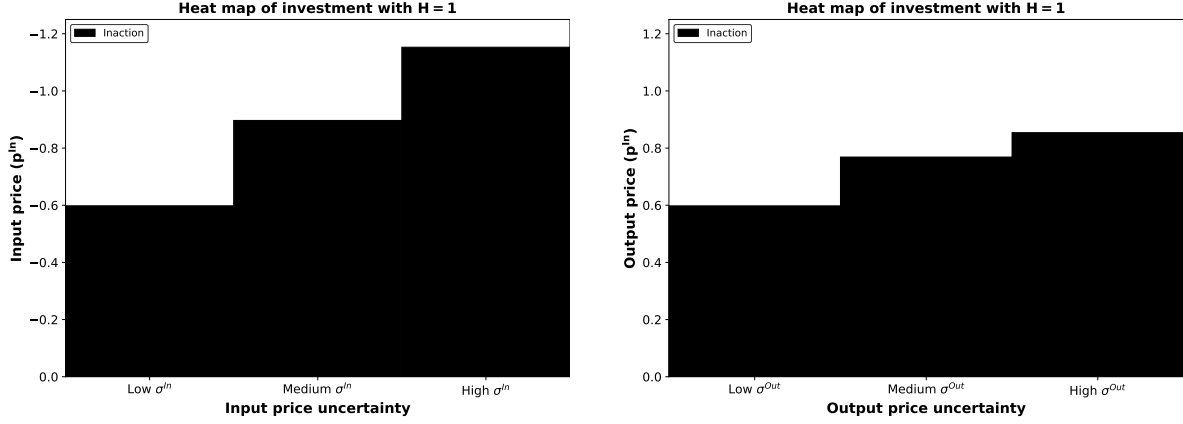
Figure IA8. Investment thresholds: Aggregate calibration. This figure shows the investment thresholds, p^* , in order of increasing (absolute) magnitude as a function of upstream uncertainty σ^{Upstream} (left column) and downstream uncertainty $\sigma^{\text{Downstream}}$ (right column) at the model's steady state after recalibrating the model to target an annualized dividend volatility of 2%. Accordingly, in the left (right) column, the thresholds p^* reflect free boundaries based on critical values of the log input (output) price, p^{In} (p^{Out}). The red-shaded region shows the model-implied 90% confidence interval of the effects of upstream or downstream uncertainty on the investment threshold, displayed on the vertical axis. The solid red line shows the median value of each confidence interval (i.e., median upstream or downstream uncertainty). Upstream and downstream uncertainty are defined in equation (9) of the main article and reflect either the supplier's or the customer's realized stock return volatility over the previous year, where the average realized volatilities in the model are set to match the volatility of excess market returns. Here, the results correspond to the case in which the time-to-build period H is set equal to eight quarters.

F. Heatmaps

Input price uncertainty and I/K

Output price uncertainty and I/K

Panel A. Short time-to-build



Panel B. Long time-to-build

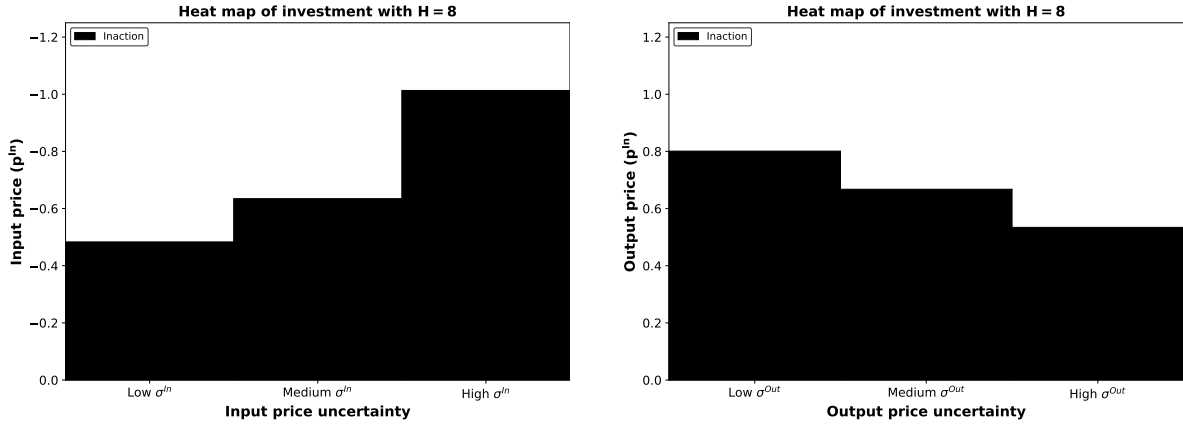


Figure IA9. Investment Action/Inaction: Heatmaps. This figure shows a heatmap for the focal firm demonstrating its inaction (black) and action (white) regions. In the left (right) column, the region is plotted in a two-dimensional space where the vertical axis represents the firm's log input (output) price and the horizontal axis represents input (output) price uncertainty. The horizontal axis considers three levels of the relevant uncertainty: medium — which corresponds to the midpoint of its grid, as well as low and high — where the relevant uncertainty is one grid point below or above the midpoint, respectively. In all figures, capital is held at its stochastic steady-state value. Moreover, the plots in the left (right) column also hold P^{Out} and σ^{Out} (P^{In} and σ^{In}) fixed at their unconditional means. Finally, in the top row (i.e., in Panel A), the time-to-build period is set to $H = 1$ period, while the bottom row (i.e., Panel B), sets the time-to-build period to $H = 8$ quarters.

VIII. Additional Micro-Level Results

A. *Supplementary Tables*

Table IAI
Summary Statistics

The table reports the summary statistics associated with the key variables employed in our micro-level (i.e., firm-level) analysis. The table reports the mean, standard deviation (“Std. dev.”), 25th percentile (p_{25}), median, and 75th percentile (p_{75}) of each variable. Section III.A of the Internet Appendix provides the definitions of all variables, and the time period underlying the analysis ranges from 1976 to 2019.

Variable	Mean	Std. dev.	p_{25}	Median	p_{75}
σ (Own)	0.540	0.329	0.313	0.455	0.666
σ (Upstream)	0.501	0.273	0.311	0.437	0.612
σ (Downstream)	0.365	0.186	0.241	0.314	0.433
Investment	0.284	0.250	0.125	0.215	0.369
log (AT)	5.955	2.283	4.243	5.894	7.616
Leverage	0.223	0.213	0.025	0.188	0.345
Tangibility	0.563	0.441	0.220	0.447	0.814
Tobin’s Q	1.781	1.034	1.088	1.447	2.121
Profitability	0.026	0.231	-0.008	0.073	0.136
Past return	0.128	0.590	-0.225	0.051	0.345
COGS growth	0.102	0.623	-0.057	0.051	0.193
Working capital growth	0.102	0.629	-0.094	0.046	0.219
Intangible growth	0.058	0.261	-0.052	0.045	0.158
Employment growth	0.089	0.603	-0.050	0.031	0.149
R&D-to-assets	0.108	0.154	0.012	0.054	0.138

Table IAI
**Investment Under Supply-Chain Uncertainties: Excluding Own
Uncertainty**

The table reports the relation between a firm’s investment rate and the contemporaneous level of the firm’s upstream uncertainty (i.e., the uncertainty of the firm’s suppliers) and the firm’s downstream uncertainty (i.e., the uncertainty of the firm’s customers). The results are based on estimating equation (10) of the main article but excluding the firm’s own uncertainty. In this regression $y_{i,t}$ is firm i ’s investment rate obtained from the most recent annual report as measured at time t . The benchmark upstream and downstream uncertainty measures are constructed at time t following the procedure outlined in Section III.A of the main article. All specifications include firm and year fixed effects, and even-numbered columns also include the following set of additional control variables: firm size, financial leverage, tangibility, Tobin’s q , profitability, and past stock returns. Section III.A of the Internet Appendix provides the definitions of all variables. All regressions are estimated using a panel of firm-year observations over the period 1976 to 2019, and t -statistics, reported in parentheses, are based on robust standard errors clustered at the firm level.

	(1)	(2)	(3)	(4)
$\sigma(\text{Upstream})$	-0.04 (-3.33)	-0.03 (-3.04)		
$\sigma(\text{Downstream})$			0.02 (2.74)	0.02 (2.66)
Controls	No	Yes	No	Yes
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Adj.- R^2	0.49	0.52	0.37	0.40
Obs.	17563	17456	34675	34344

B. Further Robustness Checks

Alternative Measures of Uncertainty. We consider alternative uncertainty proxies. First, while the realized volatility used in the benchmark case is highly persistent, and consequently proxies for expected volatility, we consider a separate measure of uncertainty that is forward-looking. This helps us to further tighten the link between the model’s predictions and our empirical results. Specifically, we construct an ex-ante measure of upstream and downstream uncertainty using the implied volatility extracted from options written on each firm’s stock. While using option-implied volatility is theoretically appealing, the use of options data has two costs: (i) the time series of our sample is truncated, since option data are only available from 1996 onward; and (ii) the cross-section of our sample is also reduced to firms that are optioned *and* have a supplier or customer that has options traded on its stock. Second, we measure upstream and downstream uncertainty using each firm’s *idiosyncratic* stock return volatility (IVOL), as defined by Ang et al. (2006). While IVOL

is also a backward-looking proxy, the use of idiosyncratic (rather than total) stock return volatility removes some part of the common variation in stock returns and typically lowers the correlation between upstream and downstream uncertainty. Details on the construction of each alternative measure are provided in Section III of the Internet Appendix.

We re-estimate equation (10) using each alternative measure of uncertainty, and report the results for IVOL (implied volatility) in Panel A (Panel B) of Table IAI. Regardless of which measure of uncertainty we employ, we draw the same conclusions as those obtained from the baseline analysis. That is, higher firm-specific upstream (downstream) uncertainty suppresses (spurs) investment. In both Panel A and Panel B, the negative and positive effects of both upstream and downstream uncertainty, respectively, are statistically significant and incremental to the negative effect of a firm’s own uncertainty on its investment rate.

Table IAI of the Internet Appendix also considers another modification to the benchmark uncertainty measures. There, we construct each firm’s upstream uncertainty at time t by weighting each supplier based on its relative sales. Similarly, we construct downstream uncertainty at time t by weighting each customer by the relative magnitude of its cost of goods sold. The results based on their weighted uncertainty measures are qualitatively and quantitatively similar to the benchmark case.

Sub-sample evidence. To ensure our results are not driven by the early part of our sample period in which Factset data is unavailable, Table IAXI in the Internet Appendix considers the effects of upstream and downstream uncertainty on firm-level investment rates in the most recent part of our sample period. That is, we report the results of estimating equation (10) using data from June 2009 to June 2019 only. The results are qualitatively and quantitatively similar to the full-sample results in Table III.

Alternative standard errors. Our baseline analysis assesses the statistical significance of the marginal effects of the supply-chain uncertainties on firm-level investment rates using robust standard errors that are clustered at the firm level. This use of firm-level clusters accounts for the fact that observations within a firm are likely to be correlated over time due to latent firm-specific characteristics (e.g., strategic initiatives that may last many years). To ensure that the statistical significance of our results is not simply driven by this method of computing standard errors, we consider two alternative approaches.

At the one extreme, we consider the use of robust standard errors that allow heteroskedasticity in the residuals of equation (10) but treat all observations as independent. The results, reported in Table IAV, show that the supply-chain uncertainties continue to have a statistically significant relation to firm-level investment rates. At the other extreme, we also use robust standard errors that are clustered by firm (as in our baseline) and time. Despite the very unbalanced sample, Table IAVI verifies the supply-chain uncertainties continue to have a statistically significant effect when using double-clustered standard errors.

Industry-by-time fixed effects. Our baseline analysis in Table III and Table IV includes a comprehensive set of firm fixed effects, which subsume time-invariant differences in how firms’ investment rates respond to fluctuations in the supply-chain uncertainties, and year

fixed effects, which subsume differences in uncertainty across time periods (e.g., the fact that the level of uncertainty was higher during the Global Financial Crisis than the period preceding this crisis).

It may also be the case that uncertainty shocks affect different industries in a heterogeneous manner over time. To account for these and other potentially heterogeneous impacts of the supply-chain uncertainties across various industries, we augment equation (10) to include industry-by-year fixed effects in place of year fixed effects. We then report the results of repeating the analysis underlying Table III and Table IV in Table IAVII and Table IAVIII, respectively. The results indicate that the magnitude and the statistical significance of the negative (positive) effect of upstream (downstream) on investment and other firm-level outcomes are virtually identical after including these industry-by-year fixed effects. This highlights that industry-level heterogeneity is unlikely to be driving our baseline results.

Heterogeneity by firm size. Table IAIX considers the degree to which the effects of upstream and downstream uncertainty differ across the distribution of firm size. To this end, we separately estimate equation (10) among small and large firms, respectively. Here, we define a firm as small (large) if its size is less than (greater than) the cross-sectional median value of firm size, measured using total assets from Compustat, at each time t .

The results of this analysis show that the negative (positive) effect of upstream (downstream) uncertainty remains pronounced within both groups of firms. The effect of each facet of uncertainty is generally economically larger among small firms. This is consistent with the intuition that smaller firms are in general more volatile, and by and large, still in their ‘construction’ stage. However, the marginal effect of each uncertainty remains economically and statistically significant among large firms as well.

Heterogeneity by firm age. A second possibility that we consider is that the effects of the supply-chain uncertainties interact with firm age. As younger firms are less established and derive more of their value from growth options, it is conceivable that firm age can also serve as a proxy of the length of the firm’s time-to-build period (recall, for example, Hypothesis (iii) of the model from Section II.C.4 of the main article and the discussion and empirical results related to the length of a firm’s time-to-build period in Section III.D of the main article). In contrast, older firms tend to be more established and derive much of their value from assets-in-place that have a relatively shorter duration.

Table IAX reports the results of separately estimating equation (10) among younger and older firms, respectively. Here, we define a firm as young (old) if its age, measured as the number of years since the firm first appeared in the CRSP/Compustat universe, is less than (greater than) the cross-sectional median value of firm age at each time t . Consistent with the notion that firm age serves as an additional proxy of the length of a firm’s time-to-build period, we show that the positive effect of downstream uncertainty is concentrated among younger firms with presumably longer time-to-build periods. Moreover, the negative effects of upstream uncertainty remain consistent across the sets of both young and old firms.

Heterogeneity across industries. Table IAVII, described above, already establishes that

the results underlying Table III are not driven by industry-level heterogeneity. However, we provide additional context to this result by considering an additional test.

Table IAXII verifies that no single industry group, as defined by the Gomes et al. (2009) industry classification scheme, is driving our results. We implement this exercise by removing each broad industry group, such as durable goods producers, from the sample and then re-estimating equation (10) among the set of remaining firms. We report the results of this analysis in Panel A and subsequently report the results of removing non-durable goods and services, investment goods, and other goods (e.g., government and net exports) in Panels B, C, and D, respectively. The results indicate that no one industry in the sample drives the results.

Effects of competition. In Section VIII.C we conduct a detailed investigation of the relation between the supply-chain uncertainties and the effects of competition and vertical bargaining power. We leave the details and the results of the various analyses to that section.

Table IAIII
Alternative Measures of Supply-Chain Uncertainty

The table reports the relation between a firm's investment rate and alternative measures of the contemporaneous level of the firm's upstream uncertainty (i.e., the uncertainty of the firm's suppliers), the firm's downstream uncertainty (i.e., the uncertainty of the firm's customers), and the firm's own uncertainty. The results are based on estimating equation (10), where $y_{i,t}$ is firm i 's investment rate obtained from the most recent annual report as measured at time t . In Panel A, the uncertainty measures are based on the idiosyncratic return volatility of stock returns. In Panel B, the uncertainty measures are based on the implied volatility extracted from at-the-money call options written on each firm's stock. Given these alternative measures, we construct the uncertainty of each firm, its suppliers, and its customers following the procedure outlined in Section III.A of the main article. All specifications include firm and year fixed effects, and even-numbered columns also include the following set of additional control variables: firm size, financial leverage, tangibility, Tobin's q , profitability, and past stock returns. Section III.A of the Internet Appendix provides the definitions of all variables. All regressions are estimated using a panel of firm-year observations over the period 1976 to 2019 in Panel A and 1996 to 2019 in Panel B. t -statistics, reported in parentheses, are based on robust standard errors clustered at the firm level.

	Panel A: IVOL				Panel B: Implied volatility			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\sigma(\text{Own})$	-0.10 (-5.89)	-0.06 (-3.48)	-0.14 (-14.03)	-0.07 (-6.18)	-0.03 (-1.31)	-0.00 (-0.01)	-0.03 (-1.50)	0.02 (1.03)
$\sigma(\text{Upstream})$	-0.03 (-3.31)	-0.03 (-2.98)			-0.03 (-2.05)	-0.03 (-2.45)		
$\sigma(\text{Downstream})$			0.02 (2.43)	0.02 (2.29)			0.04 (3.06)	0.03 (2.67)
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj.- R^2	0.50	0.52	0.38	0.40	0.54	0.56	0.48	0.51
Obs.	17563	17456	34675	34344	9376	9332	11725	11657

Table IAIV
Investment Under Supply-Chain Uncertainty: Value-Weighted Uncertainties

The table reports the relation between a firm's investment rate and the contemporaneous level of the firm's upstream uncertainty (i.e., the uncertainty of the firm's suppliers), the firm's downstream uncertainty (i.e., the uncertainty of the firm's customers), and the firm's own uncertainty. The results are based on estimating equation (10), where $y_{i,t}$ is firm i 's investment rate obtained from the most recent annual report as measured at time t . Here, the upstream and downstream uncertainty measures are constructed at time t as follows. First, let $S_{i,t}$ denote the set of suppliers of firm i at time t , and let $C_{i,t}$ denote the set of the firm's customers. Next, upstream uncertainty is constructed as $\sigma(\text{Upstream})_{i,t} = \sum_{s \in S_{i,t}} w_{s,t} \sigma_{s,t}$, where $w_{s,t} = \text{Sales}_{s,t} / \sum_{k \in S_{i,t}} \text{Sales}_{k,t}$, and $\text{Sales}_{k,t}$ is the log of firm k 's sales. Similarly, downstream uncertainty is constructed as $\sigma(\text{Downstream})_{i,t} = \sum_{c \in C_{i,t}} w_{c,t} \sigma_{c,t}$, where $w_{c,t} = \text{COGS}_{c,t} / \sum_{k \in C_{i,t}} \text{COGS}_{k,t}$, and $\text{COGS}_{k,t}$ is the log of firm k 's cost of goods sold. All specifications include firm and year fixed effects, and even-numbered columns also include the following set of additional control variables: firm size, financial leverage, tangibility, Tobin's q , profitability, and past stock returns. Section III.A of the Internet Appendix provides the definitions of all variables. All regressions are estimated using a panel of firm-year observations over the period 1978 to 2019, and t -statistics, reported in parentheses, are based on robust standard errors clustered at the firm level.

	(1)	(2)	(3)	(4)	(5)	(6)
$\sigma(\text{Own})$	-0.11 (-12.60)	-0.05 (-5.25)	-0.08 (-4.78)	-0.04 (-2.61)	-0.12 (-11.93)	-0.05 (-4.88)
$\sigma(\text{Upstream})$			-0.02 (-1.88)	-0.02 (-1.92)		
$\sigma(\text{Downstream})$					0.04 (4.73)	0.03 (4.09)
Controls	No	Yes	No	Yes	No	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj.- R^2	0.38	0.41	0.50	0.52	0.37	0.40
Obs.	50786	50319	17537	17430	34608	34277

Table IAV
Investment Under Supply-Chain Uncertainties: Robust Standard Errors

The table reports the relation between a firm's investment rate and the contemporaneous level of the firm's upstream uncertainty (i.e., the uncertainty of the firm's suppliers), the firm's downstream uncertainty (i.e., the uncertainty of the firm's customers), and the firm's own uncertainty. The results are based on estimating equation (10), where $y_{i,t}$ is firm i 's investment rate obtained from the most recent annual report as measured at time t . The benchmark upstream and downstream uncertainty measures are constructed at time t following the procedure outlined in Section III.A of the main article. All specifications include firm and year fixed effects, and even-numbered columns also include the following set of additional control variables: firm size, financial leverage, tangibility, Tobin's q , profitability, and past stock returns. Section III.A of the Internet Appendix provides the definitions of all variables. All regressions are estimated using a panel of firm-year observations over the period 1976 to 2019, and t -statistics, reported in parentheses, are based on robust standard errors.

	(1)	(2)	(3)	(4)	(5)	(6)
$\sigma(\text{Own})$	-0.11 (-14.01)	-0.05 (-5.81)	-0.08 (-5.52)	-0.04 (-2.86)	-0.12 (-13.09)	-0.05 (-5.31)
$\sigma(\text{Upstream})$			-0.03 (-3.36)	-0.03 (-3.25)		
$\sigma(\text{Downstream})$					0.03 (4.19)	0.03 (3.43)
Controls	No	Yes	No	Yes	No	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj.- R^2	0.38	0.41	0.50	0.52	0.37	0.40
Obs.	50786	50319	17563	17456	34675	34344

Table IAVI
Investment Under Supply-Chain Uncertainties: Double-clustered Errors

The table reports the relation between a firm's investment rate and the contemporaneous level of the firm's upstream uncertainty (i.e., the uncertainty of the firm's suppliers), the firm's downstream uncertainty (i.e., the uncertainty of the firm's customers), and the firm's own uncertainty. The results are based on estimating equation (10), where $y_{i,t}$ is firm i 's investment rate obtained from the most recent annual report as measured at time t . The benchmark upstream and downstream uncertainty measures are constructed at time t following the procedure outlined in Section III.A of the main article. All specifications include firm and year fixed effects, and even-numbered columns also include the following set of additional control variables: firm size, financial leverage, tangibility, Tobin's q , profitability, and past stock returns. Section III.A of the Internet Appendix provides the definitions of all variables. All regressions are estimated using a panel of firm-year observations over the period 1976 to 2019, and t -statistics, reported in parentheses, are based on standard errors double clustered at the firm and year levels.

	(1)	(2)	(3)	(4)	(5)	(6)
$\sigma(\text{Own})$	-0.11 (-7.05)	-0.05 (-2.92)	-0.08 (-3.67)	-0.04 (-2.58)	-0.12 (-6.38)	-0.05 (-3.18)
$\sigma(\text{Upstream})$			-0.03 (-2.64)	-0.03 (-2.52)		
$\sigma(\text{Downstream})$					0.03 (2.20)	0.03 (2.10)
Controls	No	Yes	No	Yes	No	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj.- R^2	0.38	0.41	0.50	0.52	0.37	0.40
Obs.	50786	50319	17563	17456	34675	34344

Table IAVII
Investment Under Supply-Chain Uncertainties: Industry-By-Time
Fixed Effects

The table reports the relation between a firm's investment rate and the contemporaneous level of the firm's upstream uncertainty (i.e., the uncertainty of the firm's suppliers), the firm's downstream uncertainty (i.e., the uncertainty of the firm's customers), and the firm's own uncertainty. The results are based on estimating equation (10), where $y_{i,t}$ is firm i 's investment rate obtained from the most recent annual report as measured at time t . The benchmark upstream and downstream uncertainty measures are constructed at time t following the procedure outlined in Section III.A of the main article. All specifications include firm and year fixed effects, and even-numbered columns also include the following set of additional control variables: firm size, financial leverage, tangibility, Tobin's q , profitability, and past stock returns. Section III.A of the Online Appendix provides the definitions of all variables. All regressions are estimated using a panel of firm-year observations over the period 1976 to 2019, and t -statistics, reported in parentheses, are based on robust standard errors clustered at the firm level.

	(1)	(2)	(3)	(4)	(5)	(6)
$\sigma(\text{Own})$	-0.11 (-12.73)	-0.05 (-5.49)	-0.07 (-4.27)	-0.04 (-2.21)	-0.12 (-11.94)	-0.05 (-5.10)
$\sigma(\text{Upstream})$			-0.03 (-2.69)	-0.03 (-2.59)		
$\sigma(\text{Downstream})$					0.03 (3.40)	0.03 (3.00)
Controls	No	Yes	No	Yes	No	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Ind. by Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj.- R^2	0.39	0.41	0.50	0.52	0.38	0.41
Obs.	50786	50319	17561	17454	34672	34341

Table IAVIII
Firm-Level Economic Activity Under Supply-Chain Uncertainties:
Industry-By-Time Fixed Effects

The table reports the relation between a firm's working capital growth rate (Panel A), employment growth rate (Panel B), COGS growth rate (Panel C), and intangible capital growth rate (Panel D), and the contemporaneous level of the firm's upstream uncertainty (i.e., the uncertainty of the firm's suppliers), the firm's downstream uncertainty (i.e., the uncertainty of the firm's customers), and the firm's own uncertainty. The results are based on estimating equation (10), where $y_{i,t}$ is a measure of firm i 's economic activity or valuation ratio obtained from the most recent annual report as measured at time t . The benchmark upstream and downstream uncertainty measures are constructed at time t following the procedure outlined in Section III.A of the main article. All specifications include firm-by-year fixed effects, and even-numbered columns also include the following set of additional control variables: firm size, financial leverage, tangibility, Tobin's q , profitability, and past stock returns. Section III.A of the Internet Appendix provides the definitions of all variables. All regressions are estimated using a panel of firm-year observations over the period 1976 to 2019, and t -statistics, reported in parentheses, are based on robust standard errors clustered at the firm level.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Panel A: Working capital				Panel B: Employment			
$\sigma(\text{Own})$	-0.11 (-5.43)	-0.06 (-2.31)	-0.14 (-12.03)	-0.08 (-6.02)	-0.13 (-6.62)	-0.12 (-4.94)	-0.14 (-12.64)	-0.11 (-8.33)
$\sigma(\text{Upstream})$	-0.03 (-2.21)	-0.03 (-1.84)			-0.03 (-2.42)	-0.03 (-2.15)		
$\sigma(\text{Downstream})$			0.03 (3.15)	0.02 (2.48)			0.02 (1.78)	0.01 (0.75)
Adj.- R^2	0.14	0.18	0.15	0.18	0.14	0.17	0.14	0.15
Obs.	17549	17116	36061	34214	17910	17476	36112	34277
	Panel C: COGS				Panel D: Intangibles			
$\sigma(\text{Own})$	-0.07 (-3.41)	-0.03 (-1.41)	-0.10 (-8.43)	-0.05 (-3.33)	-0.16 (-6.93)	-0.08 (-3.43)	-0.17 (-13.71)	-0.09 (-7.05)
$\sigma(\text{Upstream})$	-0.03 (-2.76)	-0.03 (-2.51)			-0.02 (-1.58)	-0.03 (-2.16)		
$\sigma(\text{Downstream})$			0.02 (2.73)	0.02 (1.73)			0.02 (2.17)	0.01 (1.00)
Adj.- R^2	0.15	0.17	0.14	0.12	0.18	0.22	0.15	0.19
Obs.	17861	17431	36327	34463	17023	16917	33922	33597
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ind. By Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table IAIX
Investment Under Supply-Chain Uncertainties: Heterogeneity By Firm Size

The table reports the relation between a firm's investment rate and the contemporaneous level of the firm's upstream uncertainty (i.e., the uncertainty of the firm's suppliers), the firm's downstream uncertainty (i.e., the uncertainty of the firm's customers), and the firm's own uncertainty conditional on firm size. The results are based on estimating equation (10), where $y_{i,t}$ is firm i 's investment rate obtained from the most recent annual report as measured at time t . The results in Panel A (Panel B) are obtained by estimating equation (10) among the set of small (large) firms whose size, as measured by total assets, is less than (greater than) the cross-sectional median value of total assets. The benchmark upstream and downstream uncertainty measures are constructed at time t following the procedure outlined in Section III.A of the main article. All specifications include firm and year fixed effects, and even-numbered columns also include the following set of additional control variables: firm size, financial leverage, tangibility, Tobin's q , profitability, and past stock returns. Section III.A of the Internet Appendix provides the definitions of all variables. All regressions are estimated using a panel of firm-year observations over the period 1976 to 2019, and t -statistics, reported in parentheses, are based on robust standard errors clustered at the firm level.

	Panel A: Small firms				Panel B: Large firms			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\sigma(\text{Own})$	-0.11 (-4.97)	-0.07 (-3.29)	-0.15 (-11.42)	-0.10 (-7.76)	-0.04 (-1.78)	0.02 (0.86)	-0.02 (-1.07)	-0.03 (-1.71)
$\sigma(\text{Upstream})$	-0.06 (-2.74)	-0.06 (-2.82)			-0.03 (-2.18)	-0.02 (-2.12)		
$\sigma(\text{Downstream})$			0.03 (1.66)	0.03 (2.74)			0.02 (1.98)	0.02 (2.06)
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj.- R^2	0.46	0.47	0.32	0.33	0.54	0.58	0.47	0.52
Obs.	8397	8397	16770	16770	8868	8868	17161	17161

Table IAX
Investment Under Supply-Chain Uncertainties: Heterogeneity By Firm Age

The table reports the relation between a firm's investment rate and the contemporaneous level of the firm's upstream uncertainty (i.e., the uncertainty of the firm's suppliers), the firm's downstream uncertainty (i.e., the uncertainty of the firm's customers), and the firm's own uncertainty conditional on firm age. The results are based on estimating equation (10), where $y_{i,t}$ is firm i 's investment rate obtained from the most recent annual report as measured at time t . The results in Panel A (Panel B) are obtained by estimating equation (10) among the set of younger (older) firms whose age, as measured by the number of years since the firm was first listed in CRSP/Compustat, is less than (greater than) the cross-sectional median value of firm age. The benchmark upstream and downstream uncertainty measures are constructed at time t following the procedure outlined in Section III.A of the main article. All specifications include firm and year fixed effects, and even-numbered columns also include the following set of additional control variables: firm size, financial leverage, tangibility, Tobin's q , profitability, and past stock returns. Section III.A of the Internet Appendix provides the definitions of all variables. All regressions are estimated using a panel of firm-year observations over the period 1976 to 2019, and t -statistics, reported in parentheses, are based on robust standard errors clustered at the firm level.

	Panel A: Younger firms				Panel B: Older firms			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\sigma(\text{Own})$	-0.11 (-4.31)	-0.06 (-2.53)	-0.12 (-7.95)	-0.04 (-2.35)	-0.08 (-4.31)	-0.03 (-1.49)	-0.12 (-8.66)	-0.07 (-4.65)
$\sigma(\text{Upstream})$	-0.05 (-2.11)	-0.05 (-2.24)			-0.03 (-2.74)	-0.03 (-2.34)		
$\sigma(\text{Downstream})$			0.05 (2.86)	0.03 (1.89)			0.00 (0.42)	0.00 (0.53)
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj.- R^2	0.47	0.49	0.39	0.42	0.51	0.53	0.34	0.37
Obs.	7886	7886	15764	15764	9440	9440	18157	18157

Table IAXI

Investment Under Supply-Chain Uncertainty: Recent Subsample

The table reports the relation between a firm's investment rate and the contemporaneous level of the firm's upstream uncertainty (i.e., the uncertainty of the firm's suppliers), the firm's downstream uncertainty (i.e., the uncertainty of the firm's customers), and the firm's own uncertainty. The results are based on estimating equation (10), where $y_{i,t}$ is firm i 's investment rate obtained from the most recent annual report as measured at time t . The benchmark upstream and downstream uncertainty measures are constructed at time t following the procedure outlined in Section III.A of the main article. All specifications include firm and year fixed effects, and even-numbered columns also include the following set of additional control variables: firm size, financial leverage, tangibility, Tobin's q , profitability, and past stock returns. Section III.A of the Internet Appendix provides the definitions of all variables. All regressions are estimated using a panel of firm-year observations over the period 2009 to 2019, and t -statistics, reported in parentheses, are based on robust standard errors clustered at the firm level.

	(1)	(2)	(3)	(4)	(5)	(6)
$\sigma(\text{Own})$	-0.11 (-7.67)	-0.06 (-4.05)	-0.06 (-2.74)	-0.04 (-1.66)	-0.10 (-5.89)	-0.06 (-3.08)
$\sigma(\text{Upstream})$			-0.07 (-3.93)	-0.07 (-3.86)		
$\sigma(\text{Downstream})$					0.02 (1.85)	0.02 (1.93)
Controls	No	Yes	No	Yes	No	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj.- R^2	0.46	0.48	0.55	0.57	0.47	0.48
Obs.	20094	19910	9329	9272	13403	13313

Table IAXII
Investment Under Supply-Chain Uncertainties: Heterogeneity By Industry

The table reports the relation between a firm's investment rate and the contemporaneous level of the firm's upstream uncertainty (i.e., the uncertainty of the firm's suppliers), the firm's downstream uncertainty (i.e., the uncertainty of the firm's customers), and the firm's own uncertainty after excluding broad industry groups based on the Gomes et al. (2009) classification. The results are based on estimating equation (10), where $y_{i,t}$ is firm i 's investment rate obtained from the most recent annual report as measured at time t . Panels A, B, C, and D estimate this equation after removing all durable consumption goods, non-durable consumption goods and services, investment goods, and other goods producers (e.g., net exporters), respectively. The benchmark upstream and downstream uncertainty measures are constructed at time t following the procedure outlined in Section III.A of the main article. All specifications include firm and year fixed effects, and even-numbered columns also include the following set of additional control variables: firm size, financial leverage, tangibility, Tobin's q , profitability, and past stock returns. Section III.A of the Internet Appendix provides the definitions of all variables. All regressions are estimated using a panel of firm-year observations over the period 1976 to 2019, and t -statistics, reported in parentheses, are based on robust standard errors clustered at the firm level.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Panel A: Exc. durables				Panel B: Exc. nondurables			
$\sigma(\text{Own})$	-0.08 (-4.61)	-0.04 (-2.59)	-0.12 (-11.48)	-0.05 (-4.71)	-0.05 (-2.63)	-0.01 (-0.57)	-0.11 (-9.23)	-0.04 (-3.22)
$\sigma(\text{Upstream})$	-0.04 (-3.07)	-0.03 (-2.97)			-0.03 (-2.49)	-0.03 (-2.30)		
$\sigma(\text{Downstream})$			0.03 (3.43)	0.02 (2.76)			0.05 (4.58)	0.04 (3.71)
Adj.- R^2	0.49	0.52	0.37	0.40	0.52	0.54	0.40	0.44
Obs.	16506	16400	31657	31348	12293	12228	24552	24327
	Panel C: Exc. investment				Panel D: Exc. other			
$\sigma(\text{Own})$	-0.09 (-4.85)	-0.06 (-3.12)	-0.12 (-10.12)	-0.05 (-4.11)	-0.09 (-5.03)	-0.05 (-2.93)	-0.13 (-11.28)	-0.06 (-4.91)
$\sigma(\text{Upstream})$	-0.03 (-2.53)	-0.03 (-2.56)			-0.03 (-2.11)	-0.03 (-2.21)		
$\sigma(\text{Downstream})$			0.03 (3.10)	0.03 (2.63)			0.02 (2.19)	0.02 (1.80)
Adj.- R^2	0.50	0.51	0.36	0.39	0.50	0.52	0.37	0.40
Obs.	14799	14708	26890	26626	13878	13791	26264	25999
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table IAXIII
Investment, Upstream Uncertainty, and Time-to-Build

The table reports the relation between a firm’s investment rate and the contemporaneous level of the firm’s upstream uncertainty (i.e., the uncertainty of the firm’s suppliers), conditional on one of three proxies for the length of the firm’s time-to-build period. The results are based on estimating regression (11), where $y_{i,t}$ is firm i ’s investment rate obtained from the most recent annual report as measured at time t and downstream uncertainty is constructed at time t following the procedure outlined in Section III.A of the main article. In Panel A, the “Short” (“Long”) dummy takes the value of one for firms that have an inverse depreciation rate that is below (above) the cross-sectional median value of inverse depreciation. In Panel B, the “Short” dummy takes the value of one for firms that produce nondurable consumption goods or services, while the “Long” dummy takes the value of one for firms operating in other sectors (e.g., investment good producers and durable consumption goods producers). Firms are assigned to the two groups based on the sector classification scheme of Gomes et al. (2009). In Panel C, the “Long” (“Short”) dummy takes the value of one for firms that have a level of R&D intensity that is greater (less) than the cross-sectional median value of R&D intensity. Year and firm fixed effects are included in all specifications and additional control variables are included in all even-numbered columns. This set of additional control variables includes firm size, financial leverage, tangibility, Tobin’s q , profitability, and past stock returns. Section III.A of the Internet Appendix provides the definitions of all variables. All regressions are estimated using a panel of firm-year observations ranging from 1976 to 2019 and t -statistics, reported in parentheses, are based on robust standard errors that are clustered at the firm level. Finally, the table also reports the F -statistic and p -value from a Wald test on the null hypothesis that the relation between downstream uncertainty and investment is the same for both short and long time-to-build firms ($H_0 : \beta_2 = \beta_3$ in equation (11)).

	Panel A: Depreciation		Panel B: Sector		Panel C: R&D	
	(1)	(2)	(3)	(4)	(5)	(6)
$\sigma(\text{Own})$	-0.07 (-4.43)	-0.04 (-2.42)	-0.08 (-4.72)	-0.04 (-2.53)	-0.07 (-3.52)	-0.04 (-2.13)
$\sigma(\text{Upstream}) \times \text{Short}$	-0.04 (-2.39)	-0.04 (-2.25)	-0.01 (-4.24)	-0.01 (-3.26)	-0.05 (-2.34)	-0.05 (-2.58)
$\sigma(\text{Upstream}) \times \text{Long}$	-0.04 (-2.36)	-0.04 (-2.41)	-0.03 (-2.87)	-0.03 (-2.80)	-0.04 (-1.92)	-0.03 (-1.67)
p(Long=Short)	0.65	0.80	0.17	0.16	0.65	0.33
Controls	No	Yes	No	Yes	No	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj.- R^2	0.50	0.52	0.50	0.52	0.48	0.50
Obs.	17554	17447	17563	17456	12500	12421

C. Interaction with Competition

The motivating framework assumes that the focal firm is a price taker, whose production decisions do not impact its input or output prices. However, if the focal firm has considerable market power and/or is either a critical customer of its suppliers or a critical supplier of its customers, then its own decisions could impact its trade partners' production decisions and, in turn, change the relative prices of the input and output goods. In these cases, both the forces of supply and demand, and vertical bargaining power (i.e., the ability of the focal firm to negotiate input and output prices) may provide offsetting economic channels that can weaken the impact of the supply-chain uncertainties on investment.

The converse is also true: if the focal firm does not possess vertical bargaining power, or if the focal firm is part of a diverse group of suppliers (customers) that trade with the customer (supplier) firm, then its own production decision should only exert a minimal impact, if any impact at all, on its trading partners' production and input/output prices.

We, therefore, hypothesize that the effects of the supply-chain uncertainties captured in the empirical analysis should be relatively stronger in one of three cases: (a) when the upstream uncertainty of the focal firm arises from suppliers whose own customer bases are more diverse (less concentrated); (b) when the downstream uncertainty of the focal firm arises from customers whose own supplier bases are more diverse (less concentrated); and (c) when the focal firm itself has lower market power. In each of these scenarios, the focal firm is more accurately characterized as a price taker, consistent with the economic model.

We confirm this empirically. First, we construct a measure that reflects the concentration of the customer base associated with each of firm i 's suppliers. Specifically, for each supplier firm j that sells to focal firm i at time t , we compute the variable $HHI_{i,j,t}^{\text{Customer-Base}}$ that represents the HHI index of firm j 's customers at time t . This HHI index is based on the distribution of the cost of goods sold (COGS) across all of supplier j 's customers. If focal firm i buys from a group of suppliers at time t , represented by $\mathcal{S}_{i,t}$, then this provides us with the set

$$\mathcal{HHI}_{i,t}^{\text{Suppliers' Customer-Base}} = \{HHI_{i,j,t}^{\text{Customer-Base}} | j \in \mathcal{S}_{i,t}\}.$$

With $\mathcal{HHI}_{i,t}^{\text{Suppliers' Customer-Base}}$ in hand, we decompose the upstream uncertainty of focal firm i at time t into two parts. The first part originates from the group of suppliers with more diverse (less concentrated) customer bases. Specifically, for firm i at time t , we construct this component of upstream uncertainty by taking the average stock return volatility across the subset of suppliers $j \in \mathcal{S}_{i,t}$ for which $HHI_{i,j,t}^{\text{Customer-Base}}$ is at or below the median value of $\mathcal{HHI}_{i,t}^{\text{Suppliers' Customer-Base}}$. The second part of upstream uncertainty originates from suppliers with more concentrated customer bases. We construct this component of upstream uncertainty by taking the average stock return volatility across the subset of suppliers $j \in \mathcal{S}_{i,t}$ for which $HHI_{i,j,t}^{\text{Customer-Base}}$ is above the median value of $\mathcal{HHI}_{i,t}^{\text{Suppliers' Customer-Base}}$. We then

separately estimate equation (10) using these distinct components of upstream uncertainty.

Table IAXIV reports the results for the two components of upstream uncertainty. Column (2) and Column (5) of the table show that the negative effect of upstream uncertainty is larger and statistically significant only when considering the component of upstream uncertainty that arises from suppliers with more diverse (less concentrated) customer bases. This is consistent with hypothesis (a), outlined above.

We test hypothesis (b) by constructing a similar measure based on the concentration of the supplier base of each of the focal firm i 's customers. Specifically, for each customer firm j that buys the output of focal firm i at time t , we compute the variable $HHI_{i,j,t}^{\text{Supplier-Base}}$ that represents the HHI index of firm j 's suppliers at time t . This HHI index is based on the distribution of sales across customer firm j 's suppliers. If focal firm i sells to a group of customers at each time t , denoted by $\mathcal{C}_{i,t}$, then this process provides us with the set

$$\mathcal{HHI}_{i,t}^{\text{Customers' Supplier-Base}} = \{HHI_{i,j,t}^{\text{Supplier-Base}} | j \in \mathcal{C}_{i,t}\}$$

With $\mathcal{HHI}_{i,t}^{\text{Customers' Supplier-Base}}$ in hand, we split the downstream uncertainty of focal firm i at time t into two distinct parts. The first part originates from customers with more diverse (less concentrated) supplier bases. Specifically, for each focal firm i at time t , we compute the average stock return volatility across the subset of customers $j \in \mathcal{C}_{i,t}$ for which $HHI_{i,j,t}^{\text{Supplier-Base}}$ is at or below the median value of $\mathcal{HHI}_{i,t}^{\text{Customers' Supplier-Base}}$. The second component of downstream uncertainty originates from customers with more concentrated supplier bases. In this case, we take the average stock return volatility across the subset of customers $j \in \mathcal{C}_{i,t}$ for which $HHI_{i,j,t}^{\text{Supplier-Base}}$ is above the median value of $\mathcal{HHI}_{i,t}^{\text{Customers' Supplier-Base}}$ at time t . We then use these distinct components of downstream uncertainty to re-estimate equation (10).

Table IAXIV reports the results for the two components of downstream uncertainty. Specifically, Columns (4) and (8) show that the positive effect of downstream uncertainty is larger and statistically significant at the 5% level only when considering the part of downstream uncertainty that arises from customers that have more diverse (less concentrated) supplier bases. This supports hypothesis (b).

Finally, we split the sample between the set of firms that operate in less concentrated (i.e., more competitive) industries, and thereby tend to have lower market/monopolistic power on average, and those that operate in more concentrated industries, and thereby tend to have higher monopolistic power. Here, we define concentration using the HHI of sales within each three-digit SIC industry. Table IAXV shows that while the effects of the supply-chain uncertainties are significant in both groups, the economic magnitude is substantially larger when the focal firm has low market power. For example, one standard deviation in upstream uncertainty drops investment by 5% (1%) when the focal firm has low (high) market power. This is broadly in line with hypothesis (c), described above.

Table IAXIV

Firm-Level Investment Under Supply-Chain Uncertainties: Heterogeneity By Trading Partners' Revenue Concentration

The table reports the relation between a firm's investment rate and the contemporaneous level of the firm's upstream uncertainty (i.e., the uncertainty of the firm's suppliers), the firm's downstream uncertainty (i.e., the uncertainty of the firm's customers), and the firm's own uncertainty, conditional on the concentration of the customer (supplier) base of the firm's suppliers (customers). The results are based on estimating equation (10), where $y_{i,t}$ is firm i 's investment rate obtained from the most recent annual report as measured at time t . The benchmark upstream and downstream uncertainty measures are constructed at time t following the procedure outlined in Section VIII.C. Here, the concentration of a supplier's (customer's) customer (supplier) base is constructed using the COGS (sales) of each customer (supplier) firm. All specifications include firm and year fixed effects, and even-numbered columns also include the following set of additional control variables: firm size, financial leverage, tangibility, Tobin's q , profitability, and past stock returns. Section III.A of the Internet Appendix provides the definitions of all variables. All regressions are estimated using a panel of firm-year observations over the period 1976 to 2019, and t -statistics, reported in parentheses, are based on standard errors clustered at the firm level.

	The customer (supplier) base of the focal firm's suppliers (customers) has...							
	Panel A: Low concentration				Panel B: High concentration			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\sigma(\text{Own})$	-0.09 (-5.07)	-0.05 (-2.75)	-0.11 (-7.91)	-0.04 (-2.91)	-0.10 (-5.50)	-0.05 (-2.84)	-0.11 (-7.62)	-0.04 (-2.50)
$\sigma(\text{Upstream})$	-0.03 (-2.46)	-0.02 (-2.38)			0.00 (0.20)	0.00 (0.55)		
$\sigma(\text{Downstream})$			0.03 (2.88)	0.03 (2.47)			0.01 (0.86)	0.00 (0.34)
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj.- R^2	0.51	0.54	0.42	0.44	0.52	0.54	0.42	0.44
Obs.	17563	17456	34675	34344	17563	17456	34675	34344

Table IAXV
Firm-level Investment Under Supply-Chain Uncertainties:
Heterogeneity By Firm’s Market Power

The table reports the relation between a firm’s investment rate and the contemporaneous level of the firm’s upstream uncertainty (i.e., the uncertainty of the firm’s suppliers), the firm’s downstream uncertainty (i.e., the uncertainty of the firm’s customers), and the firm’s own uncertainty, conditional on the firm’s market power. The results are based on estimating equation (10), where $y_{i,t}$ is firm i ’s investment rate obtained from the most recent annual report as measured at time t . The results in Panel A (Panel B) are obtained by estimating equation (10) among the set of low (high) market power firms whose concentration, as measured by the HHI index of the three-digit SIC industry that the firm belongs to, is less than (greater than) the cross-sectional median value of the HHI index. The benchmark upstream and downstream uncertainty measures are constructed at time t following the procedure outlined in Section III.A of the main article. All specifications include firm and year fixed effects, and even-numbered columns also include the following set of additional control variables: firm size, financial leverage, tangibility, Tobin’s q , profitability, and past stock returns. Section III.A of the Internet Appendix provides the definitions of all variables. All regressions are estimated using a panel of firm-year observations over the period 1976 to 2019, and t -statistics, reported in parentheses, are based on standard errors clustered at the firm level.

	Panel A: Low market power				Panel B: High market power			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\sigma(\text{Own})$	-0.11 (-4.92)	-0.08 (-3.30)	-0.15 (-9.61)	-0.07 (-4.32)	-0.06 (-2.80)	-0.00 (-0.02)	-0.05 (-3.50)	-0.00 (-0.06)
$\sigma(\text{Upstream})$	-0.05 (-2.41)	-0.05 (-2.41)			-0.01 (-0.84)	-0.01 (-0.91)		
$\sigma(\text{Downstream})$			0.04 (2.35)	0.03 (1.80)			0.02 (1.81)	0.02 (1.91)
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj.- R^2	0.43	0.45	0.32	0.34	0.57	0.61	0.45	0.49
Obs.	7715	7715	15017	15017	8068	8068	15248	15248

D. Instrumental Variables Approach

Our main evidence shows an association between each of the two different facets of supply-chain uncertainty and investment. We interpret these associations in a causal manner through the lens of our motivating model in Section II of the main article. This section follows an instrumental variables approach to strengthen the argument that fluctuations in upstream and downstream uncertainty have a causal impact on firm-level investment rates.

The instrumental variables approach is motivated by Alfaro, Bloom, and Lin (2024). Specifically, we instrument each firm’s realized volatility shock, measured using the 12-month change in the annualized standard deviation of daily stock returns multiplied by $\sqrt{252}$

Table IAXVI
Investment Under Supply-Chain Uncertainty: Instrumental Variables Approach

The table reports the relation between a firm’s investment rate and the contemporaneous level of the firm’s upstream uncertainty (i.e., the uncertainty of the firm’s suppliers) and the firm’s downstream uncertainty (i.e., the uncertainty of the firm’s customers) among firms with long and short time-to-build periods (Panel A) and high and low degrees of investment reversibility (Panel B). The results in Panel A are based on estimating equation (11), where we exclude a firm’s own uncertainty and $y_{i,t}$ is firm i ’s investment rate obtained from the most recent annual report as measured at time t . The results in Panel B are based on estimating a similar equation, in which the measure of investment reversibility is used in place of the proxy for time-to-build. In Panel A, the “Long” dummy takes the value of one for firms that have a level of R&D intensity that exceeds the cross-sectional median value of R&D intensity, and the “Short” dummy takes the value of one for all other firms. In Panel B, *HighReverse* (*LowReverse*) is a dummy variable that takes the value of one for firms that have values of the capital redeployability proxy from Kim and Kung (2017) that are above (below) the median value of the proxy. The uncertainty measures are constructed at time t as follows. First, let $S_{i,t}$ denote the set of suppliers of firm i at time t and let $C_{i,t}$ denote the set of the firm’s customers. Next, upstream uncertainty is constructed as $\sigma(\text{Upstream})_{i,t} = \sum_{s \in S_{i,t}} w_{s,t} \sigma_{s,t}$, where $w_{s,t} = \text{Sales}_{s,t} / \sum_{k \in S_{i,t}} \text{Sales}_{k,t}$, and $\text{Sales}_{k,t}$ is the log of firm k ’s sales. Similarly, downstream uncertainty is constructed as $\sigma(\text{Downstream})_{i,t} = \sum_{c \in C_{i,t}} w_{c,t} \sigma_{c,t}$, where $w_{c,t} = \text{COGS}_{c,t} / \sum_{k \in C_{i,t}} \text{COGS}_{k,t}$, and $\text{COGS}_{k,t}$ is the log of firm k ’s cost of goods sold. In either case, $\sigma_{s,t}$ and $\sigma_{c,t}$ are the instrumented values of each firm’s shock to the 12-month change in realized volatility, where the instruments we employ are drawn from Alfaro et al. (2024). All specifications include year fixed effects and even-numbered columns also include control variables. Section III.A of the Internet Appendix provides the definitions of all control variables. All regressions are estimated using a panel of firm-year observations over the period 1978 to 2019, and t -statistics, reported in parentheses, are based on standard errors clustered at the firm level. Finally, the table also reports Wald tests on the null hypotheses that (i) the effect of downstream uncertainty is the same between firms with long and short time-to-build, and (ii) the effects of the supply-chain uncertainties are the same among firms with high and low reversibility.

	Panel A: Time-to-build				Panel B: Reversibility			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\sigma(\text{Upstream}) \times \text{Long}$	-1.80 (-1.42)	-2.08 (-1.65)						
$\sigma(\text{Upstream}) \times \text{Short}$	-2.19 (-2.07)	-2.54 (-2.41)						
$\sigma(\text{Downstream}) \times \text{Long}$			0.28 (0.33)	0.31 (0.38)				
$\sigma(\text{Downstream}) \times \text{Short}$			-0.94 (-1.57)	-1.27 (-2.13)				
$\sigma(\text{Upstream}) \times \text{HighReverse}$					-0.06 (-0.06)	-0.09 (-0.09)		
$\sigma(\text{Upstream}) \times \text{LowReverse}$					-1.28 (-1.22)	-1.62 (-1.54)		
$\sigma(\text{Downstream}) \times \text{HighReverse}$							1.45 (2.17)	1.45 (2.23)
$\sigma(\text{Downstream}) \times \text{LowReverse}$							-0.33 (-0.52)	-0.32 (-0.51)
p(Long=Short)	0.71	0.67	0.03	0.04	0.20	0.12	0.02	0.02
Controls	No	Yes	No	Yes	No	Yes	No	Yes
Firm FE	Yes	Yes	50Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj.- R^2	0.50	0.52	0.38	0.41	0.51	0.53	0.39	0.42
Obs.	10933	10903	19144	19089	11935	11911	22766	22705

(i.e., the number of trading days in the typical year), using non-directional exposure times the change in the variation in the following nine sources of aggregate uncertainty: oil prices, the prices of seven widely-traded currencies (the Australian Dollar, British Pound, Canadian Dollar, Euro, Japanese Yen, Swedish Krona, and Swiss Franc), and economic policy uncertainty (the EPU measure of Baker, Bloom, and Davis (2016)). The idea behind this approach is to use the fact that firms have different exposures to the various sources of aggregate volatility as a way to capture exogenous variation in firm-level uncertainty. Once we obtain the instrumented value of each firm’s realized volatility shock, we then aggregate these instruments across all suppliers (customers) that trade with firm i in year t to obtain our instruments for upstream (downstream) uncertainty.

Since the instrumental variable approach described above adds an additional layer of estimation to our empirical procedure and consequently introduces some noise to our empirical analyses, we focus on testing Hypotheses (iii) and (iv) of our model. We focus on these two hypotheses because they predict that the effects of upstream and downstream uncertainty on investment rates are ex-ante unambiguous. Consequently, the effects of the supply-chain uncertainties in these instances should be more pronounced ex post.

In line with these two hypotheses, Table IAXVI confirms three of our main results. First, downstream uncertainty induces a positive impact on the investment rates of firms with sufficiently long time-to-build (Panel A): this finding is also consistent with Figure 3 of the model. Second, downstream uncertainty induces a positive impact on the investment rates of firms with more reversible projects (Columns (7) and (8) of Panel B). Third, upstream uncertainty induces a negative impact on the investment rates of firms with more irreversible investments (Columns (5) and (6) of Panel B).

IX. Upstream and Downstream Uncertainty: Prices of Risk

We show that macro-level upstream (downstream) uncertainty shocks are associated with an increase (decrease) in the marginal utility of investors. This finding is consistent with the impulse response functions in Figures 6 and 7 that shows that macro-level upstream (downstream) uncertainty decreases (increases) future consumption growth. Thus, beyond the fact that higher upstream (downstream) uncertainty signals that macroeconomic conditions will deteriorate (improve), higher upstream (downstream) uncertainty also signals bad (good) times for investors.

Ex-ante uncertainty. As investors are concerned about variation in *expected* outcomes, we compute the market prices of risk associated with forward-looking versions of aggregate upstream and downstream uncertainty measures. Specifically, we consider the time- t predictable component of each future aggregate volatility measure. We extract these ex-ante

(predictable) components by projecting the logarithm of realized volatility of aggregate upstream (downstream) uncertainty at time $t + 1$ on a set of predictors observable at time t via

$$\ln(\sigma_{x,t+1}) = \beta_0 + \beta \Gamma'_t + \varepsilon_{x,t+1} \quad \text{for } x \in \{U, D\}. \quad (\text{IA4})$$

After estimating the equation above, we define the ex-ante components of the aggregate supply-chain uncertainties as $\tilde{\sigma}_{x,t} = \exp(\hat{\beta}_0 + \hat{\beta} \Gamma'_t)$ for $x \in \{U, D\}$. Taking the logarithm ensures that the ex-ante uncertainty measures are strictly positive. We estimate these projections at the monthly frequency using data between January 1974 and December 2018. Our baseline specifications include the following control variables in Γ_t : both macro-level upstream and downstream uncertainty, the market's price-dividend ratio, the term and default spreads, and the inflation rate.

Prior to estimating the market prices of risk associated with each of the ex-ante upstream and downstream uncertainty measures, we first confirm that the impulse responses from these uncertainties to aggregate consumption growth are consistent with the baseline results in Section IV.B of the main article. To do this, we replace the quarterly measures of realized macro-level upstream and downstream uncertainty ($\sigma_{U,t}$ and $\sigma_{D,t}$, respectively), in equation (13) with the ex-ante measures of upstream and downstream uncertainty ($\tilde{\sigma}_{U,t}$ and $\tilde{\sigma}_{D,t}$, respectively). The results are reported in Figure IA14 and show that using the ex-ante measures of macro-level uncertainty supports the conclusion that macro-level upstream (downstream) uncertainty is associated with a deterioration (improvement) in real consumption growth.

Market prices of risk. We estimate the market prices of risk of the predictable components of macro-level upstream and downstream uncertainty by assuming that the stochastic discount factor (SDF) that prices all assets in the economy is

$$M_t = 1 - b_{MKT} MKTRF_t - b_U \Delta \tilde{\sigma}_{U,t} - b_D \Delta \tilde{\sigma}_{D,t}. \quad (\text{IA5})$$

The parameter b_U (b_D) in the above equation measures the market price of risk of upstream (downstream) uncertainty shocks and b_{MKT} reflects the market price of risk associated with the market portfolio, which we proxy using the excess market return from the Fama and French (1993) three-factor model. We demean all variables included in equation (IA5) and estimate $[b_{MKT} \ b_U \ b_D]'$ via generalized method of moments (GMM) using the Euler condition $\mathbb{E}[M_t r_{i,t}^e] = 0$, where $r_{i,t}^e$ denotes the excess return of test asset i at time t .

We employ two comprehensive menus of test assets to estimate the loadings in equation (IA5): (1) the monthly returns of 25 value-weighted portfolios double sorted on size and book-to-market, and (2) we follow the suggestion of Lewellen, Nagel, and Shanken (2010) and also estimate the loadings using a set of 42 portfolios that augments the first set of assets with the monthly value-weighted returns of the Fama-French 17 industry portfolios. This helps to break the strong factor structure inherent in the returns of the first set of test assets.

In robustness checks discussed below, we also show that our results hold when using an even more comprehensive menu comprised of 92 test assets. We obtain the monthly returns of all test assets from Ken French’s data library.

Table IAXVII
Market Price of Risk of Macro-Level Upstream and Downstream Uncertainty

The table reports the market prices of risk associated with macro-level upstream and downstream uncertainty (σ_U and σ_D , respectively). We estimate these market prices of risk via a generalized method of moments procedure based on the stochastic discount factor (SDF) given by equation (IA5) and the Euler equation given by $\mathbb{E}[M_t r_{i,t}^e] = 0$. When estimating these prices of risk we use the ex-ante (predictable) components of future macro-level upstream and downstream realized volatility, obtained via equation (IA4) at the monthly frequency. We control for excess market returns as a risk factor, capturing first-moment fluctuations in productivity. We use two different sets of value-weighted test assets. In Panel A the set of test assets consists of the monthly returns of 25 portfolios sorted on size and book-to-market. In Panel B, the set of test assets in Panel A is augmented by including the monthly returns of the 17 Fama-French industry portfolios. The t -statistic associated with each factor risk premium is reported in parentheses, and the mean absolute error (MAE) from each estimation procedure is reported in the bottom row of each panel. Monthly data spanning February 1974 to December 2018 is used to estimate each model.

	Panel A: 25 portfolios				Panel B: 42 portfolios			
MKTRF	3.64 (3.47)	2.76 (2.40)	3.85 (3.51)	2.97 (2.24)	3.40 (3.30)	2.79 (2.57)	3.55 (3.32)	3.03 (2.66)
σ_U		-0.67 (-2.44)		-2.42 (-3.59)		-0.46 (-2.34)		-1.41 (-3.07)
σ_D			0.40 (0.70)	4.90 (3.28)			0.28 (0.60)	2.93 (2.73)
MAE	0.98	1.03	0.97	0.93	1.01	1.01	1.00	0.97

Table IAXVII reports the loading associated with each source of risk included in equation (IA5) across the two sets of test assets and the mean absolute pricing error (MAE) from each GMM estimation. Panel A is based on the set of 25 test assets. When b_D (b_U) is restricted to zero, upstream (downstream) uncertainty has a negative (positive) and statistically significant (insignificant) price of risk. When both coefficients are unrestricted in the rightmost column of Panel A, then upstream (downstream) uncertainty has a negative (positive) price of risk and each of these slope coefficients is statistically significant at the 1% level.

Economically, the results indicate that states of high upstream (downstream) macro-level uncertainty are associated with bad (good) times for investors. The results in Panel B, which are based on a more comprehensive set of test assets, mirror those in Panel A. Thus, the table documents that marginal utility increases (decreases) with higher macro-level upstream (downstream) uncertainty.

Robustness. Table IAXVIII extends the previous analysis and shows that the market prices of risk the aggregate supply-chain uncertainties are robust along two dimensions. First, estimating these market prices of risk using more comprehensive sets of 62 or 92 test assets produces qualitatively and quantitatively similar results. Second, perturbing the set of predictors $\mathbf{\Gamma}_t$ used in equations (IA4) does not change our results.

Table IAXVIII
Market Price of Risk of Macro-Level Supply-Chain Uncertainties:
Robustness

The table reports robustness checks for the market prices of risk associated with macro-level upstream and downstream uncertainty (σ_U and σ_D , respectively). We estimate these market prices of risk via a generalized method of moments procedure based on the stochastic discount factor (SDF) given by equation (IA5) and the Euler equation given by $\mathbb{E}[M_t r_{i,t}^e] = 0$. When estimating these prices of risk we use the ex-ante (predictable) components of future macro-level upstream and downstream realized volatility, obtained via equation (IA4) at the monthly frequency. We control for excess market returns $MKTRF$ as a risk factor, capturing first-moment fluctuations in productivity. In Panel A, we use the same ex-ante macro-level uncertainties as in the benchmark analysis but we change the menu of testing assets. We use a set of 62 test assets, comprised of 25 portfolios sorted on size and book-to-market, the 17 Fama-French industry portfolios, 10 momentum-sorted portfolios, and 10 investment-sorted portfolios, or 92 test assets, comprised of the 62 aforementioned test assets plus 10 short-term reversal-sorted portfolios, 10 long-term reversal-sorted portfolios, and 10 profitability-sorted portfolios. In Panel B, we use the same menu of testing assets as in the benchmark analysis, but we change the predictors used to construct the ex-ante uncertainties, $\mathbf{\Gamma}_t$, by (i) excluding downstream (upstream) volatility when measuring the ex-ante component of upstream (downstream) uncertainty, (ii) excluding the default spread and inflation rate, or (iii) excluding the price-to-dividend ratio and term spread, while retaining each of the remaining variables in $\mathbf{\Gamma}_t$. The t -statistic associated with each factor risk premium is reported in parentheses, and the mean absolute error (MAE) associated with each estimation procedure is reported in the bottom row of each panel. Monthly data spanning February 1974 to December 2018 is used to estimate each model.

	Panel A: Test assets		Panel B: Controls					
Excluded controls	None		Other vol.		DEF/INFL		PD/TERM	
Portfolios	62	92	25	42	25	42	25	42
MKTRF	2.05	1.94	3.10	3.07	3.25	3.16	3.01	3.03
	(1.85)	(1.86)	(2.39)	(2.71)	(2.57)	(2.80)	(2.28)	(2.67)
σ_U	-1.97	-1.79	-1.87	-1.17	-1.78	-1.17	-2.34	-1.41
	(-4.51)	(-5.19)	(-3.42)	(-3.09)	(-3.20)	(-3.01)	(-3.53)	(-3.11)
σ_D	2.70	2.20	3.87	2.50	3.52	2.40	4.66	2.90
	(2.68)	(2.83)	(3.13)	(2.70)	(3.01)	(2.72)	(3.23)	(2.77)
MAE	0.96	0.84	0.94	0.96	0.96	0.97	0.93	0.96

X. Additional Macro-Level Results

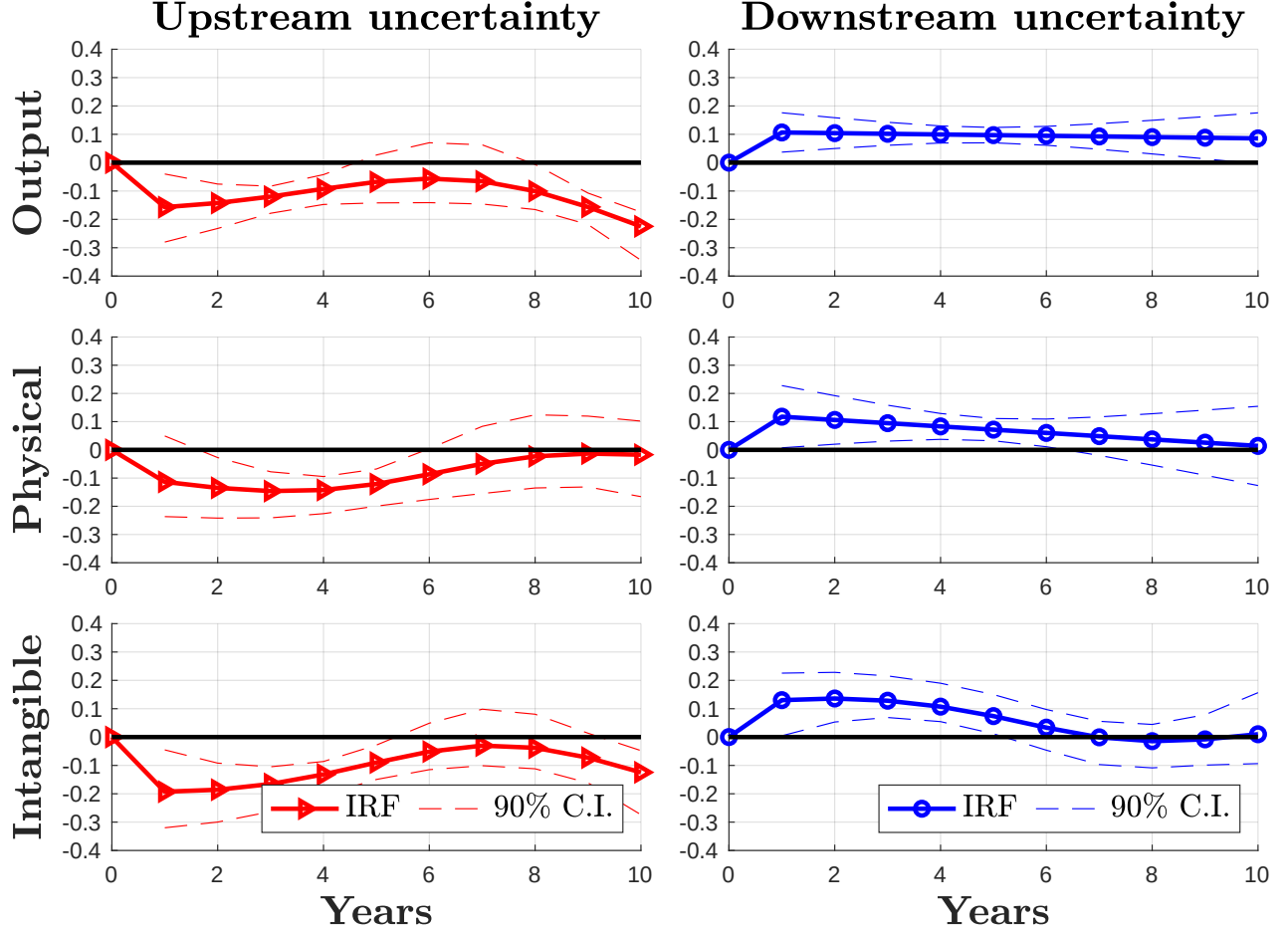


Figure IA10. IRFs from macro-level uncertainty shocks: Public firm outcomes (1). This figure reports impulse response functions (IRFs) that display the effects of a one standard deviation shock to macro-level upstream uncertainty ($\sigma_{U,t}$) in the left column and to macro-level downstream uncertainty ($\sigma_{D,t}$) in the right column on the annual growth rates of aggregate sales (denoted by “Output”), physical investment (denoted by “Physical”), and aggregate intangible investment (denoted by “Intangible”). Each of these aggregate variables is constructed using data in the CRSP/Compustat universe of firms, as described in Section III.B of the Internet Appendix. We estimate the IRFs by applying the smooth local projection method of Barnichon and Brownlees (2019) to equation (13) for forecast horizons that range from one to ten years ahead and with P equal to one year. We measure macro-level uncertainty by following the procedure described in Section IV.A of the main article. Section III.B of the Internet Appendix provides detailed descriptions of the variables included in equation (13). The estimated IRFs are denoted by solid lines, while 90% confidence intervals are represented by the dashed lines. The sample period is from 1976 to 2019.

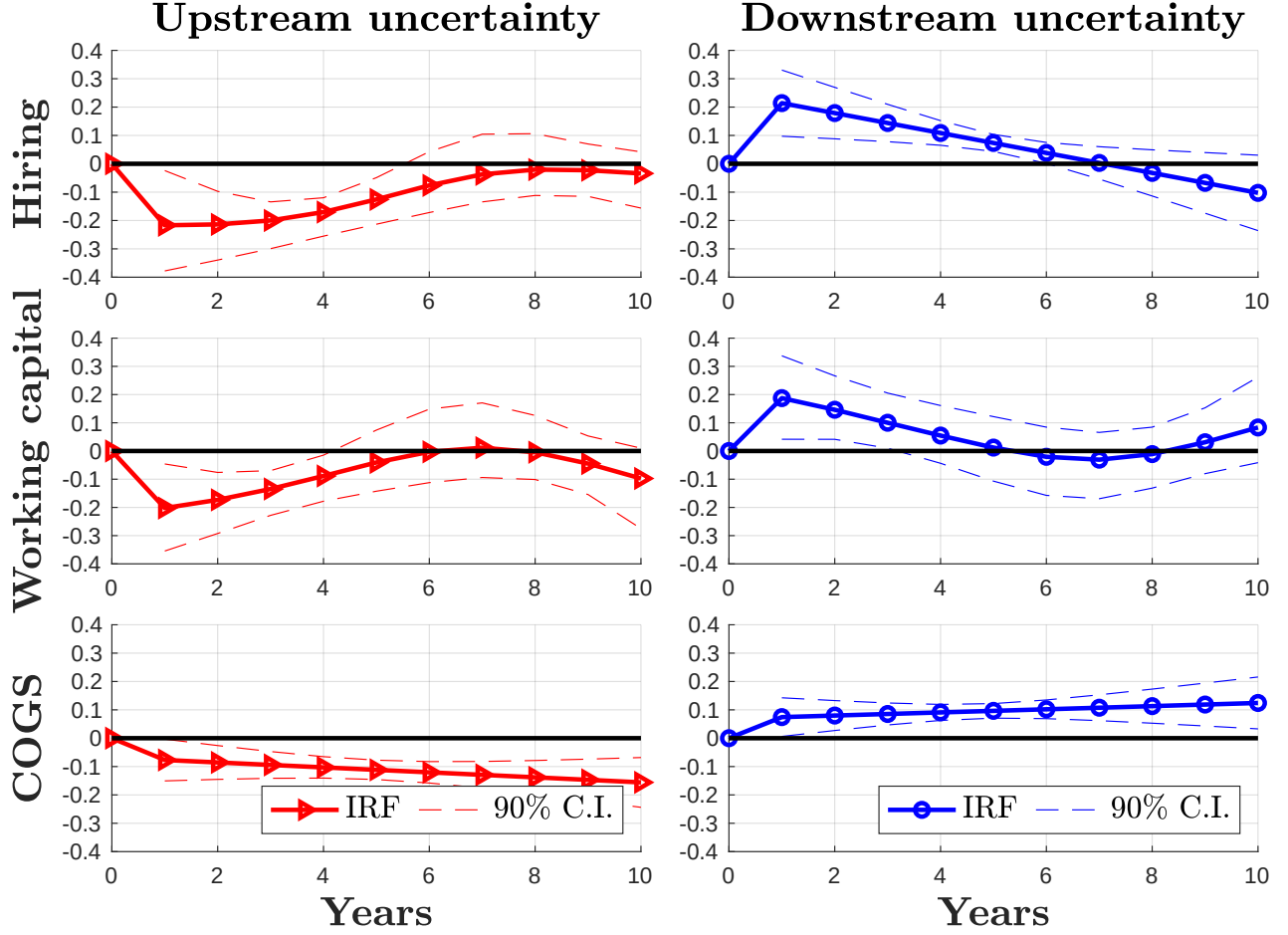


Figure IA11. IRFs from macro-level uncertainty shocks: Public firm outcomes (2). This figure reports impulse response functions (IRFs) that display the effects of a one standard deviation shock to macro-level upstream uncertainty ($\sigma_{U,t}$) in the left column and to macro-level downstream uncertainty ($\sigma_{D,t}$) in the right column on the annual growth rates of aggregate employment (denoted by “Hiring”), working capital (denoted by “Working capital”), and aggregate cost of goods sold (denoted by “COGS”). Each of these aggregate variables is constructed using data in the CRSP/Compustat universe of firms, as described in Section III.B of the Internet Appendix. We estimate the IRFs by applying the smooth local projection method of Barnichon and Brownlees (2019) to equation (13) for forecast horizons that range from one to ten years ahead and with P equal to one year. We measure macro-level uncertainty by following the procedure described in Section IV.A of the main article. Section III.B of the Internet Appendix provides detailed descriptions of the variables included in equation (13). The estimated IRFs are denoted by solid lines, while 90% confidence intervals are represented by the dashed lines. The sample period is from 1976 to 2019.

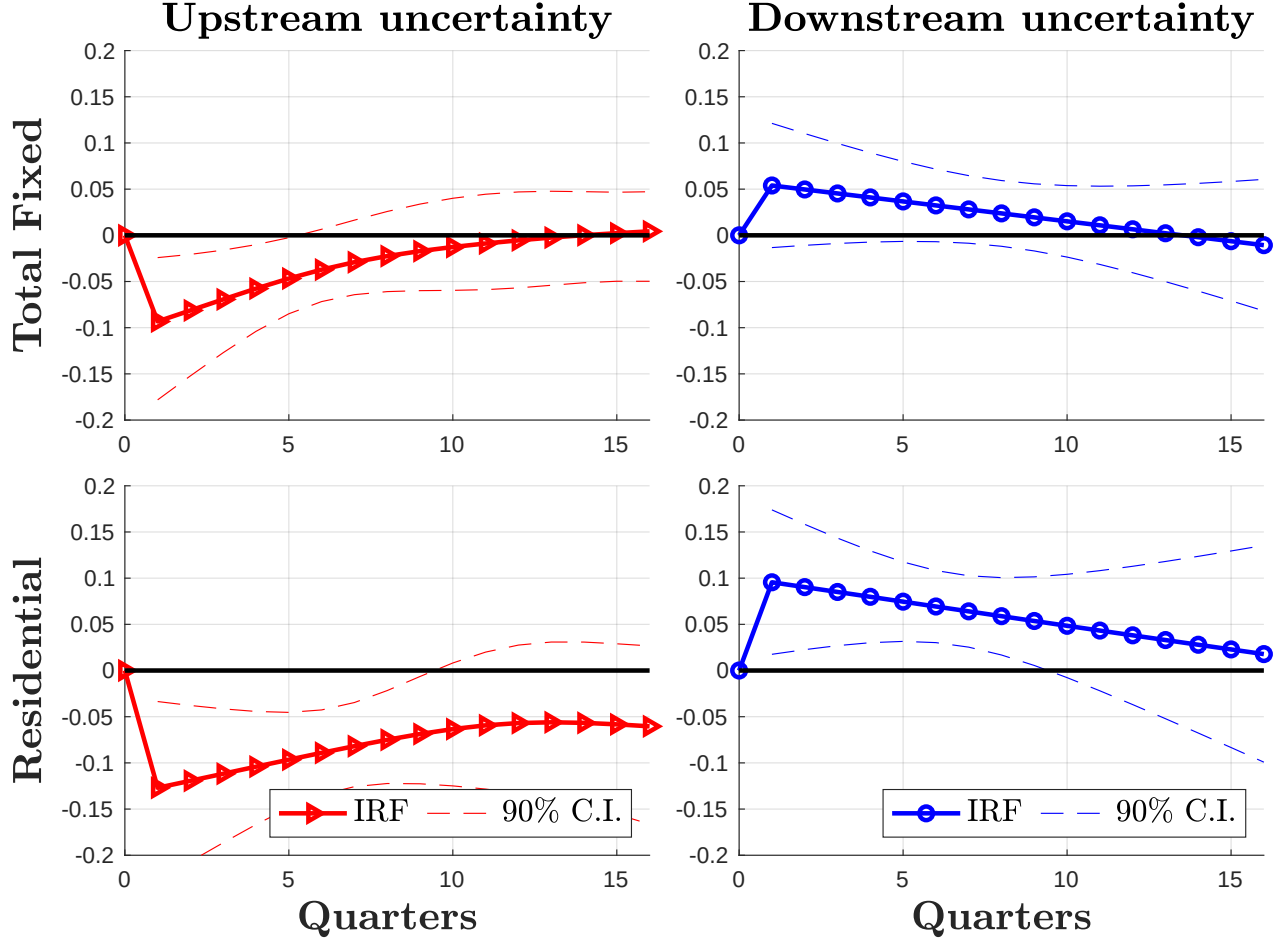


Figure IA12. IRFs from macro-level uncertainty shocks: NIPA subcomponents (1). This figure reports impulse response functions (IRFs) that display the effects of a one standard deviation shock to macro-level upstream uncertainty ($\sigma_{U,t}$) in the left column and to macro-level downstream uncertainty ($\sigma_{D,t}$) in the right column on the quarterly real growth rates of aggregate fixed investment (denoted by “Total Fixed”) and residential investment (denoted by “Residential”). The nominal level of each facet of investment is drawn from the Bureau of Economic Analysis’s National Income and Product Accounts (NIPA) Table 1.1.5, and deflated by the price indexes in NIPA Table 1.1.4. We estimate the IRFs by applying the smooth local projection method of Barnichon and Brownlees (2019) to equation (13) for forecast horizons that range from one to 16 quarters ahead and with P equal to four quarters. We measure macro-level uncertainty by following the procedure described in Section IV.A of the main article. Section III.B of the Internet Appendix provides detailed descriptions of the variables included in equation (13). The estimated IRFs are denoted by solid lines, while 90% confidence intervals are represented by the dashed lines. The sample period is from 1976Q1 to 2019Q4.

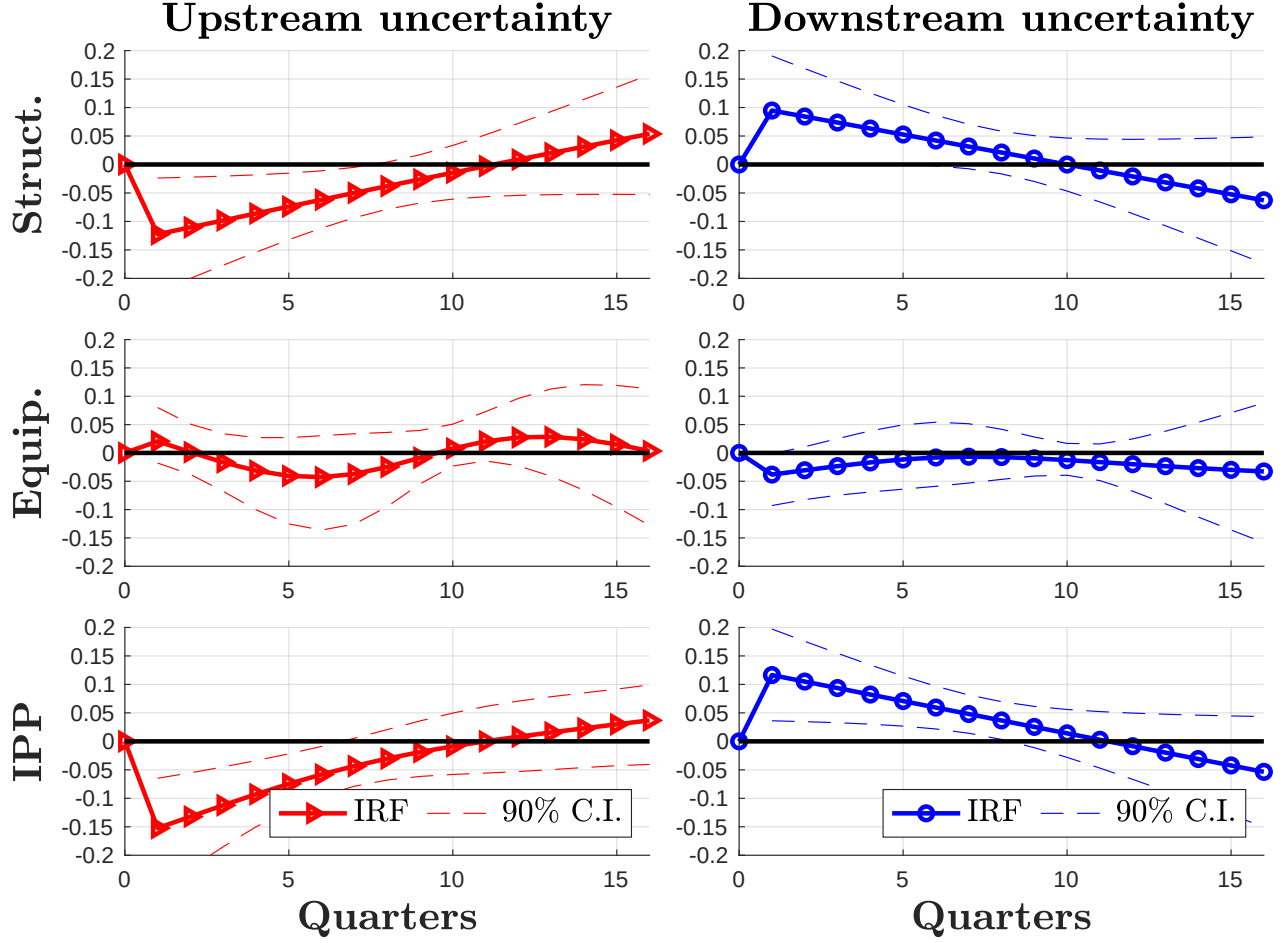


Figure IA13. IRFs from macro-level uncertainty shocks: NIPA subcomponents (2). This figure reports impulse response functions (IRFs) that display the effects of a one standard deviation shock to macro-level upstream uncertainty ($\sigma_{U,t}$) in the left column and to macro-level downstream uncertainty ($\sigma_{D,t}$) in the right column on the quarterly real growth rates of aggregate investments in structures (denoted by “Struct.”), equipment (denoted by “Equip.”), and intellectual property products (denoted by “IPP”). The nominal level of each facet of investment is drawn from the Bureau of Economic Analysis’s National Income and Product Accounts (NIPA) Table 1.1.5, and deflated by the price indexes in NIPA Table 1.1.4. We estimate the IRFs by applying the smooth local projection method of Barnichon and Brownlees (2019) to equation (13) for forecast horizons that range from one to 16 quarters ahead and with P equal to four quarters. We measure macro-level uncertainty by following the procedure described in Section IV.A of the main article. Section III.B of the Internet Appendix provides detailed descriptions of the variables included in equation (13). The estimated IRFs are denoted by solid lines, while 90% confidence intervals are represented by the dashed lines. The sample period is from 1976Q1 to 2019Q4.

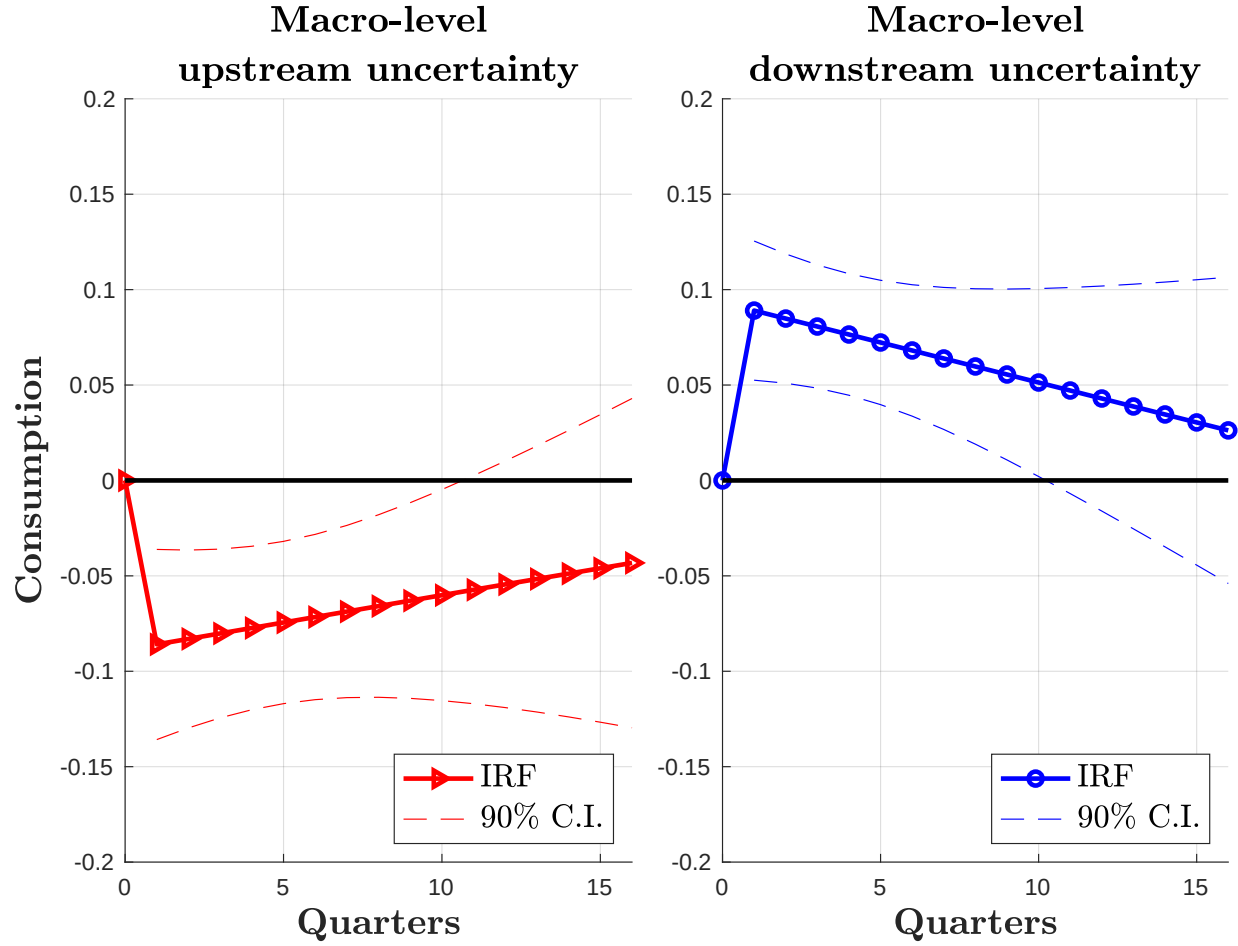


Figure IA14. IRFs of ex-ante macro-level uncertainty to consumption growth. This figure reports impulse response functions (IRFs) that display the effects of a one standard deviation shock to macro-level upstream uncertainty (left panel) and macro-level downstream uncertainty (right panel) on the quarterly growth rate of real consumption. We estimate the IRFs by applying the smooth local projection method of Barnichon and Brownlees (2019) to equation (13) for forecast horizons that range from one to 16 quarters ahead and with P equal to four quarters. In estimating equation (13), we replace the realized measures of the macro-level measures of the supply-chain uncertainties ($\sigma_{U,t}$ and $\sigma_{D,t}$) with the ex-ante (predictable) components of each uncertainty from equation (IA4) ($\tilde{\sigma}_{U,t}$ and $\tilde{\sigma}_{D,t}$). Section III.B of the Internet Appendix provides detailed descriptions of the variables included in equation (13). The estimated IRFs are denoted by solid lines, while 90% confidence intervals are represented by the dashed lines. The sample period is from 1976Q1 to 2019Q4.

Table IAXIX
Industry Membership in Macro-Level Upstream and Downstream Portfolios

The table reports the set of ten industries that are most frequently assigned to each of the upstream (Panel A) and the downstream (Panel B) categories. The table is constructed by first computing the vertical position score of each industry following the approach outlined in Section IV.A of the main article. Next, we use these vertical position scores to assign industries to the high and low vertical position groups at the end of each month from December 1975 to November 2019. Finally, we count the number of times that each industry is assigned to the high or low vertical position group and report the ten industries in each group with the highest frequencies. The table reports the ranking of each industry within each group, the industry’s four-digit SIC code, the industry’s name, and the number of months that each industry is assigned to the given group.

Ranking	SIC	Industry	N(Months)
Panel A: High vertical position industries			
1	3541	Machine Tools, Metal Cutting Types	153
2	3743	Railroad Equipment	143
3	1041	Gold Ores	137
4	3662	Radio and Television Broadcasting and Communications Equipment	134
5	3721	Aircraft	123
6	3761	Guided Missiles and Space Vehicles	114
7	3728	Aircraft Parts and Auxiliary Equipment, Not Elsewhere Classified	107
8	3724	Aircraft Engines and Engine Parts	69
9	3825	Instruments for Measuring and Testing of Electricity and Electrical Signals	68
10	2522	Office Furniture, Except Wood	67
Panel B: Low vertical position industries			
1	3143	Men’s Footwear, Except Athletic	104
2	8062	General Medical and Surgical Hospitals	84
3	8351	Child Day Care Services	83
4	7231	Beauty Shops	67
5	8322	Individual and Family Social Services	66
6	8080	Outpatient Care Facilities	61
7	8350	Child Day Care Services	59
8	5411	Grocery Stores	58
9	8051	Skilled Nursing Care Facilities	56
10	8090	Miscellaneous Health and Allied Services, Nec	53

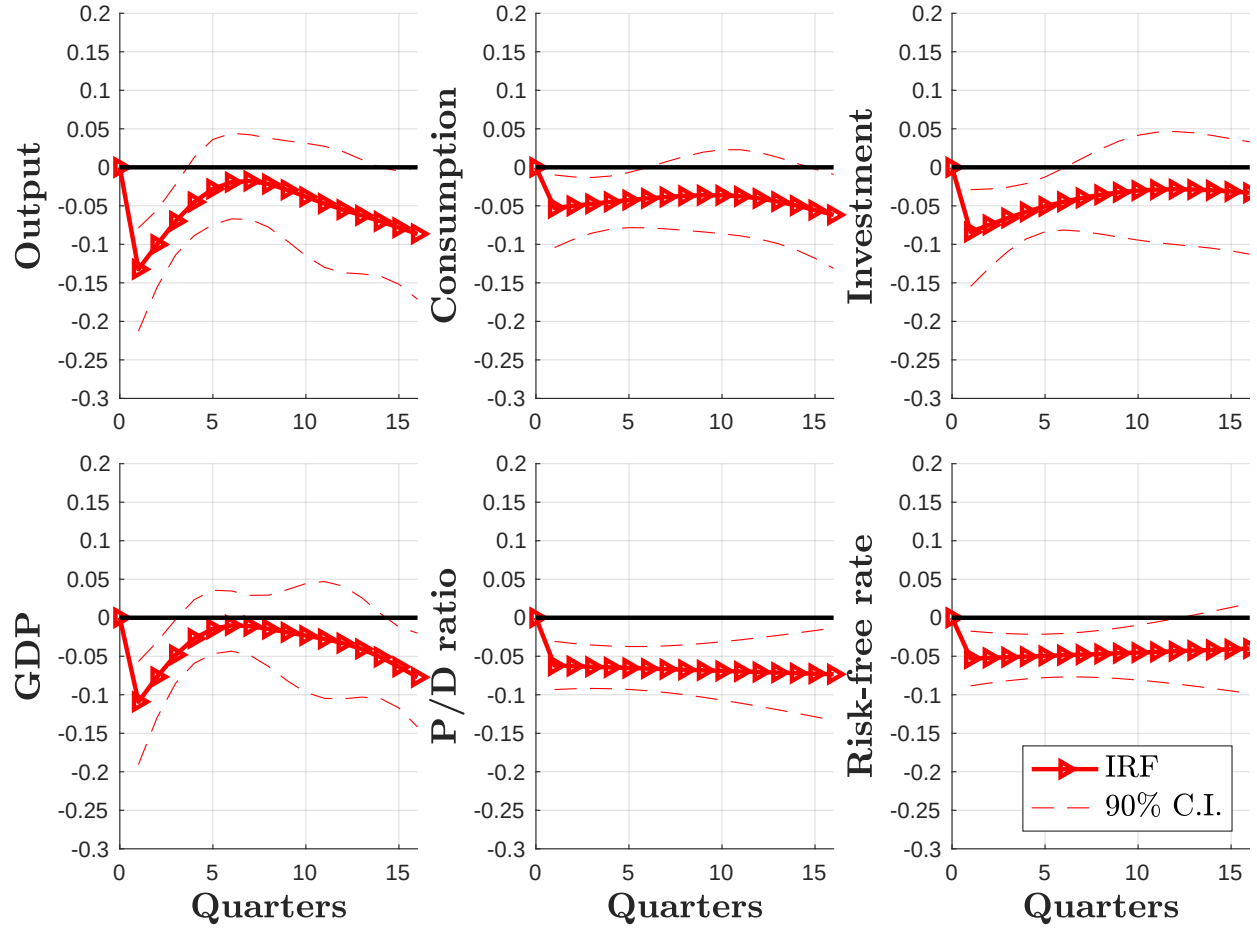


Figure IA15. IRFs from macro-level upstream uncertainty shocks: Including IST. This figure reports impulse response functions (IRFs) that display the effects of a one standard deviation shock to macro-level upstream uncertainty ($\sigma_{U,t}$) on the quarterly growth rates of industrial production, real consumption, real nonresidential investment, real GDP, and the levels of the aggregate price-dividend ratio and the risk-free rate. Beyond controlling for the set of typical control variables described in Section III.B of the Internet Appendix, the IRFs reported here also control for investment-specific technology (IST) shocks, which we proxy using the return spread of investment-goods producers minus consumption-goods producers, as identified by the industry classification of Gomes et al. (2009). We estimate the IRFs by applying the smooth local projection method of Barnichon and Brownlees (2019) to equation (13) for forecast horizons that range from one to 16 quarters ahead. We measure macro-level upstream uncertainty by following the procedure described in Section IV.A of the main article. The estimated IRFs are denoted by solid lines, while 90% confidence intervals are represented by the dashed lines. The sample period is from 1976Q1 to 2019Q4.

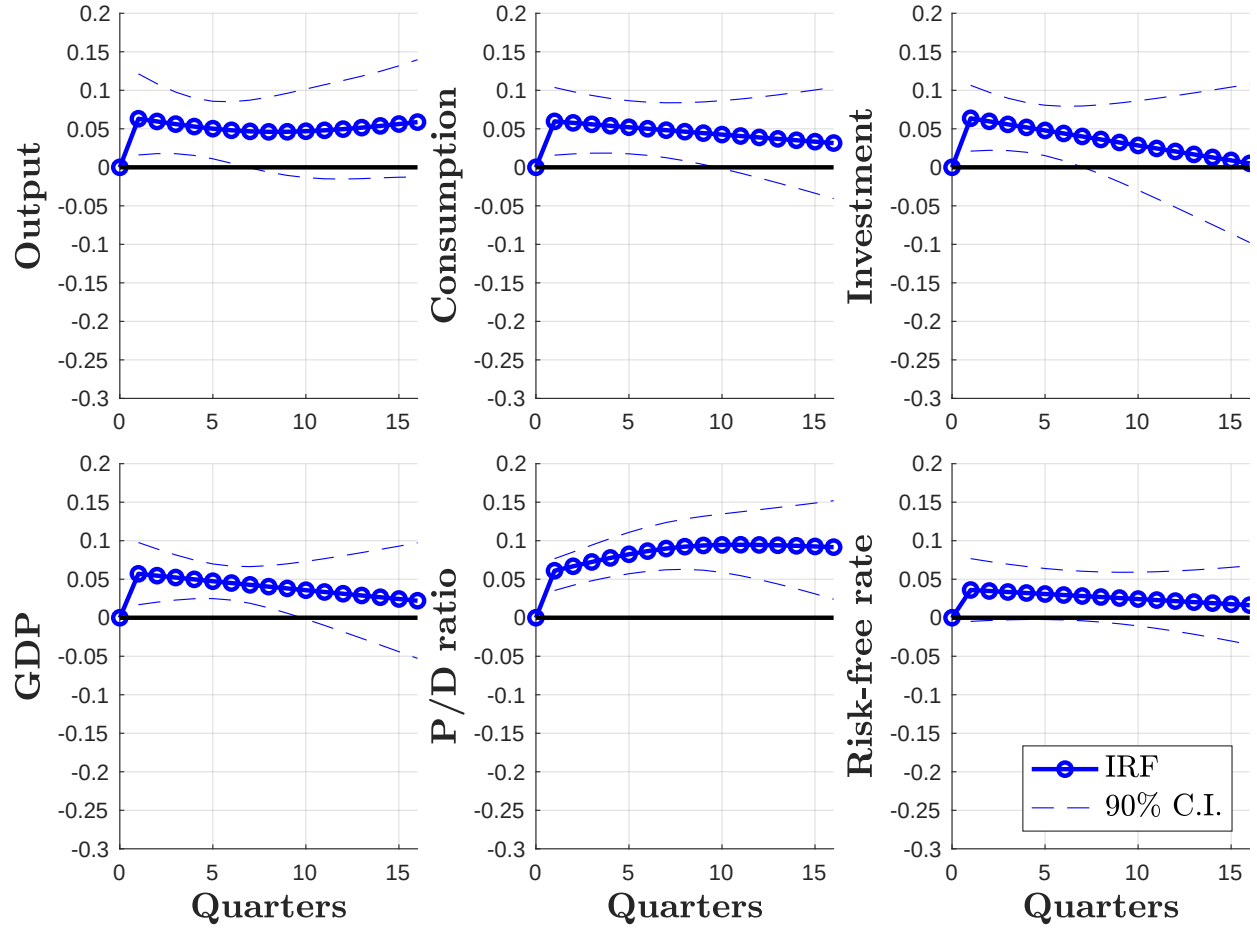


Figure IA16. IRFs from macro-level downstream uncertainty shocks: Including IST. This figure reports impulse response functions (IRFs) that display the effects of a one standard deviation shock to macro-level downstream uncertainty ($\sigma_{D,t}$) on the quarterly growth rates of industrial production, real consumption, real nonresidential investment, real GDP, and the levels of the aggregate price-dividend ratio and the risk-free rate. Beyond controlling for the set of typical control variables described in Section III.B of the Internet Appendix, the IRFs reported here also control for investment-specific technology (IST) shocks, which we proxy using the return spread of investment-goods producers minus consumption-goods producers, as identified by the industry classification of Gomes et al. (2009). We estimate the IRFs by applying the smooth local projection method of Barnichon and Brownlees (2019) to equation (13) for forecast horizons that range from one to 16 quarters ahead. We measure macro-level downstream uncertainty by following the procedure described in Section IV.A of the main article. The estimated IRFs are denoted by solid lines, while 90% confidence intervals are represented by the dashed lines. The sample period is from 1976Q1 to 2019Q4.

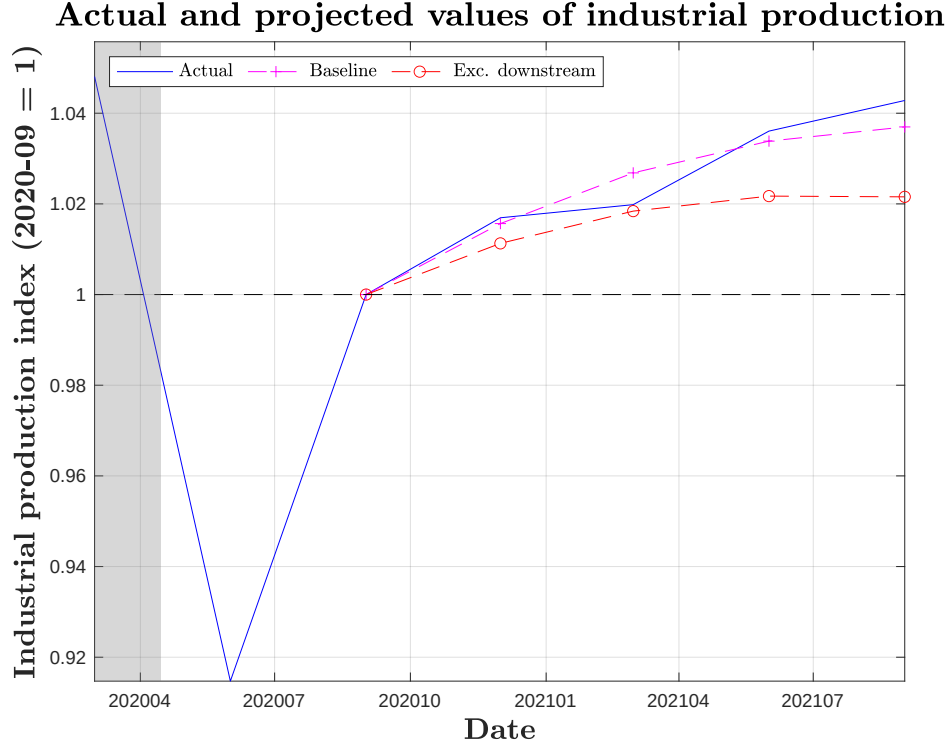


Figure IA17. IRFs from macro-level uncertainty shocks: Counterfactual analysis. This figure reports the quarterly level of the industrial production index (scaled such that the index is equal to one in September 2020) and the predicted paths of industrial production based on (i) the baseline impulse response function (IRF) represented by equation (13) and (ii) an alternative IRF in which the coefficient $\beta_{2(h)}$ in equation (13), which reflects the impact of downstream uncertainty, is restricted to equal zero. We then estimate equation (13) using quarterly data between 1976Q1 and 2019Q4, save the resulting point estimates, and then use these slope coefficients, together with observable data from September 2020, to predict the level of industrial production at the end of each of the following four quarters (i.e., the level of industrial production at the end of December 2020, March 2021, June 2021, and September 2021). The ex-post realized path of industrial production is plotted in the solid blue line, the path of industrial production implied by our baseline model is represented by the dashed magenta line, which is marked with “+”, and the path of industrial production implied by the restricted model in which $\beta_{2(h)} = 0$ is represented by the dashed red line, which is marked with “o.”

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