Financial Constraints, Sectoral Heterogeneity, and the Cyclicality of Investment*

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Abstract

While investment in most sectors declines in response to a contractionary monetary policy shock, investment in the manufacturing sector *increases*. Using manually digitized aggregate income and balance sheet data for the universe of US manufacturing firms, I show this increase is driven by the types of firms which are least likely to be financially constrained. A two-sector New Keynesian model with financial frictions can match these facts; unconstrained firms take advantage of the decline in the user cost of capital caused by the monetary contraction, while constrained firms are forced to cut back. Removing firm financial constraints in the model dampens the response of aggregate output to monetary shocks by about 25%.

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1 Introduction

Productive capital goods are among the most volatile and interest-sensitive components of GDP and receive significant attention from monetary policymakers. While past work such as Bernanke et al. (1999) and Christiano et al. (2005) has confirmed the conventional wisdom that aggregate investment is strongly procyclical in response to monetary shocks, these findings belie meaningful heterogeneity across sectors; in particular, investment in the manufacturing sector is strongly *countercyclical* conditional on monetary policy shocks. A model with financial constraints that vary across sectors can explain this behavior and suggests that the easing of financial constraints can attenuate the response of aggregate output and inflation to monetary shocks.

I start by establishing several new stylized facts regarding manufacturing investment in Section 2. The main analysis utilizes manually digitized aggregate data from the Quarterly Financial Report for Manufacturing Corporations (QFR), which contain detailed income and balance sheet information for the entire manufacturing sector dating back to 1966. Using these data, I show that the aggregate capital stock in the manufacturing sector increases by about 1.7% in the years following a 100 basis point contractionary monetary shock. This increase is driven entirely by nondurable producers, as durable producers reduce their investment in response to the shock. The QFR data also show that durable manufacturers display a greater degree of financial constraint across several metrics commonly cited in the finance literature: they rely more on short-term debt, their cash flow is more volatile, and they have consistently lower dividend payout ratios.

The key feature underlying the countercyclical responses of manufacturing investment to monetary shocks is the long lifespan of investment goods. Transitory shocks that do not affect the relative price of investment will have a small effect on the demand for investment, because most of its value comes from future service flows after the shock dissipates. In contrast, shocks that affect relative prices can lead to large changes in investment, as getting a discount today is equivalent to locking in a long series of lower marginal costs in the future.

Firms that are financially constrained may not be able to take advantage of these buying opportunities, however, because falling investment prices also mean reduced collateral values and therefore reduced borrowing capacity. This means contractionary demand shocks can have a net expansionary effect on investment for unconstrained firms (but not constrained firms) if they sufficiently lower its relative price.

I argue that monetary policy acts as this type of shock. In an economy with only one good, contractionary monetary policy will raise interest rates and lower demand, but there will be no relative price effects, so demand for investment goods will fall. In a multi-sector economy with separately priced investment and non-investment goods, however, monetary policy can also affect relative prices. If the decline in the relative price of investment is sufficiently large, it can offset the higher interest rates and make investment more appealing. If firms' expenditure is constrained by the value of their collateral, then the decline in the price of investment can instead force them to cut back.

In Section 3, I provide evidence for this mechanism by calculating a measure of the user cost of capital that incorporates relative prices, interest rates, and depreciation. The decline in the relative price of investment more than offsets the higher financing costs caused by rising interest rates and ultimately lowers the user cost following a contractionary monetary policy shock. I argue that heterogeneity in financial constraints can explain why durable manufacturers are forced to reduce their investment in response to a monetary shock, while nondurable producers are able to take advantage of falling capital goods prices and increase their investment.

In Section 4, I analyze the quantitative implications of these findings by developing a New Keynesian model with heterogeneous financial frictions. Consistent with the stylized facts shown in the QFR data, I model durable producers as exhibiting a greater degree of financial constraint than nondurable producers. In response to a monetary contraction, the relative price of durable goods declines, which reduces the value of collateral held by the constrained durable producers. These producers are forced to reduce their durable purchases, while unconstrained nondurable producers are able to take advantage of the lower prices and increase their investment expenditure. By generating investment responses consistent with the data, my model is able to resolve the "comovement puzzle" first reported in Barsky et al. (2007), who pointed out that simple New Keynesian models produce unrealistic investment behavior. Counterfactual exercises show that eliminating firm financial constraints reduces the volatility of real output and inflation coming from monetary shocks by 25% and 10%, respectively.

These results complement recent work analyzing how firm and industry characteristics can influence the transmission of shocks including Cloyne et al. (2019), Crouzet and Mehrotra (2020), Durante et al. (2020), Guo (2020), Jeenas (2019), and Ottonello and Winberry (2020), and have two important implications. First, they suggest policymakers should pay particularly close attention to the balance sheets of financially constrained firms when trying to use monetary policy as a tool to stabilize business cycles, as binding financial constraints can actually prevent them from adjusting and instead lead to offsetting investment responses in other, less-constrained sectors. Second, to the extent that financial deepening can reduce these financial constraints in other sectors, my model suggests that more firms should be able to take advantage of temporary demand-driven drops in prices when choosing the timing of their capital goods purchases, which can ultimately reduce the sensitivity of the aggregate economy to monetary policy shocks.

2 Investment responses to monetary shocks

This section uses manually digitized historical data from the Quarterly Financial Report for Manufacturing Corporations to show that the aggregate manufacturing sector capital stock increases in response to a contractionary monetary shock. This increase is driven by nondurable producers, while durable producers—who exhibit a greater degree of financial constraint in the data across several commonly cited metrics—reduce their investment in response to the shock. In Section 3, I show this heterogeneity can be explained by a simple user cost of capital mechanism. While contractionary monetary policy shocks raise interest rates, they also lower the relative price of investment. In the data, the latter effect dominates, implying that monetary contractions reduce the user cost of capital for manufacturers. Unconstrained firms in the nondurable sector are able to take advantage of these lower prices and increase their investment. In contrast, financially constrained firms in the durable sector are forced to cut back as lower investment prices reduce the value of their collateral.

2.1 Data

The main source of data in this paper is the Quarterly Financial Report for Manufacturing Corporations (QFR), a comprehensive survey of income and balance sheet information for the US manufacturing sector.[1] This survey dates back to World War II, when it was administered by the Office of Price Administration, and has been administered by the Census Bureau since 1982. These data series are used to construct macroeconomic aggregates such as corporate profits. The QFR sample, which includes approximately 10,000 firms in a given quarter, is chosen based on asset sizes reported in corporate tax returns; any firm with more than \$250,000 in domestic assets is eligible for inclusion, and any firm with more than \$250 million is included in the sample with certainty. Firms who reside between these thresholds are chosen randomly with the goal of obtaining a representative sample and are included for eight consecutive quarters with one-eighth of the sample replaced each quarter.

The QFR data are well suited for analyzing the response of manufacturing investment to monetary shocks. First and foremost, they are representative of the entire manufacturing sector, including small and non-public firms. Including these firms is important because a large body of empirical evidence such as Hadlock and Pierce (2010) finds that small and non-public firms are more likely to be financially constrained. The data offer detailed income and balance sheet information at the quarterly frequency, including sales, assets and liabilities by

[1] In addition to manufacturing, the QFR began coverage of mining, wholesale trade, and retail trade in 1974 and was expanded to include a selection of service industries in 2010.

type and maturity, and stocks of physical productive capital. This makes them better suited to analyze the responses of short-term fluctuations in monetary policy than annual data from the Bureau of Economic Analysis (BEA) or Census. And unlike the US Financial Accounts data, which aggregate balance sheet information across nonfinancial corporate businesses of all sectors and sizes, the QFR data provide detail at the sectoral level.

Historically, analyzing the QFR data has been complicated by the fact that a consistent time series was not available for observations prior to the late 1980s. Due in part to these constraints, relatively few papers have used these data; the most famous example is Gertler and Gilchrist (1994), who used the data to suggest that small firms are more sensitive to monetary policy changes than large firms. Some more recent examples include Crouzet (2017), Kudlyak and Sánchez (2017), and Crouzet and Mehrotra (2020).

To get around this issue, I digitized the data going back to 1966Q1 from physical publications. One contribution of this paper is the creation of consistent, harmonized time series for the durable and nondurable manufacturing sectors that can be used by researchers. Each release includes observations for the current quarter as well as the four preceding quarters. Using these five level observations each year, I calculated the four implied quarterly growth rates and retroactively applied these rates to the levels of the most recent releases, effectively adjusting the original growth paths to the most up-to-date levels. Because this approach only calculates changes within releases that use identical methodologies, it allows for the construction of a consistent time series for each sector that is comparable across several methodological revisions (including changes in accounting procedures in 1973 and industry reclassification in 1984 and 2001). Further details regarding the data and its construction can be found in Appendix A.

2.2 Aggregate investment responses to monetary shocks

To analyze the empirical responses of investment to monetary policy shocks, I use a local projection specification based on Jordà (2005). The estimating equation, which is similar to the one used in Ramey (2016), is shown in Equation 1. In this setup y^i_{t+h} represents the h-period ahead realization of the log of the outcome variable y for sector i at time t, ϵ_t represents the monetary policy shock at time t, and $\nu^i_{t,h}$ is an error term.

$$y^i_{t+h} = c^i_h + q^i_h + Trend + \sum_j \beta^i_{j,h} X^i_{t-j} + \sum_k \Omega^i_{k,h} Z_{t-k} + \gamma^i_h \epsilon_t + \nu^i_{t,h} \tag{1}$$

In this equation X^i includes sector-specific controls (8 lags of the dependent variable y^i_t in my baseline specification) and Z includes aggregate controls (8 lags of the monetary shock ϵ_t in my baseline specification). The regression also includes a linear time trend and calendar quarter fixed effects q^i_h to deal with seasonality. The coefficient γ^i_h is the primary object of interest and represents the estimated percent change in the h-period ahead value in variable y for sector i in response to a monetary shock ϵ_t. I use Newey-West standard errors to account for the serial correlation in residuals that arises from successively lagging the dependent variable.

I begin by analyzing the response of the total manufacturing sector's real capital stock[2] to a monetary policy shock using several different identification strategies in Figure 1. The top-left panel shows my baseline results using the narrative shock series developed by Romer and Romer (2004) (R&R) and extended by Coibion (2012). Following a 100bp contractionary monetary shock, the manufacturing sector's capital stock is estimated to increase by up to 1.7% by the end of the response horizon. The top-right panel shows results from the shock series of Gertler and Karadi (2015), who use a high-frequency instrument to identify monetary shocks in a vector autoregression, and finds very similar results to the baseline R&R series.

The panels in the bottom row show the responses to contractionary shocks identified using the approaches of Miranda-Agrippino and Ricco (2021) and Bu et al. (2021). Both of these series employ strategies that identify monetary policy shocks based on financial

[2] I use capital stocks because measures of investment or capital expenditure are not directly recorded in the QFR and deflate them using the nonresidential fixed investment price index.

market responses to Fed announcements. These approaches directly control for the fact that monetary policy actions can also inform market participants about the Fed's information set (the "Fed information effect"). Despite the fact that these series all cover different time horizons[3] and employ different identification strategies, they all suggest that aggregate manufacturing investment increases in response to a monetary contraction.

2.3 Sectoral heterogeneity

To better understand why manufacturing investment increases following a monetary contraction, I analyze how the responses differ across sub-industries. Given the similarities across shock identification strategies shown in the previous section, I focus on the R&R shocks for this exercise, as they are available over the longest period. The top panels of Figure 2 show the responses of sales and the capital stock for each sector. Following a 100 basis point contractionary monetary shock, sales of manufacturing firms decline steadily, falling by close to 4% by the end of the response horizon. The right panel shows the responses for capital stocks. The yellow line shows the same aggregate manufacturing sector response as in top-left panel of Figure 1. The red line shows that this increase in aggregate investment is driven by a large and statistically significant increase of 2.3% on the part of nondurable producers. However the capital stock of durable producers, shown as the blue line, declines by up to 1.4% following the shock.

The persistence of these responses is consistent with Ramey (2016), who does not directly estimate the responses of investment to monetary policy shocks but finds the largest effects on industrial production at the 2-4 year horizon across a variety of specifications. These findings are also in line with Jeenas (2019), who analyzes the response of investment to monetary policy shocks in Compustat and finds the largest investment effects occur between 1-3 years after the shock, and can be accounted for by mechanisms such as those in Zorn

[3] My baseline approach uses R&R shocks starting in 1970 and stopping in 2008 to avoid concerns surrounding the zero lower bound on nominal interest rates and the financial crisis. However, the other shock series I use are unavailable throughout this entire time frame. The date ranges I use for each shock can be found in the notes to Figure 1.

(2020) and Arredondo (2020).

These estimates are obtained from separate regressions for each sector. An alternative approach is to directly estimate the differential responses between the durable and nondurable sectors in the same equation. The bottom panels of Figure 2 show the coefficient estimates from Equation 1 with the dependent variable replaced with "gaps" measuring the differential effect between sectors instead of estimating the effects on each sector separately. The gaps are defined as the log difference between the durable and nondurable sectors. The capital stock gap falls slowly to around 2% before stabilizing around two and a half years after the shock. This is consistent with the results shown in the top panels and provides further evidence for the contrasting behavior of the capital stocks in each sector.

These results complement the findings of Durante et al. (2020), who analyze heterogeneity in the transmission of monetary policy to investment across industries in Europe. As in my results, they show that investment declines more sharply in response to contractionary monetary shock for durable producers than for nondurable producers, and argue that this difference is the result of fundamental differences in the properties of the goods produced by that sector. One difference between our papers is that they find that investment for nondurable producers declines by a smaller amount than durable producers following a monetary policy shock, whereas I find it actually *increases*.[4] Despite the differences in the magnitudes of the absolute responses for each sector, however, the fact that both of our papers capture the same differential effects suggests similar underlying mechanisms are at work.

In the online appendix, I consider several extensions and robustness checks that support these findings. First, I show that my main results are robust to including a range of different control variables, specifications, and time periods. I also show similar results using a standard recursive vector autoregression (VAR) instead of a local projection framework. Finally, I

[4] This reflects in part the different geographies and time periods we examine; they analyze annual firm-level data from Germany, France, Italy, and Spain starting in 1999, whereas I use quarterly US data aggregated at the sectoral level starting in 1970. These differences would be consistent with the predictions of the mechanism I propose if European manufacturing firms on aggregate faced a greater degree of financial constraint than their US counterparts during this time.

analyze both aggregate and firm-level data in Compustat and show that the same patterns emerge. Across all of these specifications, methodologies, and data sets, aggregate investment for the manufacturing sector increases following a monetary contraction. Next, I provide evidence for the mechanism underlying these results.

3 Mechanism

In this section, I argue that the sectoral heterogeneity in the investment responses for durable and nondurable manufacturers to monetary shocks is the result of two factors. The first is that durable producers show more signs of being financially constrained in the data: they rely more on short-term liabilities, they have more volatile cash flows, and they pay fewer dividends. The second factor is that the relative price of investment declines following a monetary policy contraction. In the data, this decline is sufficient to offset the higher interest rates caused by the monetary shock and lower the user cost of capital. The nondurable manufacturing sector, which is less financially constrained, is able to take advantages of these temporary price declines. In contrast, firms in the financially constrained durable sector are forced to cut back as falling prices reduce the value of their collateral.

3.1 Financial Constraints

I begin by documenting differences in the degree of financial constraint faced by durable and nondurable producers in the QFR data. This exercise builds on an extensive literature[5] that attempts to analyze financial constraints empirically. While there is no single empirical metric that is universally understood to quantify these constraints, I focus on three commonly used measures in the literature: 1) reliance on short-term debt, 2) cash flow volatility, and 3) dividend disbursements.

[5] A non-exhaustive list of examples include Fazzari et al. (1988), Kaplan and Zingales (1997), Almeida and Campello (2001), Whited and Wu (2006), Giroud and Mueller (2017), and Farre-Mensa and Ljungqvist (2016), among many others.

Figure 3 plots each of these measures in the QFR for durable and nondurable manufacturers over time. The first panel shows the share of total liabilities with a maturity of less than one year for each sector. While this ratio has been trending downward over time for both sectors, it is consistently about ten percentage points higher for durable producers. Past studies of the determinants of debt maturity such as Barclay and Smith (1995) and Guedes and Opler (1996) find that smaller, riskier, and more credit-constrained firms are more likely to rely on short-term liabilities. Thus the fact that durable producers rely more on short-term debt is consistent with the idea that they are more likely to face credit constraints.

The second panel shows the ratio of cash flow to the capital stock by sector. While the average levels are similar across sectors, durable manufacturers experience much larger fluctuations. This difference is especially pronounced during recessions, which are shown as the shaded gray bars. While net income was modestly lower for nondurable producers during the last few recessions, it declined for the durable manufacturing sector as a whole. Holding expected returns equal, risk-averse investors will prefer assets with lower variance, which can reduce the supply and increase the cost of financing for durable producers.[6] This is consistent with Gomes et al. (2009), who show that durable goods manufacturers have a large equity risk premium and argue this is a fundamental consequence of the higher volatility of demand for their products.

The third panel shows dividend payout ratios by sector, which are calculated as dividend payments divided by the value of equity. The ability of a firm to pay dividends is commonly cited as an indicator of financial constraints in the literature, including Whited and Wu (2006), because firms that face barriers to obtaining outside financing will place a higher value on holding internal funds relative to paying out dividends. The right panel of Figure 3 shows that the dividend payout ratio is consistently lower for durable producers, particularly since the mid-1980s.

[6] Appendix D explores this issue more formally. Using a model based on Tirole (2010), I show that an increase in volatility of demand for a firms product endogenously reduces its borrowing capacity.

These results contribute to a body of literature that links the durability of a firm's output to the degree of financial constraint that it faces. Rajan and Zingales (1998), for example, find that six of the eight manufacturing industries with the highest reliance on external finance are durable producers. Almeida and Campello (2007) argue that the assets of durable producers are less liquid than their nondurable counterparts, which reduces their value as collateral. Banerjee et al. (2008) show evidence that durable producers in bilateral relationships maintain lower levels of leverage than nondurable producers as a way of maintaining bargaining power to prevent holdup problems. These papers all support my finding that durable goods manufacturers tend to be more financially constrained than nondurable producers.

3.2 User cost

This section illustrates why contractionary monetary policy shocks can make investment more appealing for firms with financial flexibility. Firms' investment decisions will depend on a wide range of factors including interest rates, depreciation, financial constraints, and both current and expected future prices. In models in which firms own their own capital, these factors can be summarized into an implicit rental rate known as the user cost of capital. Deriving an empirical estimate of the user cost of capital is the driving question behind a large literature which dates back to Hall and Jorgenson (1967) and includes more recent examples such as Chirinko et al. (1999). This section shows that while contractionary monetary shocks increase firm financing costs through higher interest rates, they also reduce the relative price of investment, and that the net effect of these shocks is a decline in the user cost of capital.

To analyze the behavior of the user cost in the data, I follow Chirinko et al. (1999) who construct an empirical measure based on a simple neoclassical model. In this specification, the user cost (UC_t) is written as follows:

$$UC_t = \frac{P_t^I}{P_t^Y}\left[r_t + \delta_t - E_t \Delta P_{t+1}^I\right] \tag{2}$$

Here P_t^I and P_t^Y are the prices of investment and output, which I measure using the nonresidential fixed investment deflator and the producer price index, respectively. δ_t is the depreciation rate for the manufacturing sector calculated from BEA fixed asset tables. r_t represents the cost of financing; to calculate this measure, I follow Chirinko et al. (1999) and use weighted average of the costs of debt and equity.[7] Because I cannot observe inflation expectations, to proxy for ΔP_{t+1}^I, I use the average quarterly nonresidential fixed investment price inflation from 1970-2008, though my results are robust to alternative choices including weighted averages of past inflation or actual forward inflation.

I analyze the response of this empirical user cost measure and its components to a monetary shock in Figure 4. The top left panel shows the response of the Federal Funds Rate. As expected, it increases sharply following the shock before returning back to its original level over the course of the next several years. The top right panel shows the response of firm financing costs. As with interest rates, this measure increases following a monetary contraction, though the effects occur more gradually and are much noisier. These differences reflect both the fact that it takes time for higher policy rates to pass through to the interest rates actually paid by firms, and the fact monetary policy shocks do not necessarily have the same effects on the costs of debt and equity financing.[8]

[7]The cost of equity is calculated as the quarterly dividend yield of the S&P500 plus an expected long-run growth rate of 2.4%, with a weight of 0.67. The cost of debt is calculated as the average effective interest rate for manufacturing firms from Compustat after adjusting for its tax deductibility (using the top statutory corporate tax rate for each year) and subtracting the average inflation rate from 1970-2008 (approximately 1%), with a weight of 0.33. These interest rates are derived by first calculating the rate of interest expenses to total debt using the WRDS financial ratio suite, winsorizing the top and bottom 1% of observations, and calculating a mean for manufacturing firms in each quarter weighted by total debt. Because these observations are only available starting in 1975, change in yields on AAA bonds between 1970 and 1975 are retroactively applied to the 1975 Compustat series to get a measure running back to 1970.

[8]These empirical user cost estimates do not include direct measures of financial constraints, as these cannot be directly observed in the data, although they may enter indirectly via interest rate risk premia. As I show in Section 4, these differences can lead to drastically different user cost responses for constrained and unconstrained firms.

The bottom two panels show the responses of the relative price of investment goods as well as the user cost of capital. The similarity between these responses suggests that fluctuations in the relative price of investment play an outsized role in driving the behavior of the user cost and thus investment dynamics. This estimate shows a reduction in aggregate manufacturing user costs of up to 0.8% following the shock. In Section 2.2, I estimated an increase in the capital stock of almost 1.7%, implying a back-of-the-envelope user cost elasticity of roughly -2. These numbers fall on the high end of past estimates, which usually range between -0.5 and -1.0 according to Hassett and Hubbard (2002), but they are closer to the larger estimates found in Zwick and Mahon (2017). They are also in line with the manufacturing-specific estimates of Caballero et al. (1995), who estimate industry-specific elasticities between 0 and -2 with an average around -1.

3.3 Discussion

The previous two sections illustrate the mechanism by which investment in the manufacturing sector increases in response to a monetary contraction. Section 3.1 showed that nondurable producers are less financially constrained than durable producers, while Section 3.2 showed that monetary shocks lower the user cost of capital. Unconstrained firms in the nondurable sector are able to take advantage of these price declines, while durable producers are forced to cut back. In this section, I discuss these results in the context of the broader economy.

This response of manufacturing investment to a monetary shock stands in contrast to most other sectors. Establishing this fact requires moving beyond the QFR, which has historically focused on manufacturing. To analyze the investment responses of other sectors, I use BEA fixed asset data. While there are methodological differences between the QFR and BEA capital stock measures, Appendix A shows that both show series generate extremely similar annual growth rates for manufacturers. The BEA data are available for all sectors, but only at an annual frequency, so I sum the quarterly monetary policy shocks to generate an annual series that matches the frequency of the BEA data. I then regress the log of this series on the shock, a linear time trend, and four autoregressive lags. This approach loses much of the identifying variation based on higher-frequency changes in monetary policy, but allows for comparison across sectors.

The responses of several different types of investment are shown in the top row of Figure 5. As in the QFR data, investment in the manufacturing sector increases in response to a contractionary monetary shock.[9] The second is that investment in most other industries (including the aggregate, which is shown as the solid black line) decline. The middle and right panels of the top row show the responses of equipment and structures, which collectively comprise the majority of the manufacturing sector's fixed assets. While the dispersion of the equipment investment responses is a bit higher than for total fixed assets, the pattern is quite similar. As in the total fixed asset case, manufacturing appears to be an outlier. The right panel of the top row shows that investment in manufacturing structures displays an even larger increase.

Why does the manufacturing sector display such starkly different investment responses compared to other sectors in the economy? Financial constraints again provide a compelling explanation. Based on the mechanism proposed in this paper, less financially constrained industries should show smaller reductions (or increases) in investment relative to more financially constrained industries in response to contractionary monetary shocks. While there are few sources of balance sheet information that include small and non-public firms at the industry level outside of the QFR, data from the Census Bureau's Business Dynamics Statistics (BDS) include sector-specific information on firm size and age, both of which have been cited by Hadlock and Pierce (2010) and others as being useful indicators of constraint.

The left panel of the bottom row of Figure 5 shows the share of firms aged 16 years or older across industries. This share is around 30% at the aggregate level and has been increasing since the mid-1990s.[10] It is much higher for manufacturing firms and has increased

[9] This increase is statistically significant for the first two years of the response horizon. Standard errors for the manufacturing sector are are shown in Appendix B.

[10] Regardless of when a firm was first established, the definition of firm age used in the BDS is relative to the beginning of the sample in 1977, so 1993 is the first year that firms could be recorded as having an age

to more than 50% in recent years. The right panel of the bottom row shows the share of firms in an industry with at least 10 employees. In aggregate, this share has been stable at around 20% for the past several decades. For manufacturing firms, however, this share is more than 40%, and even briefly rose above 50% in the early 1980s. The fact that manufacturing firms are more likely to be larger and older than firms in other industries is consistent with the sector being less financially constrained and can help explain why the investment response of manufacturing firms looks different from that of other sectors.[11]

Further evidence that manufacturing firms are less financially constrained relative to firms in other industries can be found in Greenwald et al. (2021), who analyze the degree to which firms drew down credit lines in response to COVID-19 during the first quarter of 2020. They find that the vast majority of new credit during the first half of 2020 flowed to large and publicly traded firms, which are the types of firms least likely to be constrained. When they analyze their results by industry, the show that the manufacturing sector accounted for the largest share of the aggregate change in utilized credit, suggesting that these firms were able to take advantage of their borrowing capacity during downturns. This ability to borrow more than firms in other sectors following a negative shock allows manufacturing firms to take advantage of lower investment prices in response to monetary contractions and can help explain why investment in the manufacturing sector displays a fundamentally different response than other sectors.

In the Appendix, I consider two extensions which provide further support for the channel described in this section. First, I use data from Dodge Analytics to analyze how building permits for manufacturing structures respond to monetary policy shocks in Appendix B. Structures account for more than one-third of the total manufacturing capital stock, and they are particularly sensitive to price changes given their long useful lifespans. In response

of at least 16 years.

[11] Buera et al. (2011) also point out that manufacturing establishments generally operate at a larger scale due to fixed costs that require financing. Thus while the manufacturing sector is more constrained *ex ante*, firms in this sector should on average be less financially constrained than their non-manufacturing counterparts *conditional on operating*.

to a monetary contraction, I show the total value of new manufacturing building permits increases despite declines in both the number of new building permits and construction costs such as building materials and construction wages. The fact that monetary contractions lead to fewer (but more valuable) projects is consistent with the idea that the largest and least financially constrained firms are able to take advantage of declining prices caused by monetary contractions to secure discounts on long-lived investment goods.

Second, in Appendix C, I replicate my analysis using Compustat data. I find that the aggregate capital stock for publicly traded nondurable producers in Compustat increases, while it declines for durable producers, mirroring the findings from the QFR data. I also exploit firm-level variation to show that less financially constrained firms increase their investment relative to financially constrained firms regardless of industry, which provides further evidence that financial frictions are the mechanism driving my results.

4 Model

This section develops a model that can match the empirical findings in Section 2 through the channel described in Section 3. The model's key contribution is the addition of heterogeneous financial frictions, which improves its ability to generate empirically consistent investment dynamics for the manufacturing sector. In light of the results outlined from the QFR, I model durable goods producers as being financially constrained while nondurable producers are unconstrained. In response to a contractionary monetary shock, the relative prices of durable goods, which Bils and Klenow (2004) and Klenow and Malin (2010) show are more flexible than those of nondurable goods, decline. Durable producers and borrower households are constrained and unable to take advantage of these lower prices, while nondurable producers and saver households increase their durable purchases. Counterfactual exercises suggest that easing firm financial frictions can cause the economy to become less sensitive to monetary shocks and lead to a reduction in the volatility of output and inflation. A detailed treatment of the model is provided in Appendix D.

4.1 Households

The household side of the model builds off Chen and Liao (2014). Measure ω of households are savers with discount factor β_S, while measure $(1-\omega)$ are borrowers with discount factor β_B. Savers are more patient ($\beta_S > \beta_B$), which allows for borrowing in the steady state, and are endowed with ownership of the firms. Households of type $i \in \{S, B\}$ maximize utility over nondurable consumption $C^N_{i,t}$ with habit formation in the manner of Fuhrer (2000), stocks $D_{i,t}$ and flows $C^D_{i,t}$ of durable consumption, labor $H_{i,t}$, and nominal bonds $B_{i,t}$:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_i^t \left[\eta \log(C^N_{i,t} - hC^N_{i,t-1}) + (1-\eta)\log(D_{i,t}) - \nu \frac{H_{i,t}^{1+\chi}}{1+\chi} \right]. \tag{3}$$

Durable goods accumulate according to a law of motion with depreciation rate δ_D:

$$D_{i,t} = C^D_{i,t} + (1-\delta_D)D_{i,t-1}. \tag{4}$$

Labor is perfectly substitutable between sectors, meaning that households only derive disutility from total labor $H_{i,t}$ and that equilibrium wages will be equal across sectors. The budget constraints are identical for savers and borrowers except for the inclusion of profits in the budget of savers. Relative prices p^j_t are defined as the ratio of the nominal price in sector j to the aggregate price level, with Π_t representing the aggregate inflation rate.

$$p^N_t C^N_{B,t} + p^D_t C^D_{B,t} + B_{B,t} = \frac{(1+i_{t-1})B_{B,t-1}}{\Pi_t} + w_t H^D_{B,t} + w_t H^N_{B,t}, \tag{5}$$

$$p^N_t C^N_{S,t} + p^D_t C^D_{S,t} + B_{S,t} = \frac{(1+i_{t-1})B_{S,t-1}}{\Pi_t} + w_t H^D_{S,t} + w_t H^N_{S,t} + \frac{1}{\omega}\left(Profits_t\right). \tag{6}$$

The Lagrange multiplier on the budget constraint for each household is $\lambda_{i,t}$. Households supply labor through a common labor market so that the same wage w_t applies to both savers and borrowers in both sectors. Real wages are subject to rigidity as in Blanchard and Galí (2007) and will be weighted averages of past real wages and consumers' current marginal disutility of labor times a markup μ^w, which helps prevent the real wage from dropping below the marginal disutility of labor:[12]

$$w_t = \left(\frac{\nu H_{i,t}^{\chi}}{\lambda_{i,t}} (1 + \mu^w) \right)^{1-\rho_w} \left(\frac{w_{t-1}}{\Pi_t} \right)^{\rho_w}. \tag{7}$$

All households are constrained in that they can only borrow up to some exogenous fraction m of the value of their stock of durable goods. This constraint will bind in the steady state for borrowers but not savers due to the difference in discount factors.

$$(1 + i_t)B_{B,t} = p_t^D D_{B,t} m \tag{8}$$

Let ψ_t be the Lagrange multiplier on the borrowing constraint. If the constraint does not bind, $\psi_t = 0$ and the intertemporal efficiency conditions look the same for both borrowers and savers. If $\psi_t > 0$, then the decisions of borrowers are distorted in two ways. First, the marginal value of one dollar today will be greater than the discounted expected marginal value of a dollar tomorrow. Second, borrowers will receive an additional benefit to buying durable goods because they will ease the borrowing constraint.

4.2 Firms

Each firm produces according to a standard Cobb-Douglas production technology and has a law of motion for capital subject to "second-order" adjustment costs in the manner of

[12]This mechanism helps lead to smoother and more persistent model dynamics across all variables in response to shocks, but none of the main results in the paper depend on it (see Figure 10).

Christiano et al. (2005):

$$Y_t^j = A_t \left(K_t^j\right)^{\alpha_j} \left(H_t^j\right)^{1-\alpha_j}, \quad K_{t+1}^j = (1-\delta_K)K_t^j + I_t^j \left[1 - \frac{\theta_j}{2}\left(\frac{I_t^j}{I_{t-1}^j} - 1\right)^2\right]. \tag{9}$$

Output in each sector Y_t^j will be a function of aggregate productivity A_t, capital stock K_t^j, and labor H_t^j. Capital is owned by the firms and depreciates at rate δ_K. The good produced by the durable sector can be used as either a consumer durable good or as productive capital; all durable goods have the same price and can be traded between firms and households.[13] Adjustment costs for investment I_t^j, which are governed by θ_j, help the model generate more realistic persistence in the dynamics of the capital stock but are not necessary for the paper's main results.

Durable goods producers face financial frictions in the spirit Holmstrom and Tirole (1997) and Kiyotaki and Moore (1997). Their purchases of labor and investment are constrained to be an exogenous share ξ of the value of their stock of durable goods:[14]

$$w_t H_t^D + p_t^D I_t^D = \xi p_t^D K_t^D \tag{10}$$

For simplicity, I model durable producers as being financially constrained and nondurable producers as being unconstrained. This modeling choice is consistent with the empirical results shown in Section 3.1 and the literature regarding financial constraints of durable producers such as Gomes et al. (2009). I also show in Appendix D that a simple model in which durable goods producers face more volatile demand for their product will endogenously lead to more restrictive financial constraints for durable producers relative to nondurable producers with less volatile demand.

[13] In Appendix D, I relax this assumption and show that allowing for separately priced consumer durables and capital goods does not meaningfully change the model's behavior.

[14] Producers in the model borrow intratemporally at zero net interest. This is a conservative assumption, as increases in the cost of capital will exacerbate the constraints faced by durable producers. In Appendix D, I show that forcing durable producers to borrow at the risk-free interest rate does not change the results.

Let μ_t be the Lagrange multiplier on the durable firm financial constraint. If the constraint binds, $\mu_t > 0$ and durable producers face an effective wedge on their input prices relative to nondurable producers. In addition to increasing production, expanding their capital stock also eases the working capital constraint faced by durable producers in both the current and future periods.

Firms maximize the expected sum of future dividend payments subject to their production function, the financial and investment frictions discussed previously, the household demand curve, and Rotemberg-style price adjustment costs. Because savers own the firms, their stochastic discount factors are used to value future dividend flows. Define mc^j and mk^j to be the marginal cost and marginal product of capital, respectively, for the firm in sector j. The firm maximization problem can be written:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta_S^t \frac{\lambda_{S,t}}{\lambda_{S,0}} \Bigg\{ p_t^j(i) \left(\frac{p_t^j(i)}{P_t^j} \right)^{-\epsilon_j} Y_t^j - w_t N_t^j - p_t^D I_t^j - \frac{\phi_j}{2} \left(\Pi_t^j(i) - 1 \right)^2 Y_t^j(i)$$
$$+ mk_t^j \left[I_t^j \left(1 - \frac{\theta_j}{2} \left(\frac{I_t^j}{I_{t-1}^j} - 1 \right)^2 \right) + (1-\delta_j) K_t^j - K_{t+1}^j \right] + \mu_t^j \left[\xi p_t^D K_t^j - w_t N_t^j - p_t^D I_t^j \right]$$
$$+ mc_t^j \left[A_t (K_t^j)^{\alpha_j} (N_t^j)^{1-\alpha_j} - Y_t^j(i) \right] \Bigg\}. \tag{11}$$

4.3 Equilibrium and Solution

The market clearing conditions for labor in each sector (H_t^N, H_t^D) and household expenditure (C_t^N, C_t^D) require that the aggregates be equal to the sum across different types of households weighted by their measure. Market clearing for household borrowing implies that the total quantity of bonds demanded by borrowing households is supplied by lending households.

$$\omega H_{S,t}^D + (1-\omega) H_{B,t}^D = H_t^D, \quad \omega H_{S,t}^N + (1-\omega) H_{B,t}^N = H_t^N \tag{12}$$

$$\omega C_{S,t}^{D} + (1-\omega) C_{B,t}^{D} = C_t^D, \quad \omega C_{S,t}^{N} + (1-\omega) C_{B,t}^{N} = C_t^N, \quad \omega B_{S,t} + (1-\omega) B_{B,t} = 0 \tag{13}$$

Market clearing in the durable goods market requires that the total quantity of durable output Y_t^D be equal to total household durable purchases C_t^D plus total investment $(I_t^D + I_t^N)$. Total output in the nondurable sector Y_t^N must be equal to household consumption C_t^N plus any output loss due to price adjustment.

$$C_t^D + I_t^D + I_t^N = Y_t^D, \quad C_t^N + \frac{\phi_N}{2} \left(\Pi^N - 1\right)^2 Y_t^N = Y_t^N \tag{14}$$

To close the model, I specify a standard Taylor Rule for the nominal interest rate:

$$\beta_S(i + i_t) = (\beta_S(i_{t-1}))^{\rho} \left(\Pi_t^{\phi_\Pi}\right)^{1-\rho} \exp(e_t^M). \tag{15}$$

Following Monacelli (2009) and Chen and Liao (2014), I ensure that the calibration results in the constraint binding in the steady state and then linearize around that steady state, assuming that it will continue to bind for small perturbations. Appendix D includes the full set of equilibrium conditions.

The model's parameter values are shown in Table 1. Most of the parameters related to household borrowing, including the share of borrowers ($\omega = 0.5$), the discount rates ($\beta_S = 0.99, \beta_B = 0.98$), and the nondurable share of consumption ($\eta = 0.8$) are taken from Chen and Liao (2014).[15] I also use their values for price stickiness for each sector ($\phi_D = 0, \phi_N = 58.25$).[16]

The modeling assumption that the prices of durable goods are more flexible is backed by a large body of work in the pricing literature. The benchmark paper on the price flexibility of

[15]The household borrowing limit is set to $m = 0.7$, which is slightly smaller than their value of 0.75. This helps the model generate more persistent consumption dynamics but has a negligible impact on the behavior of investment.

[16]In linearized models this choice of Rotemberg adjustment parameter for nondurable producers is equivalent to a Calvo parameter of 0.67, implying an average expected price duration of roughly three quarters.

durable prices comes primarily from Bils and Klenow (2004), who look at BLS microdata for 350 categories of goods from 1995-1997 and find that durable goods show more frequent price changes than nondurable goods. More recent work by Klenow and Malin (2010) uses the same CPI microdata over a longer range (1988-2009) to show that the mean price duration for durable goods (3.0 months) is much shorter than for nondurables (5.8 months). Both of these papers abstract from housing and structures in their analysis; including them would likely make durable prices look even more flexible.

This evidence is used as the basis for virtually all other papers in the literature analyzing the effects of monetary shocks on New Keynesian models with durable goods. Some examples of papers assuming perfectly flexible durable prices include Barsky et al. (2007), Monacelli (2009), Carlstrom and Fuerst (2010), Kim and Katayama (2013), and Chen and Liao (2014). In addition to a baseline calibration that assumes durable prices are more flexible, Kim and Katayama (2013) also use Bayesian techniques to estimate the degrees of price stickiness across sectors using their model and finds that the data support parameterizations in which durable producers are able to adjust their prices far more frequently.

The persistence of wage stickiness is set to $\rho_w = 0.3$, while the wage markup ($\mu^w = 0.1$) is chosen to help ensure that the addition of wage stickiness does not cause real wages to fall below the marginal product of labor (see Blanchard and Galí (2007)). Other parameters including the capital shares of each industry ($\alpha_D = \alpha_N = 0.33$), the Taylor Rule parameters governing the central bank's response to inflation and persistence in the interest rate ($\phi_\Pi = 1.5, \rho = 0.9$), the parameters governing labor supply ($\nu = 4, \chi = 1$), the elasticity of substitution across intermediate goods ($\epsilon_D = \epsilon_N = 11$), depreciation rates ($\delta_D = 0.02, \delta_K = 0.03$), and capital adjustment costs ($\theta_D = \theta_N = 2$) are standard in the literature. The major addition relative to past work is the parameter governing the exogenous working capital constraint ξ, which is set to be 0.1. In addition to resulting in a positive value for the Lagrange multiplier μ in the steady state given the other parameter values, it is also close to the sample averages for the ratios of cash (14.4%) and short-term bank debt

(8.2%) to the capital stock observed in the QFR.[17]

4.4 Results and Mechanism

The model impulse responses for the capital stocks of producers can be seen in the left panel of Figure 6. When a contractionary monetary policy shock hits, the price of durable goods falls. Nondurable producers, which are unconstrained, take advantage by increasing their capital purchases. Durable producers, whose constraint is exacerbated by the decline in the value of their capital stock used as collateral, are forced to reduce their investment. The increase in capital expenditure by the nondurable sector is larger than the decline from the durable sector, so the aggregate capital stock rises. For comparison, the right panel shows the estimated capital stock responses from the QFR that were previously shown in Figure 2. The model is able to match the empirical dynamics of the manufacturing capital stock quite well.

The long life of durable goods combined with the decline in their relative price leads investment in my model to increase following a monetary contraction. When a monetary shock hits, both types of producers want to cut prices. Because nondurable prices are sticky, durable producers are able to cut their prices by a larger amount. Even small drops in the relative price are able to spur large increases in durable purchases in this model because durables are long-lived; buying the durable good at a low price today is equivalent to getting a discount on a long series of future service flows. As a result, this drop in the relative price of durable goods is large enough to cause nondurable producers to expand their investment. Financial constraints prevent durable producers from increasing investment because the fall in the relative price of durables reduces the value of their capital stock, and thus the amount of money that they can borrow to fund production.

The key driver of the model's ability to generate an increase in investment in response to a contractionary monetary shock is that the user cost of capital, driven by a decline in

[17] My results are robust to parameter values throughout this range. For large enough changes, however, adjustments to other parameters are necessary to ensure the firm borrowing constraint will bind.

the prices of investment goods, falls in response to a contractionary shock. For durable producers, the financial constraints are powerful enough to push up the user cost of capital and lead to a reduction in their capital stock. Nondurable producers, undeterred by financial constraints, experience a decline in user costs that leads them to increase their capital stock.

This mechanism can be seen directly by looking at the model responses of the prices of durable goods and the user cost in the left panel of Figure 7. The orange line shows that the relative price of durable goods falls sharply in response to a contractionary monetary shock before ultimately rising above its pre-shock level. The red and blue lines represent the respective user costs—that is, the implicit rental rate set equal to the marginal product of capital—for the durable and nondurable producers. These expressions are complicated and include both current and expected prices, demand, adjustment costs, and, for the durable firms, degrees of financial constraint. For durable producers, the financial constraints are powerful enough to push up the user cost of capital and lead to a reduction in their capital stock. This can be seen in the right panel, which shows the impulse response to the Lagrange multiplier on the durable producer's financing constraint. The sharp increase following a monetary contraction shows that these constraints become more severe, and can account for the increase in the durable producer user cost despite the decline in prices.

The model's ability to match my empirical investment results does not come at the expense of its ability to generate reasonable dynamics for other types of shocks and other variables. The model impulse responses for a wide range of variables in response to a contractionary monetary policy shock are shown in Figure 8. The top three rows show the same impulse responses shown in Figure 6. The left two panels of the middle rows show the behavior of flow investment, which display peak effects about four quarters after the shock hits. The remaining panels show that consumption, the relative price of durables, total inflation, and total output all decline in response to a monetary contraction. Together, these figures illustrate the ability of the model to push non-investment variables in the right direction following a monetary policy shock.

Next, I expand the model to include shocks to the following parameters in addition to monetary policy shocks: aggregate productivity (A_t), labor disutility (ν), risk aversion (σ), financial frictions (ξ), depreciation (δ), and government spending.[18] These responses are shown in Figure 9. Despite being designed to match responses to monetary shocks, the model is able to generate reasonable responses to these other shocks as well. Unlike monetary shocks, which are shown in the first row, all of the other shocks I consider push investment and output in the same direction. This means that the version of the model which includes additional shocks can easily match the empirical fact that investment in the data is unconditionally procyclical. Together, Figures 8 and 9 provide reassurance that my model's financial structure and choice of parameters do not disrupt its ability to generate a wide range of well-behaved impulse responses for non-investment variables and non-monetary shocks.

4.5 Alternative models and aggregate implications

Heterogeneous financial frictions allow the model generate responses of investment to monetary policy shocks for manufacturers that are consistent with the data. The key channel through which this mechanism operates was first pointed out in Barsky et al. (2007): periods of lower demand are a good time to buy durable goods because these goods are cheap and will provide service flows for a long time. This has been termed the "comovement puzzle" and resulted in a literature attempting to generate more empirically accurate impulse responses of durable purchases to monetary shocks. A major contribution of my model is to highlight the fact that financial frictions can limit the operation of this channel for financially constrained producers in a manner consistent with the patterns observed in the QFR data.

Figure 10 provides insight into the model's ability to match the data by comparing impulse responses under a variety of alternative assumptions. The top row compares my

[18] The baseline model does not include government spending, so to study study the effects of a government spending shock I use a modified version of the model in which the government consumes a share $g_t \in [0, 1]$ of output. This modification has a negligible effect on the dynamics of other shocks in the baseline model.

baseline results to models which have perfectly flexible prices in both sectors (the top-right panel) and which do not include any non-financial frictions such as sticky wages or habit formation (the bottom-left panel). While these changes alter the size and persistence of the investment responses relative to the baseline model, they do not change their direction. The lower-right panel, which displays the results if financial constraints for durable producers are removed entirely, shows large expansions in the capital stocks of both sectors. To the extent that more financially constrained firms are able to obtain access to funding through financial deepening over time, my model suggests that more sectors may view demand-driven declines in capital goods prices as investment opportunities.

The changing nature of firm financial frictions over time also has important implications for the behavior of the model beyond investment. Easing financial constraints lead to an economy that is, on aggregate, less responsive to monetary shocks; I find removing financial frictions for durable producers reduces the volatility of real output coming from monetary shocks by approximately 25%, and the volatility of inflation caused by monetary shocks by almost 10%. At the same time, removing financial frictions drastically *increases* the volatility of investment. This is driven primarily by durable producers, which experience a ten-fold increase in investment volatility following the removal of financial constraints, while investment volatility for nondurable producers increases by roughly 13%. This is consistent with the idea that removing the collateral constraints, which tie the prices of capital goods to real outcomes, allows producers to be more flexible in their deployment of capital goods and allows for a net reduction in aggregate volatility. This exercise reinforces the findings of Jermann and Quadrini (2006), who argue that deepening financial markets allows for greater financial flexibility and reduces the volatility of real activity. These results suggest that the easing of financial constraints can result in an economy that is both less volatile and less sensitive to monetary policy shocks.

5 Conclusion

Understanding which types of firms are financially constrained and how this affects aggregate dynamics is a crucial research question in macroeconomics and corporate finance. I use a manually digitzed data set to show that the capital stock in the manufacturing sector increases in response to a contractionary monetary policy shock. This behavior is driven by nondurable producers, which display fewer signs of financial constraint. A model in which durable producers and impatient consumers face financial constraints can match the data well. In response to a contractionary monetary policy shock, the relative price of durables falls and the unconstrained firms respond by increasing their investment expenditure. This model suggests that the firms which respond *most* to monetary shocks are actually the *least* financially constrained. Removing firm financial constraints in the model causes aggregate output and inflation to respond less to monetary shocks and reduces aggregate volatility.

These findings have two important implications for policymakers. The first is that monetary policy can have a larger impact on the investment of unconstrained producers than constrained producers even when the latter have much more volatile and interest-sensitive demand. The second is that the response of investment to monetary shocks may become more countercyclical over time as financial deepening eases financial constraints in more sectors. Removing financial constraints gives producers greater flexibility in deploying their capital, which can reduce the sensitivity of the real economy to monetary shocks.

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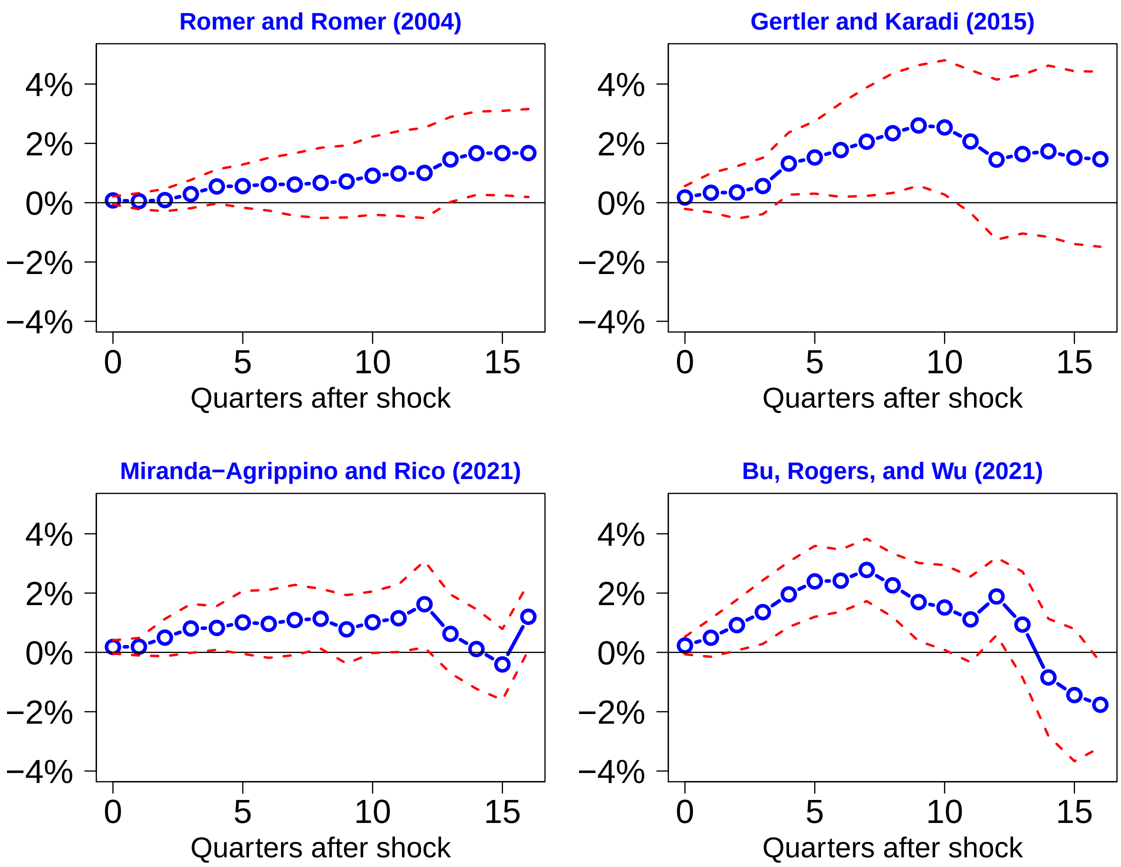

Figure 1: Responses of aggregate manufacturing NPPE to contractionary monetary shocks

Note: This figure shows the response of the aggregate real capital stock for the manufacturing sector from the QFR to a variety of monetary policy shocks. The top left panel shows the response to a 100bp contractionary shock identified using the approach of Romer and Romer (2004) including data from 1970-2008 (I use the extended version of the shocks developed by Coibion (2012)). The upper right panel shows the response to a 100bp contractionary shock identified in Gertler and Karadi (2015) including data from 1975-2008. The lower left panel shows responses to a two standard deviation contractionary shock identified in Miranda-Agrippino and Ricco (2021) including data from 1991-2008. The lower right panel shows the response to a two standard deviation contractionary shock identified in Bu et al. (2021) including data from 1995-2008. All regressions include a linear time trend and eight lags each of the dependent variable and the shock. Dashed red lines show 90% confidence intervals calculated using Newey-West standard errors.

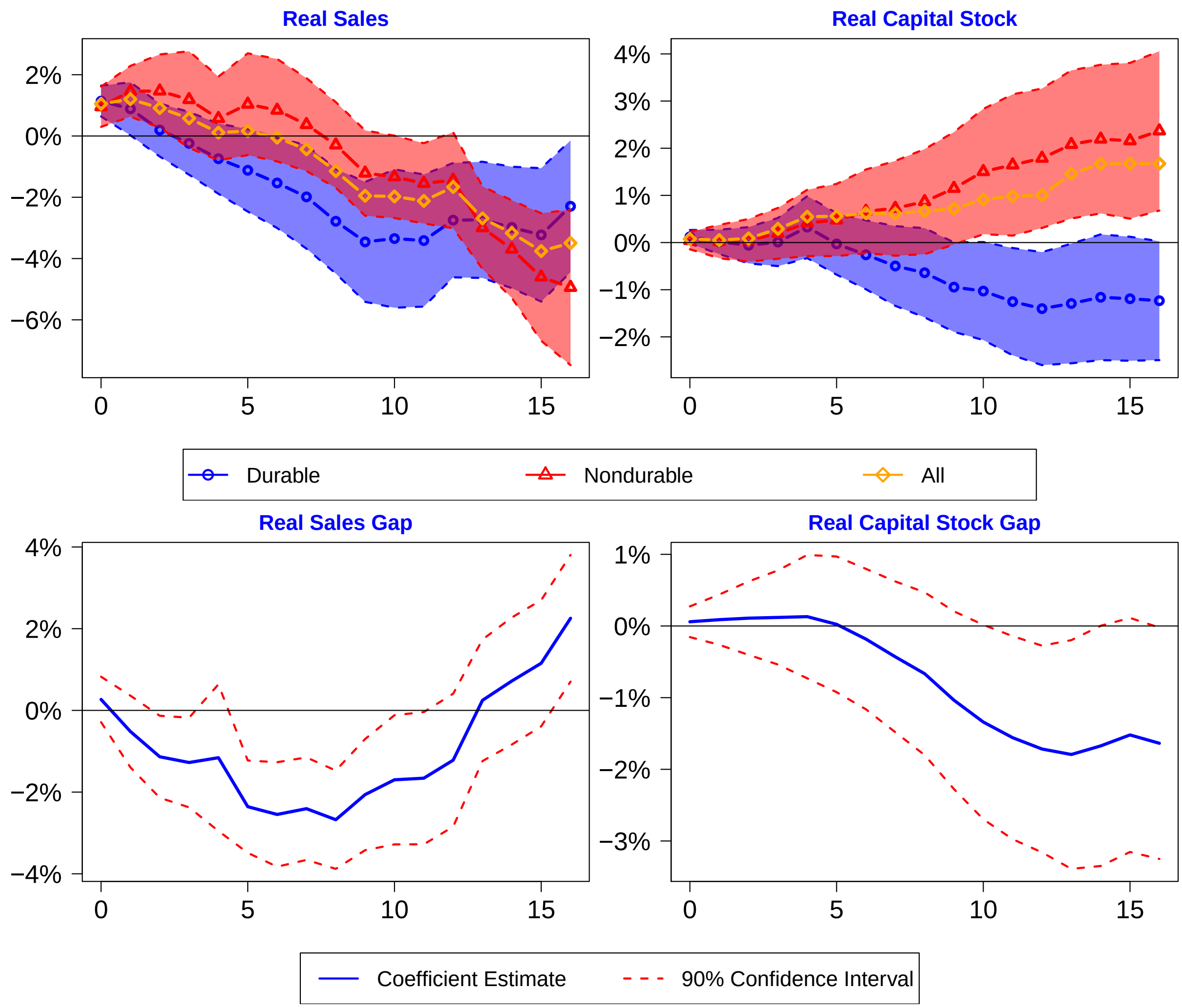

Figure 2: Responses of manufacturing subsector NPPE to contractionary monetary shock

Note: This figure shows the coefficient estimates γ_h^i from Equation 1, which correspond to the effects of a 100bp contractionary monetary shock. The horizontal axes correspond to quarters after the shock. The top row shows the responses of NPPE, which is measured by the QFR item "Stock of Property, Plant, and Equipment Net of Depreciation" and deflated using the NIPA nonresidential fixed investment price index, and sales, which is the QFR sales measure deflated by GDP price index. The bottom row shows the estimated effects on the log difference between each measure: $y_t \equiv \log(X_t^D) - \log(X_t^N)$. All regressions include a linear time trend and eight lags each of the dependent variable and the shock. 90% confidence intervals are calculated using Newey-West standard errors. Regressions include data from 1970-2008.

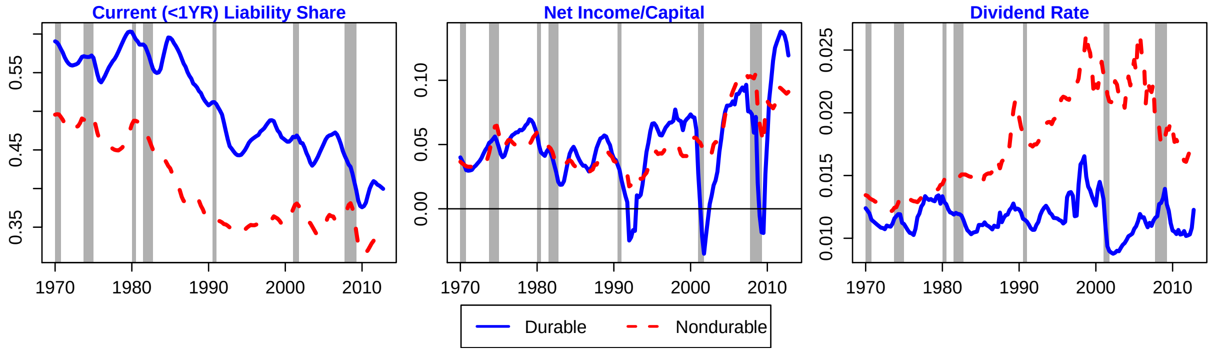

Figure 3: Financial constraint measures

Note: All figures show four-quarter moving averages calculated from the QFR. The first panel shows the ratio of each sector's aggregate liabilities with maturity of less than one year to its total liabilities. The second panel shows the ratio of net income after taxes to the stock of property, plant, and equipment net of depreciation. The rightmost panel shows the ratio of dividend payments to the book value of equity. Shaded areas indicate recessions.

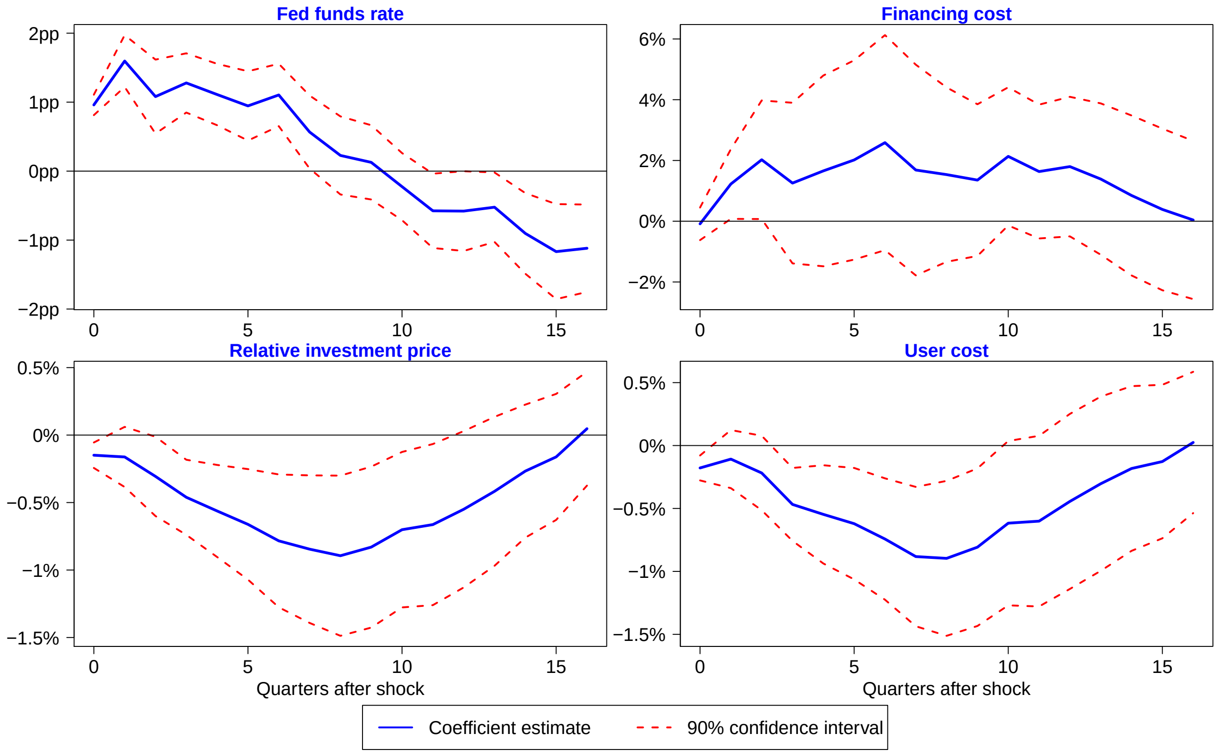

Figure 4: Response of user cost and its components to contractionary monetary shock

Note: This figure shows impulse responses to a 100bp contractionary monetary policy shock. I use the same specification as Equation 1 with the addition of eight lags each of the unemployment rate, GDP growth, and BAA bond yields to control for higher-frequency changes in prices and interest rates. As in my baseline results, all regressions use data from 1970-2008. The top left panel shows the response of the Federal Funds Rate. The top right panel shows the response of the firm financing costs. Following Chirinko et al. (1999), this measure is calculated as a weighted average of the costs of debt and equity financing. The cost of equity is calculated as the quarterly dividend yield of the S&P500 plus an expected long-run growth rate of 2.4%, with a weight of 0.67. The cost of debt is calculated as the average effective interest rate for manufacturing firms from Compustat after adjusting for its tax deductibility (using the top statutory corporate tax rate for each year) and subtracting the average inflation rate from 1970-2008 (approximately 1%), with a weight of 0.33. These interest rates are derived by first calculating the rate of interest expenses to total debt using the WRDS financial ratio suite, winsorizing the top and bottom 1% of observations, and calculating a mean in each quarter weighted by total debt. Because these observations are only available starting in 1975, change in yields on AAA bonds between 1970 and 1975 are retroactively applied to the 1975 Compustat series to get a measure running back to 1970. The bottom left panel shows the response of the ratio of the nonresidential fixed investment price index to the producer price index (PPI). The lower right panel shows the response of the user cost of capital (Equation 2). All series other than the Federal Funds Rate are smoothed using a four-quarter moving average before estimating impulse responses.

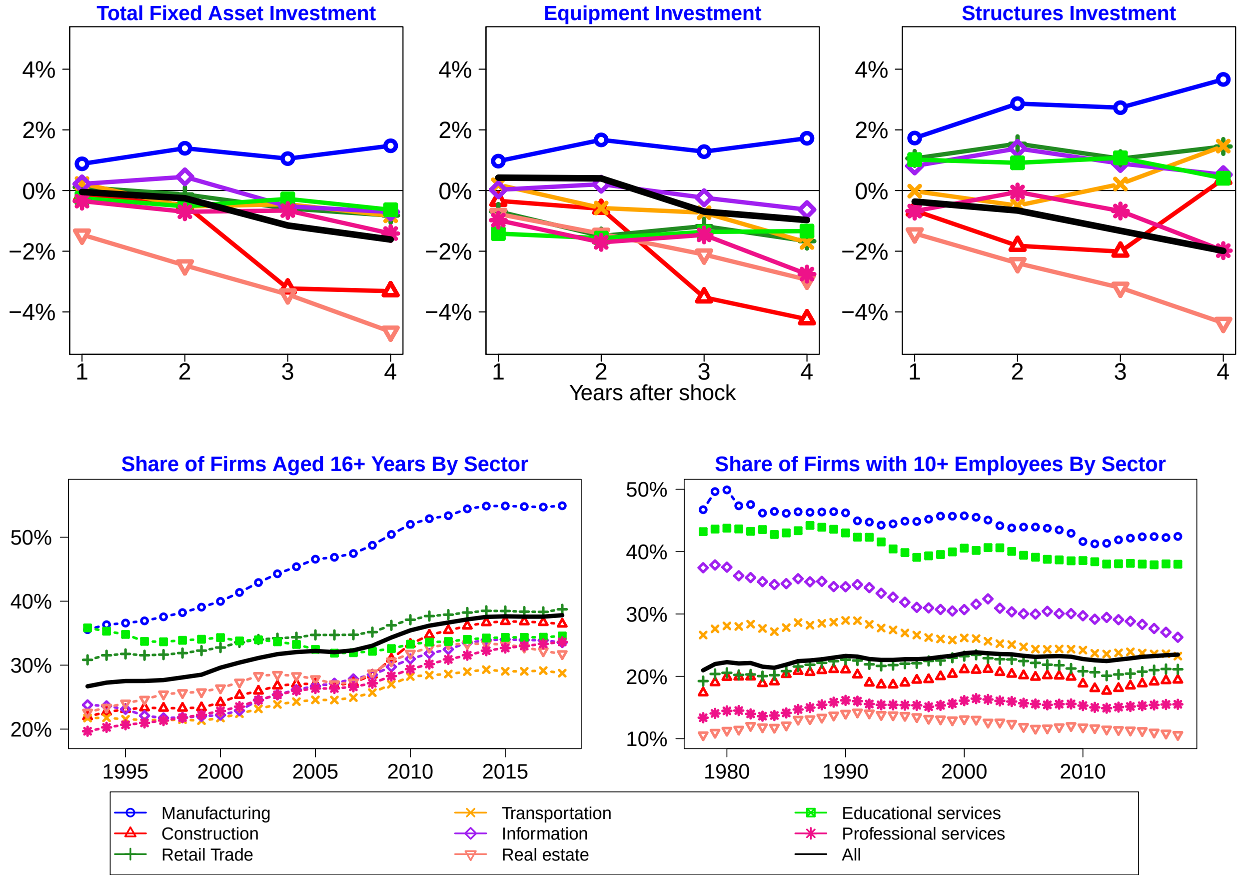

Figure 5: Investment responses and financial constraints by sector

Note: The top three panels show the impulse responses of investment in total fixed assets, equipment, and structures for a range of industries in response to a 100bp contractionary monetary shock. I add up the quarterly monetary shock series in each year to obtain an annual series to facilitate analysis of the BEA data (which is at the annual frequency). Regressions use a local projection specification that includes a linear time trend and four lags of the dependent variable as controls. The bottom two panels show firm age and size detail calculated from the Census Bureau's Business Dynamics Statistics (BDS). The left panel shows the share of firms aged 16 or more years by sector. The series starts in 1993 because firm age is calculated relative to when a firm entered the BDS sample, so it is the first year in which a firm could be counted as being at least 16 years old. The right panel shows the share of firms in each sector with at least 10 employees starting in 1978 when the data are first reported.

Parameter	**Value**	**Description**
β_S, β_B	0.99, 0.98	Discount factors
ω	0.5	Share of savers
η	0.8	Nondurable consumption share
ρ_w, μ_w	0.3, 0.1	Wage rigidity and wage markup
h	0.5	Habit formation
ν, χ	4, 1	Labor disutility and elasticity
m, ξ	0.7, 0.1	Borrowing limits
ϕ_D, ϕ_N	0, 58.25	Price adjustment costs
θ_D, θ_N	2	Investment adjustment costs
δ_D, δ_K	0.02, 0.03	Depreciation rates
ϵ_D, ϵ_N	11	Substitution elasticities
α_D, α_N	0.33	Capital shares
ϕ_π, ρ	1.5, 0.9	Taylor Rule

Table 1: Model parameter values

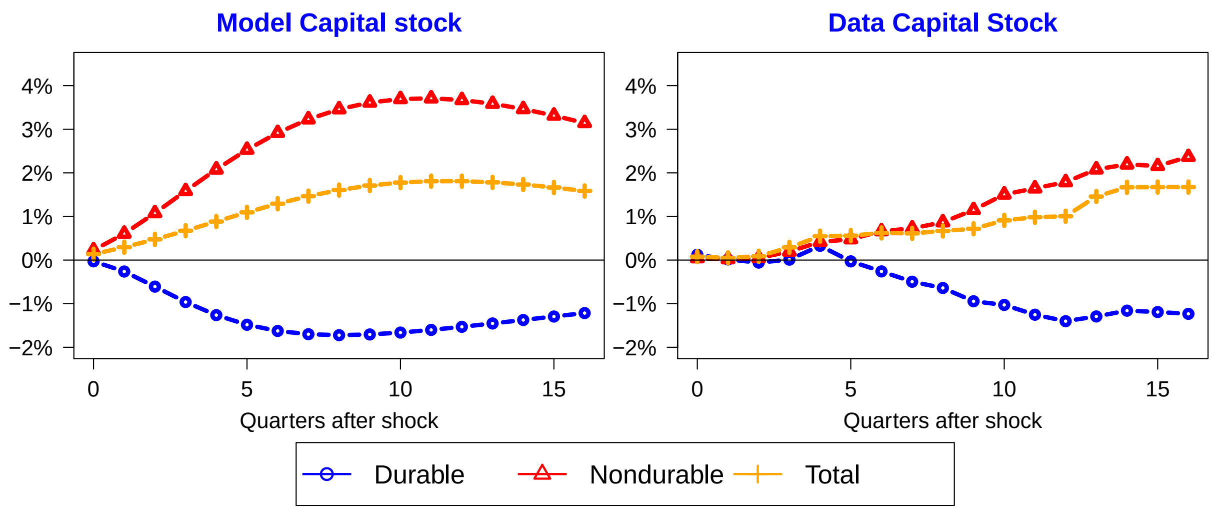

Figure 6: Model and data responses to contractionary MP shock

Note: The left panel shows the model responses to a 100bp contractionary monetary shock to the capital stocks for the total manufacturing sector as well as each subsector. The right panel shows the empirical responses to a 100bp contractionary monetary shock shown previously in Figure 2.

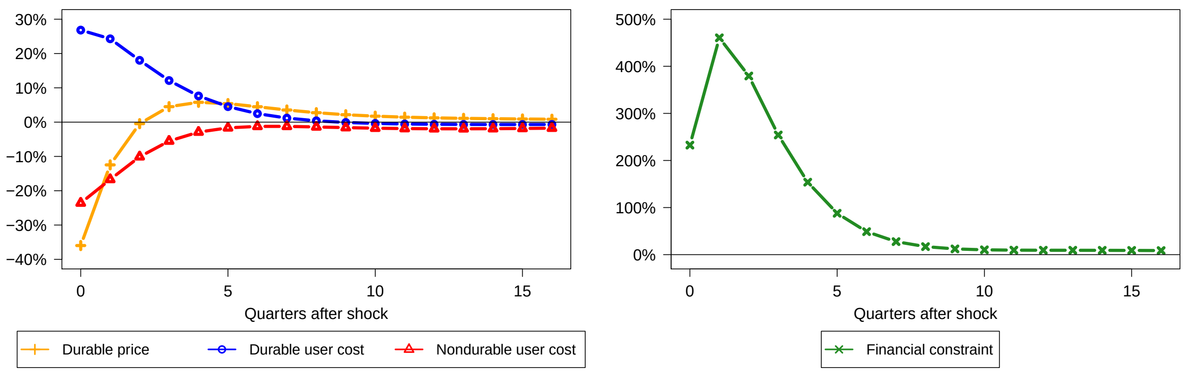

Figure 7: Model user cost responses to contractionary MP shock

Note: This figure shows the model response to a 100bp contractionary monetary shock. The left panel shows the response for the relative price of the durable good (which serves as the investment good in both sectors) as well as the user costs for each sector. The right panel shows the response of the Lagrange multiplier on the durable producer financial constraint μ_t.

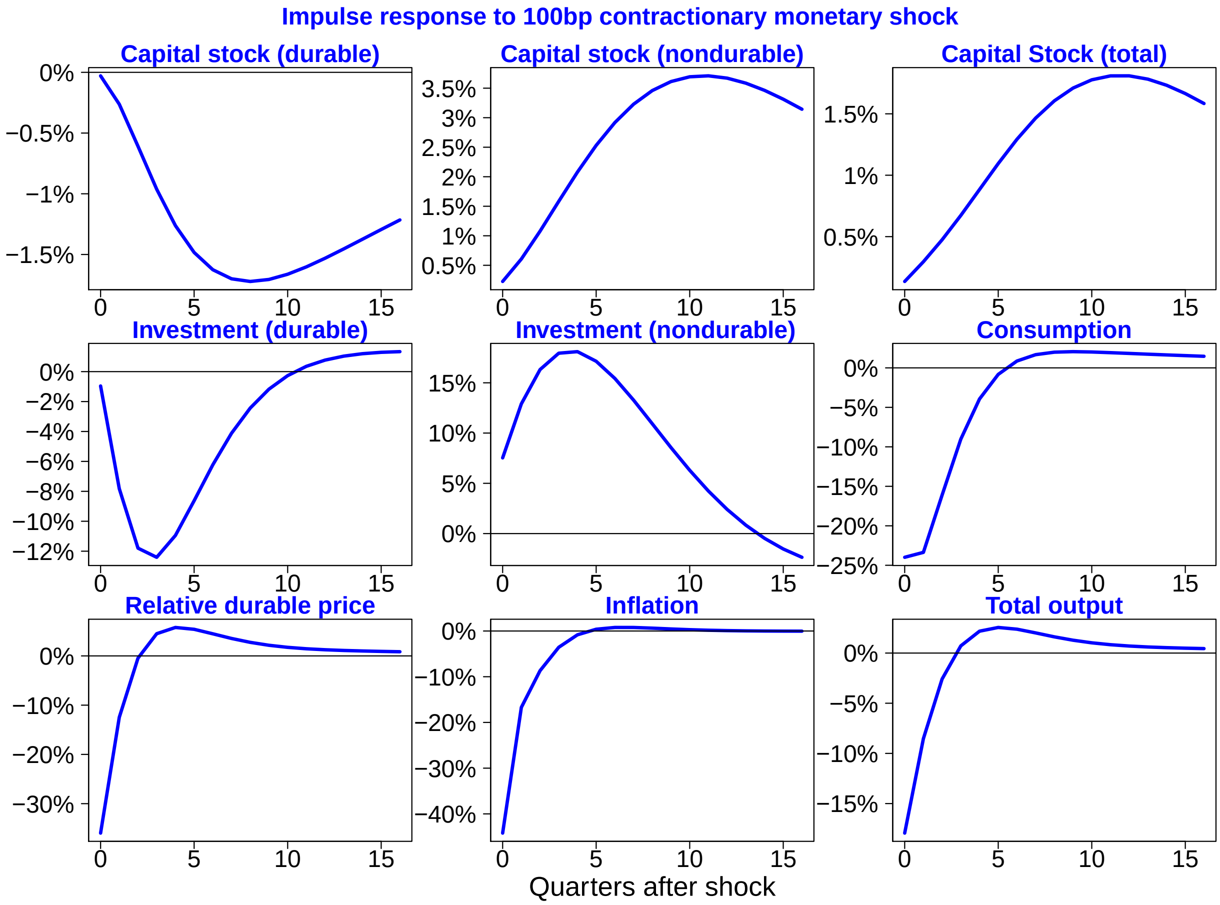

Figure 8: Model impulse responses to contractionary MP shock

Note: This figure shows impulse responses to a 100bp contractionary monetary policy shock in the baseline model.

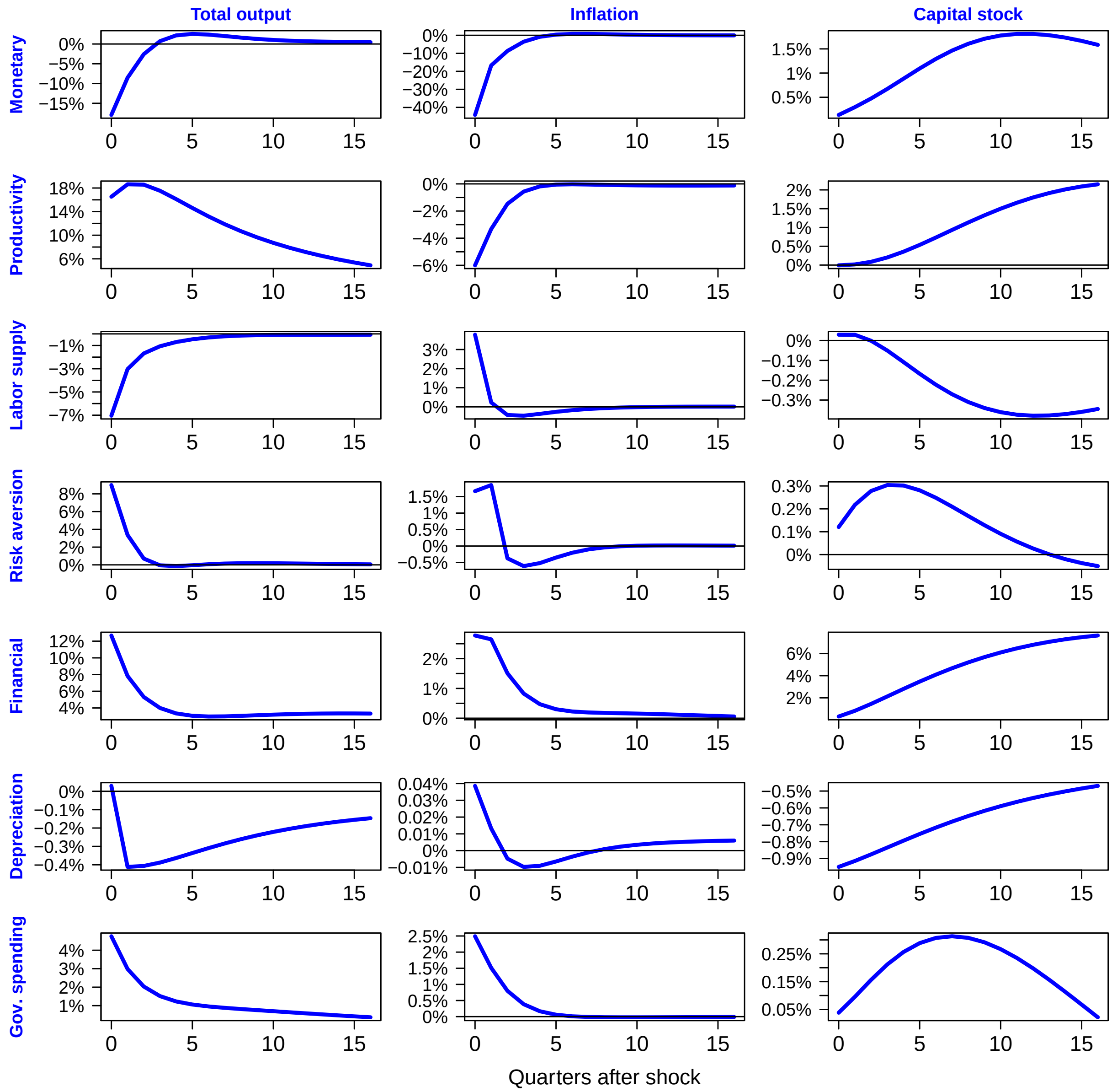

Figure 9: Model impulse responses to a range of shocks

Note: This figure shows impulse responses for a version of the baseline model extended to accommodate additional shocks. Each row corresponds to a specific shock, which is shown to the left of the first column. Each column corresponds to the variable shown above the top row.

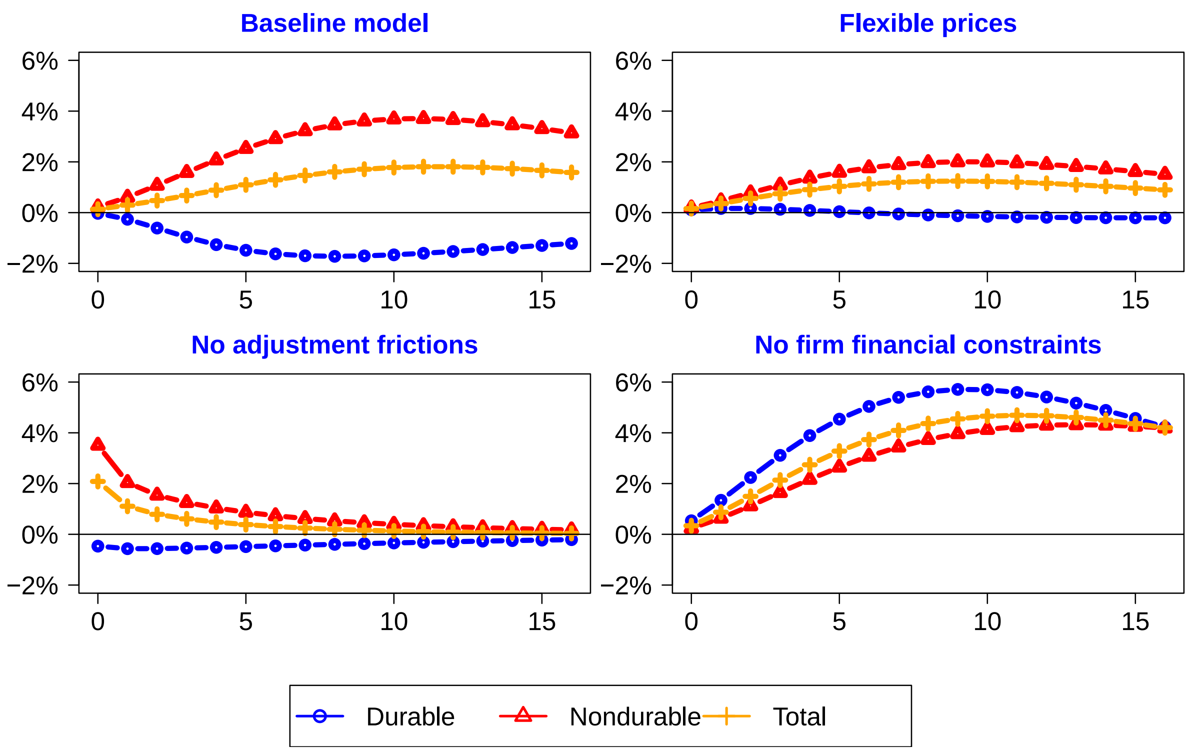

Figure 10: Capital stock responses to MP shock under alternative model assumptions

Note: All responses shown are for the capital stock to a 100bp contractionary monetary shock. The baseline model (top left) shows the same responses as in the left panel of Figure 6. The top right panel shows responses for a model with the same structure as the baseline but with no price stickiness in either sector ($\phi_D = \phi_N = 0$). The model without adjustment frictions (bottom left) is the same as the baseline model (including price frictions) but does not have adjustment costs on investment, wage stickiness, persistence in the Taylor Rule, or habit formation. The responses in the bottom right removes financial frictions for firms.

Internet Appendix

A Data Description

A.1 Quarterly Financial Report

The main source of aggregate data is the Quarterly Financial Report for Manufacturing Corporations (QFR). This survey dates back to World War II, when it was administered by the Office of Price Administration. The Census Bureau has been responsible for administering the survey since 1982. These data series are used to construct macroeconomic aggregates such as corporate profits. The QFR sample, which includes approximately 10,000 firms in a given quarter, is chosen based on asset sizes reported in corporate tax returns; any firm with more than $250,000 in domestic assets is eligible for inclusion, and any firm with more than $250 million is included in the sample with certainty. Firms who reside between these thresholds are chosen randomly with the goal of obtaining a representative sample and are included for 8 consecutive quarters with one-eighth of the sample replaced each quarter.

Historical data dating back to 1947 are available for download from the Census Bureau's website.[19] At the time of the first draft of this paper in February 2019, publicly available data from before 1987 were only be available in physical publications or microfilm. Using these physical copies, I digitized the data going back to 1966Q1. This process consisted of mostly manual entry and occasional use of optical character recognition (OCR) software when available. To ensure that the data series were digitized correctly, I have checked that aggregating the component series by either size or sector add up to the correct total in each quarter.

Each physical publication includes observations for the current quarter as well as the four preceding quarters. With few exceptions most of the data series were digitized from the publications in Q1 of each year. Using these five level observations, I calculated the

[19] `https://www.census.gov/econ/qfr/`

four implied quarterly growth rates, giving me a series of growth rates. By using growth rates calculated within each release, I avoid problems from comparing levels before and after methodological changes (including changes in accounting procedures in 1973 and industry reclassifications in 1984 and 2001). I then applied these growth rates to the levels of the most recent releases, effectively taking the original growth paths and shifting them to the most up-to-date level. I deflate the stock of net property, plant, and equipment using the nonresidential fixed investment price index. All other variables are deflated using the GDP price index.

The respondents are aggregated by sector as well as asset size. The data consist of eight nominal asset "buckets": under \$5 million, \$5-10 million, \$10-25 million, \$25-50 million, \$50-100 million, \$100-250 million, \$250-1,000 million, and \$1+ billion. One issue with using the size data is that the cutoffs are in nominal values and fixed over time; a firm with \$50 million in assets in 1967 is much larger relative to the size of the total manufacturing sector than a firm with \$50 million assets in 2007. One way to address this is to combine many of the smaller bins into one "small" classification. For my baseline specification, I follow Crouzet (2017) in classifying all of the firms with less than \$1 billion in nominal assets as being "small". An alternative approach uses percentiles of sales. This is the approach used in Gertler and Gilchrist (1994) (who use a 30% threshold) and Kudlyak and Sánchez (2017) (who use 25%). My results are robust to calcuating the size cutoffs in this way.

Industries are classified by the Census Bureau based on sources of revenue. As part of its submission, each company in the survey reports a breakdown of gross receipts by source industry. To be in the scope of the QFR manufacturing sample, a firm must have manufacturing as its largest source of gross receipts. Once a corporation is assigned to the manufacturing sector, it is categorized into a subsector based on its largest share of *manufacturing* receipts. For example, if a firm has 40% of its revenue from manufacturing and 30% each from mining and retail trade, then the firm would be classified in the manufacturing sector. If 60% of the firm's manufacturing activity was conducted in the machinery subsector and 40% in the chemicals subsector, then the activities of the entire corporation would be assigned to the machinery subsector. These classifications are reviewed periodically and changed as needed for as long as the corporation remains in the sample.

To provide further evidence that the QFR data are in line with other measures of the capital stock, I can compare them to fixed asset data from the Bureau of Economic Analysis (BEA). These data provide end-of-year estimates of the value of total fixed assets for both the durable and nondurable manufacturing sectors. Figure A.1 shows the year-over-year changes in the BEA measure compared to the Q4/Q4 changes in the QFR data and suggests that the two data series are capturing the same fundamental investment behavior. The correlations between the BEA and QFR measures are high for the total series (0.87) as well as both the durable (0.83) and nondurable (0.81) subseries, suggesting that the QFR data can be appropriately described as a higher-frequency and more detailed version of the BEA fixed asset data.

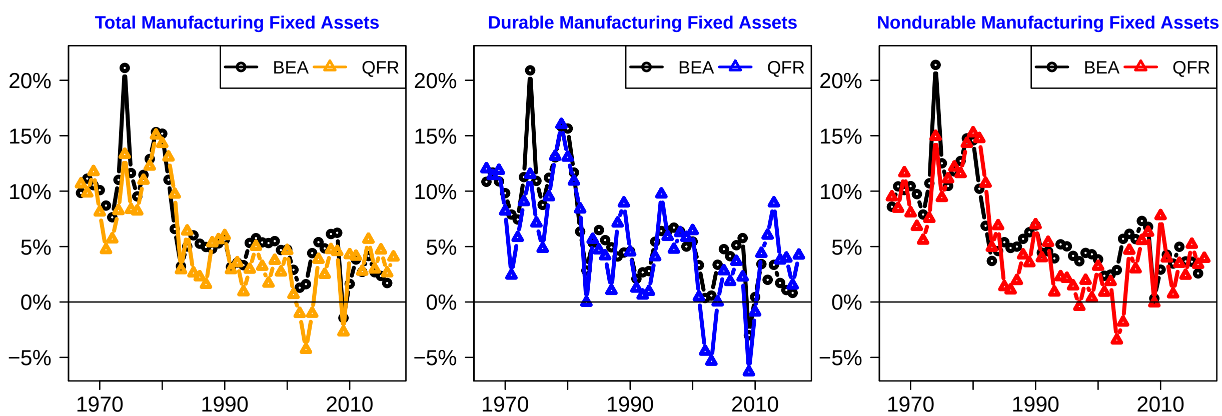

Figure A.1: Y/Y % Changes in BEA and QFR Fixed Asset Measures

Note: This figure compares the yearly percent changes in the BEA and QFR measures of the nominal fixed asset stock for the manufacturing sector. The QFR numbers are shown as the year-over-year change in the fourth quarter of each year for comparison to the BEA data (which are at an annual frequency and recorded at year-end).

A.2 Building Permit Data

This section describes the building permit data used in the paper. Building permits are required when undertaking new construction, and this information is publicly available through local municipalities. Dodge Analytics[20] collects this information, which includes the type of structure and a cost estimate used for tax purposes.

Obtaining accurate cost information is important for local permit issuing authorities because more expensive construction projects are assessed greater permit fees. Section 108.3 of the 2018 International Existing Building Code states:

"The applicant for a permit shall provide an estimated permit value at time of application. Permit valuations shall include total value of work including materials and labor for which the permit is being issued, such as electrical, gas, mechanical, plumbing equipment, and permanent systems. If, in the opinion of the code official, the valuation is underestimated on the application, the permit shall be denied unless the applicant can show detailed estimates to meet the approval of the code official. Final building permit valuation shall be set by the code official."[21]

These are used as guidelines by local municipalities and form the foundation of permit procedures in most cases. They are generally taken at face value by the issuing agencies. In some cases jurisdictions will also include their own terms and requirements. Rather than relying on contractor estimates, many municipalities establish a fixed formula determining the cost per square foot based on the type of construction.[22]

In general, contractors have incentives to underestimate how much projects will cost given that these estimates for the basis for permit fees and certain types of taxes. Some municipalities will require a contractor to submit a signed affidavit showing the final construction costs for tax purposes, and Dodge Analytics will often follow up with contractors

[20] https://www.construction.com/

[21] https://codes.iccsafe.org/content/IEBC2018/CHAPTER-1-SCOPE-AND-ADMINISTRATION?site_type=public

[22] Boulder, Colorado is an example of such a county. Their valuation table can be found here: https://bouldercolorado.gov/links/fetch/23187

to obtain final valuations as part of its data collection process, but it is likely that many of the permits included in their data are ultimately based on the initial estimates provided by contractors before work has started. In practice these institutional features can certainly lead to variation in the valuations of similar projects across municipalities, but they are likely to wash out when aggregating up to the national level and comparing these totals over time.

A.3 Compustat Data

A.3.1 Measuring investment

All of the variable definitions are standard and follow the literature closely, especially Jeenas (2019) and Ottonello and Winberry (2020). I use the nonresidential fixed investment price index to deflate the capital stock and the GDP price index to deflate all other variables. I use data starting in 1985 to avoid changes with sampling composition before that. In line with my analysis of aggregate data, I only consider monetary shocks that occur up to 2004.

- **Manufacturing**: My main analysis focuses on the manufacturing sector. I define a firm to be in the manufacturing sector if it is classified as being in manufacturing according to either the SIC (codes starting with 20-39) or NAICS (codes starting with 31-33). These can be classified into durable or nondurable producers according to the following sectors:

	SIC	**NAICS**
Durable	24-25, 32-40	33, 321, 327
Nondurable	20-23, 26-31	31, 322-326

  To match the definitions used in the QFR data as closely as possible, I classify firms as durable or nondurable according to the following procedure:

  1. Firms are classified as durable producers if they have a durable NAICS code as defined above.

2. If a firm has no NAICS code but has a durable SIC code as defined above, I define it as durable.

3. In rare instances, the NAICS and SIC codes suggest different sectors; this occurs because a small number of industries have been reclassified over time. In these cases I use the NAICS classification.

- **Investment**: This variable denotes the capital stock of each firm at the end of the quarter. As the initial entry I use the firm's first observation of *Property, Plant, and Equipment (Gross)*, which is item 118 and denoted *PPEGTQ* in the Compustat database. From this initial level, I add the quarterly change in *Property, Plant, and Equipment (Net)*, which is item 42 and denoted *PPENTQ*. I use this method because there are many more observations of the net measure than the gross measure of each firm's capital stock. If a firm is missing a single value of *PPENTQ* between two nonmissing values, I linearly impute it using the observations on either side. For instances of two or more consecutive missing values for a firm, no imputation is done. I only consider investment "runs" of least 40 consecutive quarterly observations after imputation in my main analysis.

- **Dropped observations**: To minimize the effects of outliers and reporting errors, I exclude firm-quarter observations with any of the following features:

1. A ratio of acquisitions ($AQCY$) to assets (ATQ) larger than 5%.

2. An investment rate (defined as $\frac{k_t - k_{t-1}}{k_{t-1}}$) in the top or bottom 0.5 percent of the distribution.

3. A leverage ratio greater than 10 or a net current leverage ratio either above 10 or below -10.

4. Changes in quarterly real sales of more than 100% or less than -100%.

Summary statistics are shown in Table A.1.

Variable	All Manufacturing Δk_t	Assets	Nondurable Δk_t	Assets	Durable Δk_t	Assets
Mean	0.012	\$1,766	0.013	\$2,784	0.011	\$1,207
Median	-0.002	\$111	-0.001	\$149	-0.003	\$98
Std. Dev.	0.126	\$8,650	0.134	\$11,979	0.122	\$5,699

Table A.1: Summary Statistics for Manufacturing Firms in Compustat

Note: These statistics cover only manufacturing firms in Compustat from 1985-2008. Assets are deflated using the GDP price index and expressed in millions of 2009 dollars. Δk_t refers to the change in the log level of property, plant, and equipment net of depreciation (NPPE) deflated by the nonresidential fixed investment price index. Statistics for changes in NPPE are calculated across all firm-quarters while the ones for assets are calculated as the time average of the cross sectional value in each quarter.

A.4 Monetary Shocks

I use as a measure of exogenous monetary policy shocks the series generated by Coibion (2012) that extends the original work of Romer and Romer (2004). This methodology uses the FOMC Greenbook forecasts, which are a crucial and high-quality source of information for FOMC participants, to represent the Fed's information set. These forecasts are used as the input for a forward-looking Taylor Rule similar to the one below, and the shocks are taken to be the series of residuals ϵ_t^m.

$$\Delta i_t = \beta i_{t-1} + \sum_k \phi_x^k E_t x_{t+k} + \sum_k \phi_\pi^k E_t \pi_{t+k} + \epsilon_t^m \tag{16}$$

The time series of shocks is shown in Figure A.2 below.

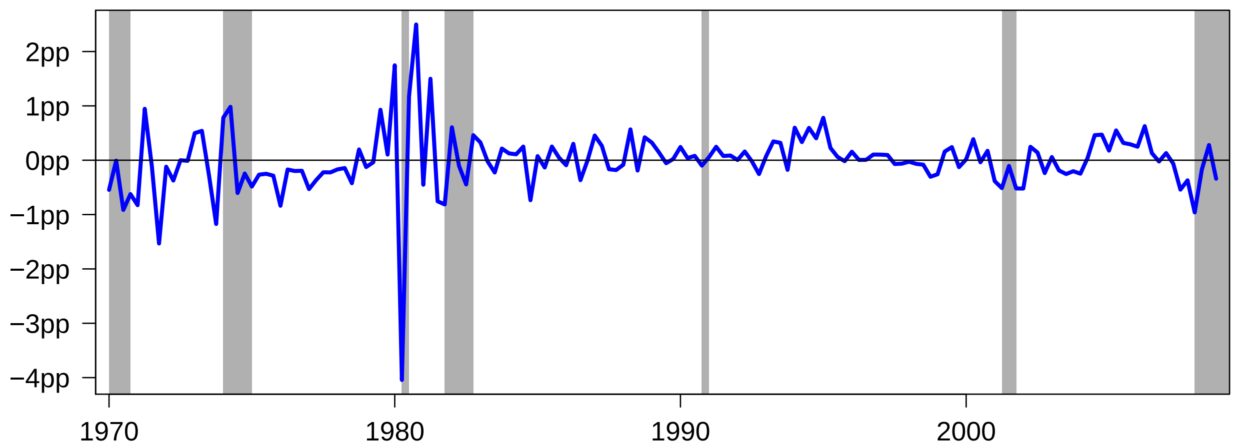

Figure A.2: Time Series of Monetary Shocks

Note: This figure shows the monetary shock series used in my analysis. The shock series I use is developed in Romer and Romer (2004) and extended in Coibion (2012). Positive values correspond to contractionary shocks.

B Additional empirical results

This section shows a range of additional robustness checks and extensions to my main results. In Section B.1, I show that my main results are robust to alternative econometric specifications, controls, lag lengths, and time periods, and that the main findings still obtain using a standard recursive VAR instead of a local projection framework. I also provide standard errors for estimates based on BEA investment data and show that the difference between manufacturing investment and that of several other sectors is statistically significant, including for aggregate investment. In Section B.2, I analyze structures investment for manufacturers, which is the type of investment with the longest useful lifespan and thus should be most sensitive to the user cost channel I describe in the main paper.

B.1 Robustness checks

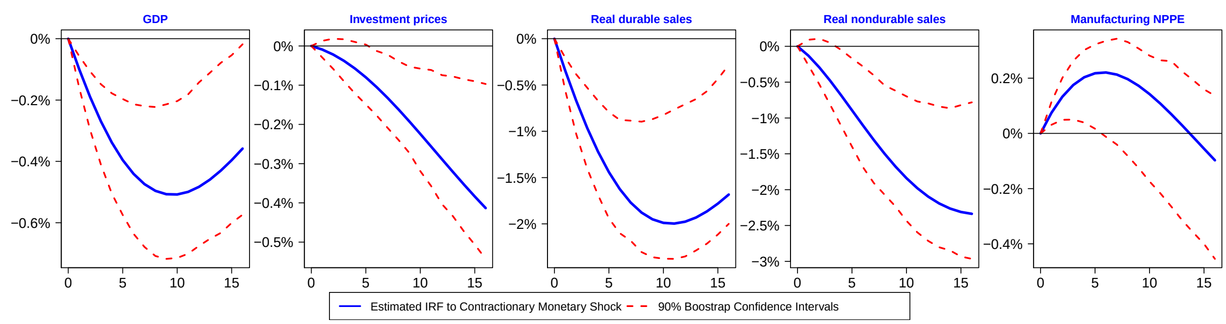

Figure A.3: VAR impulse responses to contractionary MP shock (90% CI)

Note: This figure shows the impulse response to a one standard deviation contractionary FFR shock estimated from a standard recursive SVAR using the following variable ordering: real GDP, the relative price of the nonresidential fixed investment to the GDP deflator, real durable sales, real nondurable sales, the real aggregate capital stock for the manufacturing sector, and the Federal Funds Rate. The FFR is in levels and all other data series are in logs. The data span 1970-2008 to match the baseline specification. Bootstrapped 90% confidence intervals are calculated based on 250 draws.

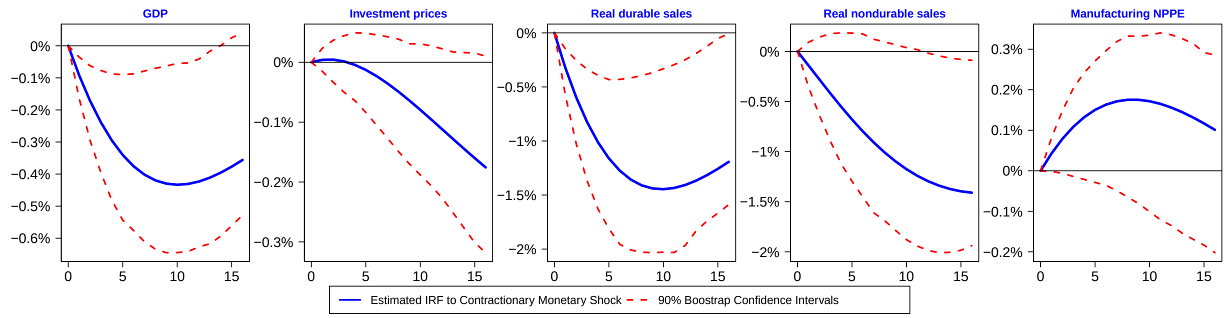

Figure A.4: VAR using data from 1970-2021

Note: This figure shows the impulse response to a one standard deviation contractionary FFR shock estimated from a standard recursive SVAR using the following variable ordering: real GDP, the relative price of the nonresidential fixed investment to the GDP deflator, real durable sales, real nondurable sales, the real aggregate capital stock for the manufacturing sector, and the Shadow Funds Rate (SFR) developed in Wu and Xia (2016). Data cover 1970-2021. The SFR is in levels and all other data series are in logs. Bootstrapped 90% confidence intervals are calculated based on 250 draws.

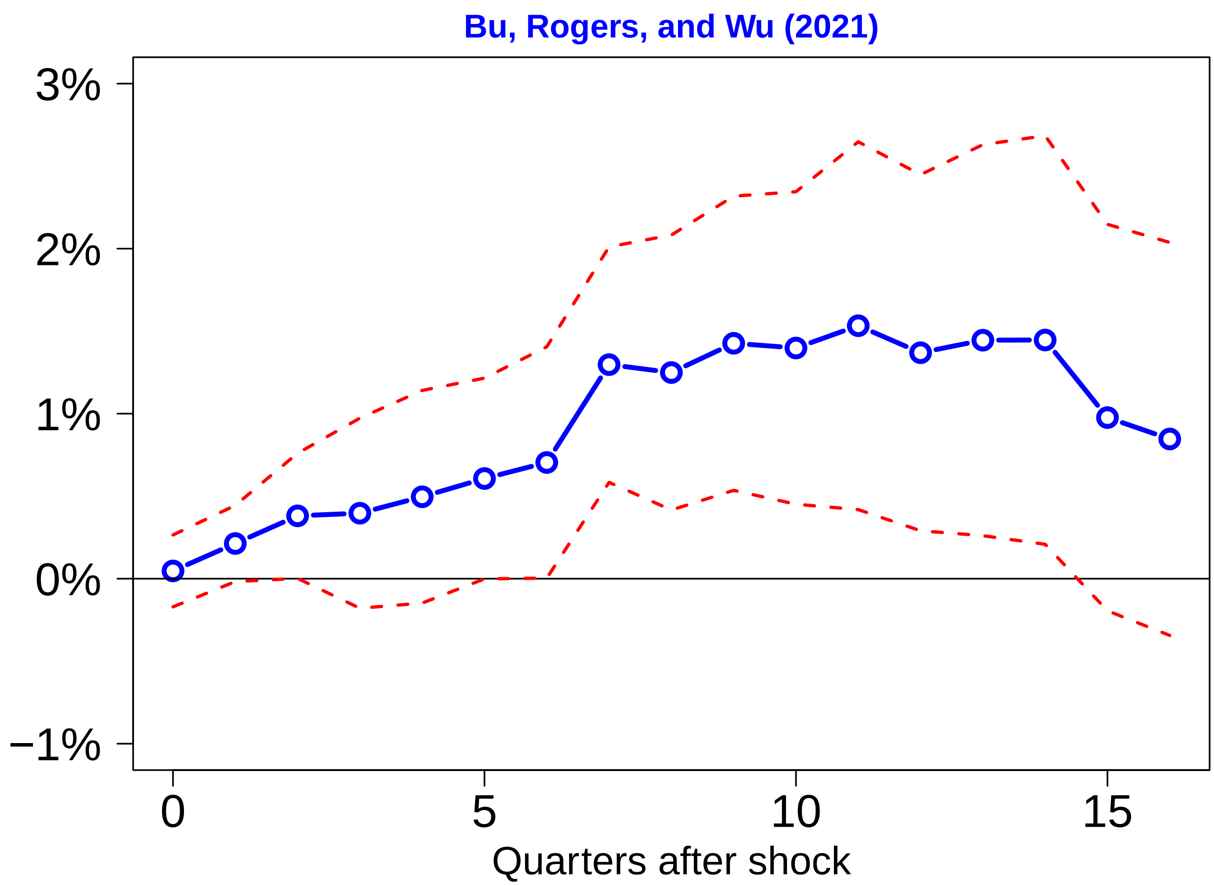

Figure A.5: IRF using data from 1995-2021

Note: This figure shows the response of the aggregate real capital stock for the manufacturing sector from the QFR to a two standard deviation monetary policy shock identified in Bu et al. (2021) including data from 1995-2021. The regression includes a linear time trend and eight lags each of the dependent variable and the shock. Dashed red lines show 90% confidence intervals calculated using Newey-West standard errors.

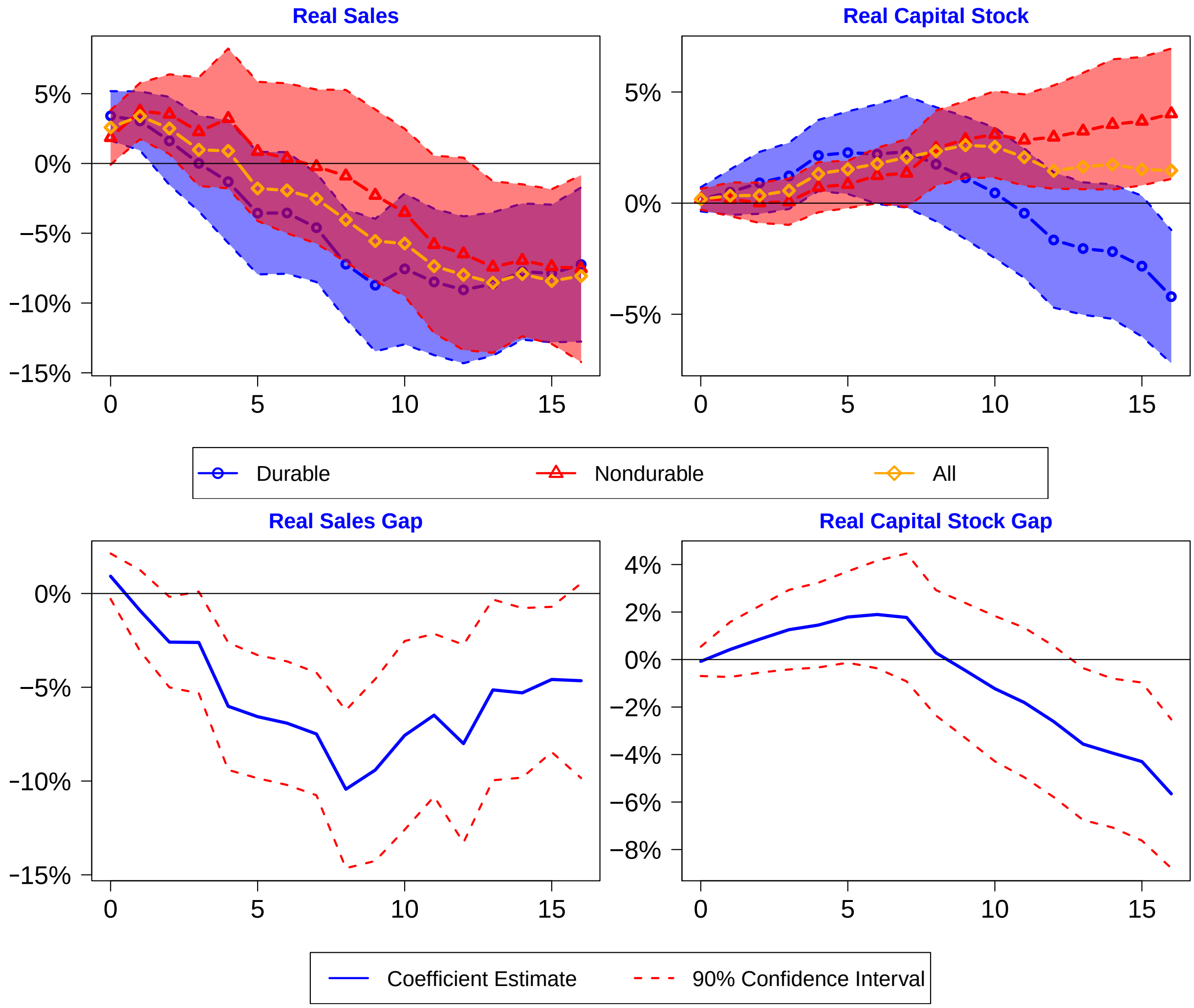

Figure A.6: IRFs using Gertler-Karadi shocks

Note: This figure shows the coefficient estimates γ_h^i from Equation 1 of the main paper using the shocks identified in Gertler and Karadi (2015). I use the identified series of shocks from their VAR and use them as exogenous regressors in my baseline LP approach. The top row shows the responses of NPPE, which is measured by the QFR item "Stock of Property, Plant, and Equipment Net of Depreciation" and deflated using the NIPA nonresidential fixed investment price index, and sales, which is the QFR sales measure deflated by the GDP deflator. The bottom row shows the estimated log difference between each measure: $y_t \equiv \log(X_t^D) - \log(X_t^N)$. 90% confidence intervals are calculated using Newey-West standard errors. Regressions include data from 1975-2008.

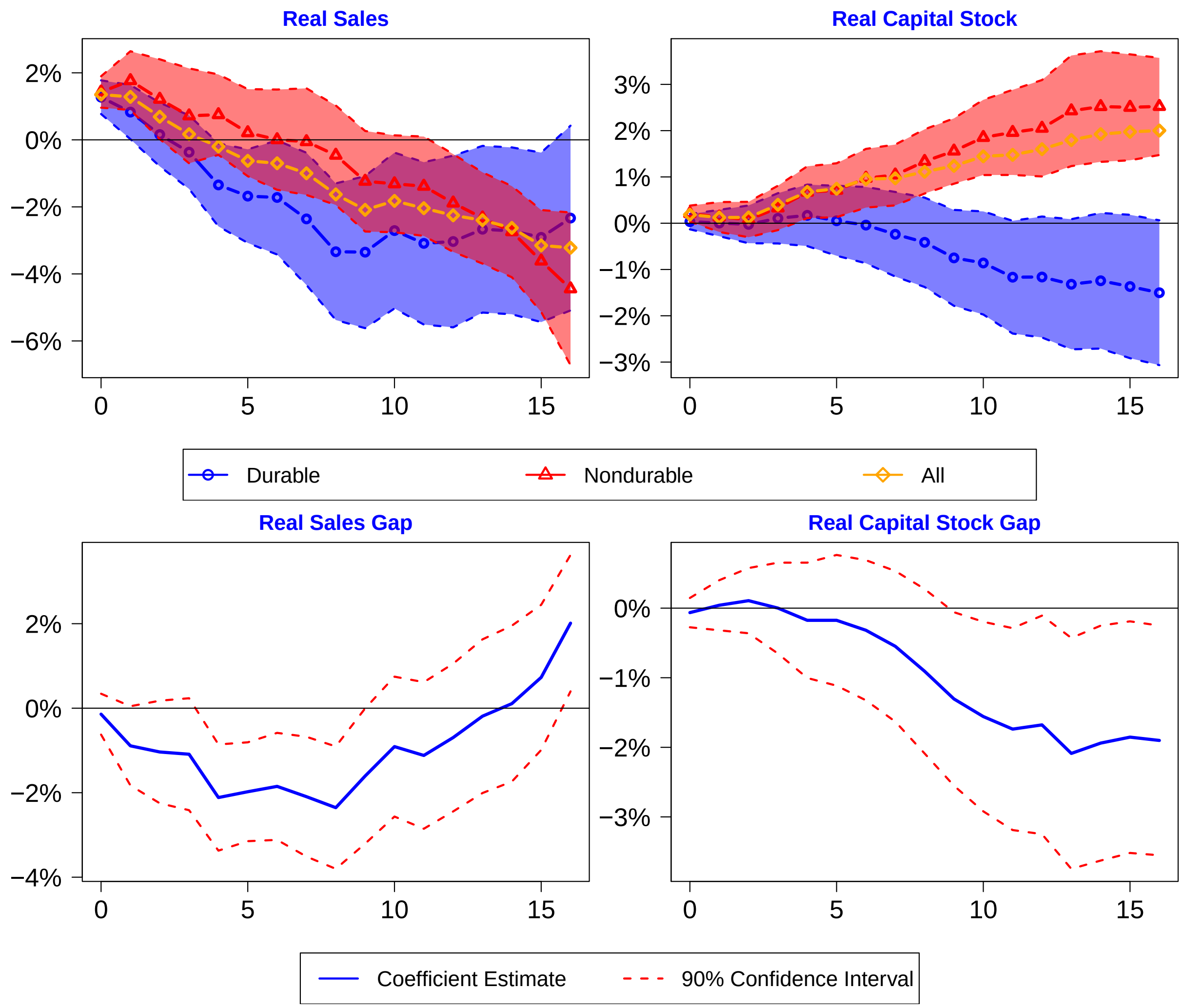

Figure A.7: IRFs using data from 1975-2008

Note: This figure shows the coefficient estimates γ_h^i from Equation 1, which correspond to the effects of a 100bp contractionary monetary shock. The horizontal axes correspond to quarters after the shock. The top row shows the responses of NPPE, which is measured by the QFR item "Stock of Property, Plant, and Equipment Net of Depreciation" and deflated using the NIPA nonresidential fixed investment price index, and sales, which is the QFR sales measure deflated by GDP price index. The bottom row shows the estimated effects on the log difference between each measure: $y_t \equiv \log(X_t^D) - \log(X_t^N)$. All regressions include a linear time trend and eight lags each of the dependent variable and the shock. 90% confidence intervals are calculated using Newey-West standard errors. Regressions include data from 1975-2008.

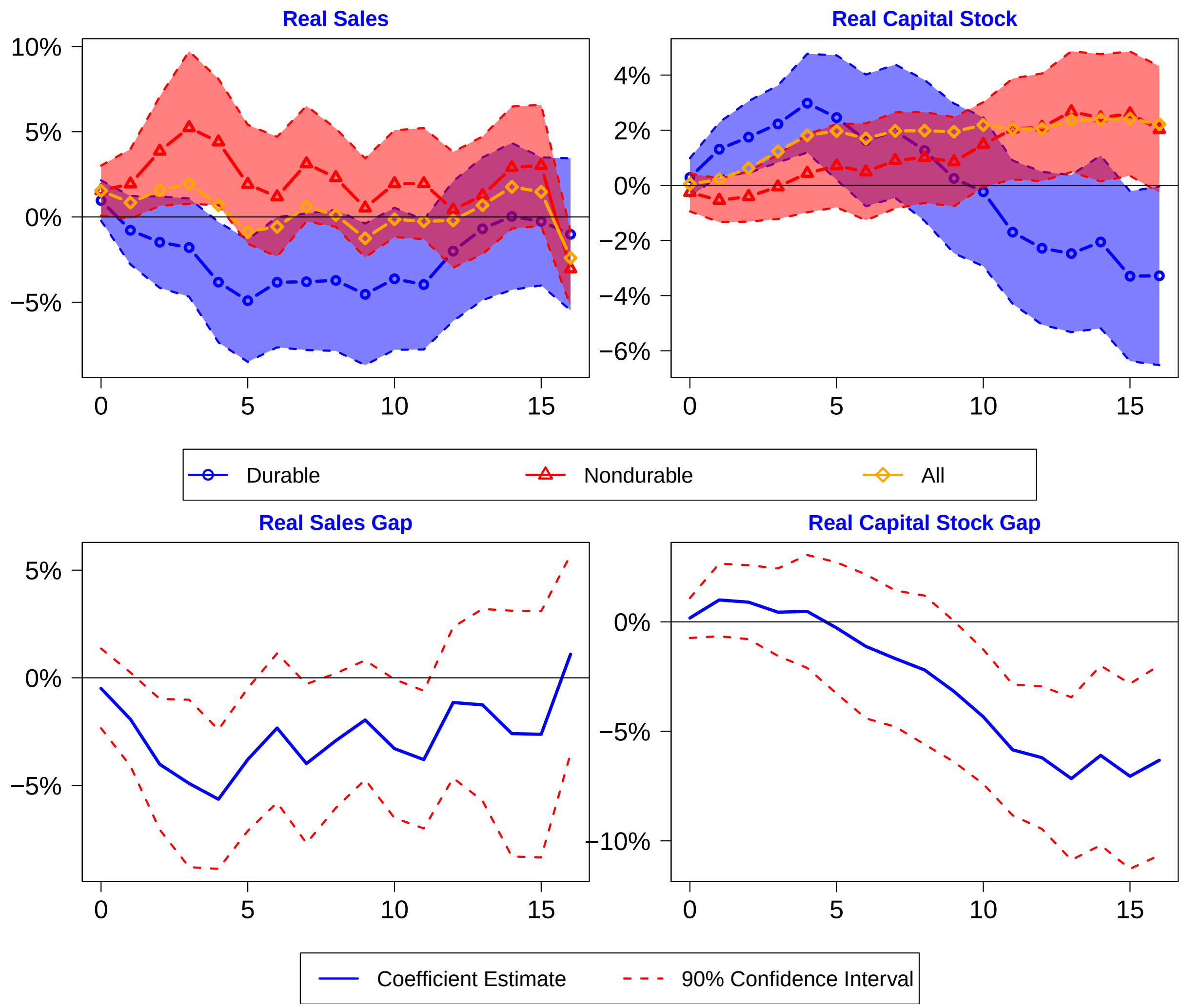

Figure A.8: IRFs using data from 1975-2008

Note: This figure shows the coefficient estimates γ_h^i from Equation 1, which correspond to the effects of a 100bp contractionary monetary shock. The horizontal axes correspond to quarters after the shock. The top row shows the responses of NPPE, which is measured by the QFR item "Stock of Property, Plant, and Equipment Net of Depreciation" and deflated using the NIPA nonresidential fixed investment price index, and sales, which is the QFR sales measure deflated by GDP price index. The bottom row shows the estimated effects on the log difference between each measure: $y_t \equiv \log(X_t^D) - \log(X_t^N)$. All regressions include a linear time trend and eight lags each of the dependent variable and the shock. 90% confidence intervals are calculated using Newey-West standard errors. Regressions include data from 1975-2008.

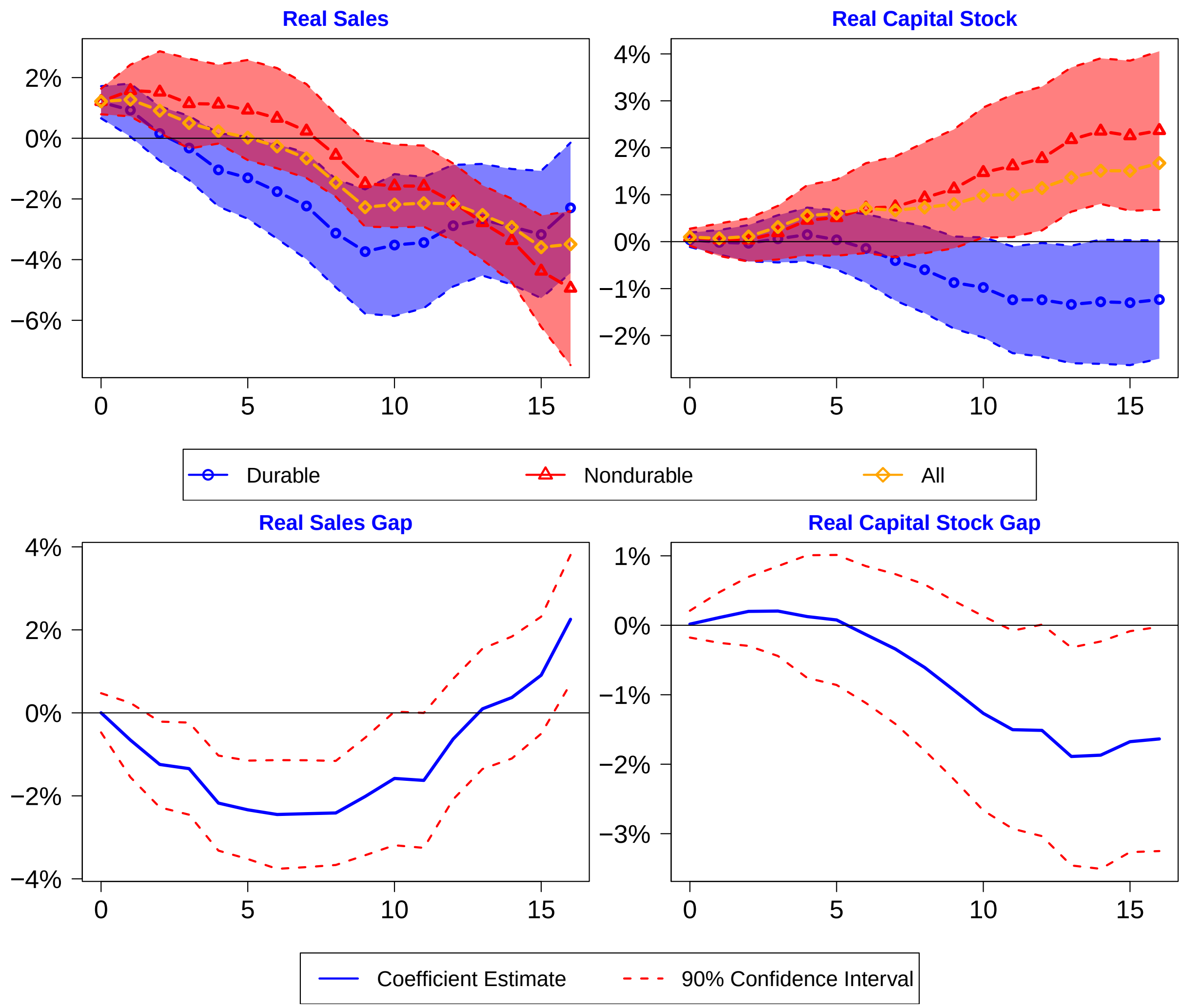

Figure A.9: IRFs using data from 1970-2000

Note: This figure shows the coefficient estimates γ_h^i from Equation 1, which correspond to the effects of a 100bp contractionary monetary shock. The horizontal axes correspond to quarters after the shock. The top row shows the responses of NPPE, which is measured by the QFR item "Stock of Property, Plant, and Equipment Net of Depreciation" and deflated using the NIPA nonresidential fixed investment price index, and sales, which is the QFR sales measure deflated by GDP price index. The bottom row shows the estimated effects on the log difference between each measure: $y_t \equiv \log(X_t^D) - \log(X_t^N)$. All regressions include a linear time trend and eight lags each of the dependent variable and the shock. 90% confidence intervals are calculated using Newey-West standard errors. Regressions include data from 1970-2000.

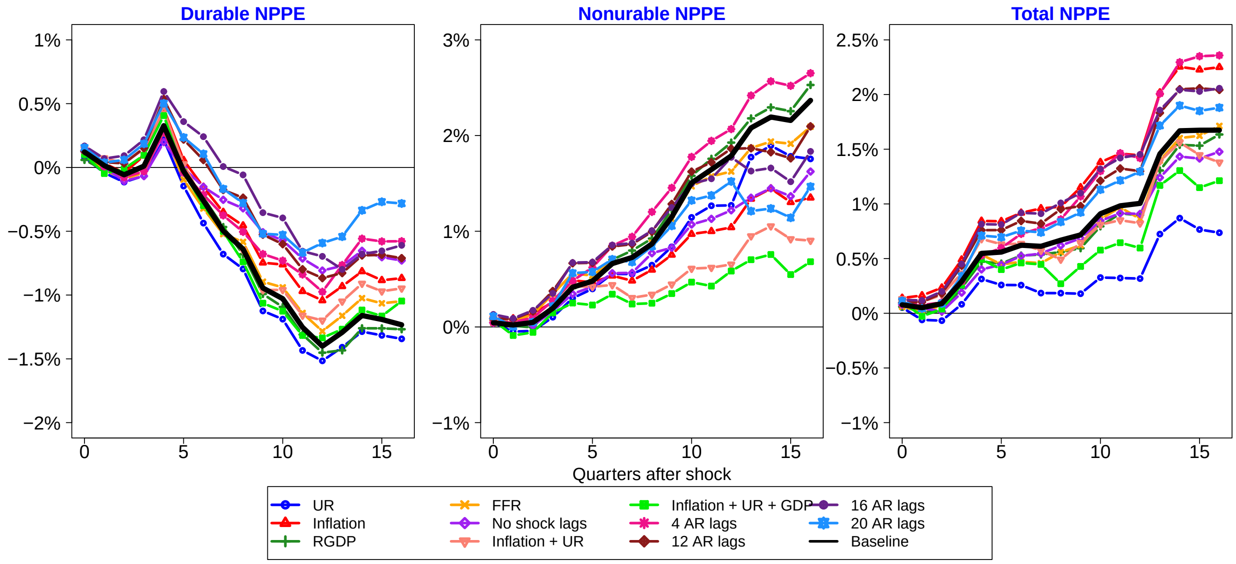

Figure A.10: Robustness of main results to different controls

Note: This figure shows the impulse responses of the capital stocks for the durable, nondurable, and aggregate manufacturing sectors to a 100bp contractionary monetary shock. All regressions use data from 1970-2008. Each line corresponds to a different econometric specification shown in the legend. The "Baseline" specification, shown as the black line, corresponds to my main specification in Section 2. The "UR", "Inflation", "RGDP", and "FFR" specifications adds eight lags each of the unemployment rate, CPI inflation, real GDP growth, and the Federal Funds Rate, respectively, as controls to the baseline specification. The "No shock lags" specification excludes lags of the monetary shock as controls. The "N AR lags" specifications correspond to using $N \in \{4, 12, 16, 20\}$ lags each of the dependent variable and the monetary shock instead of the 8 lags used in my baseline specification.

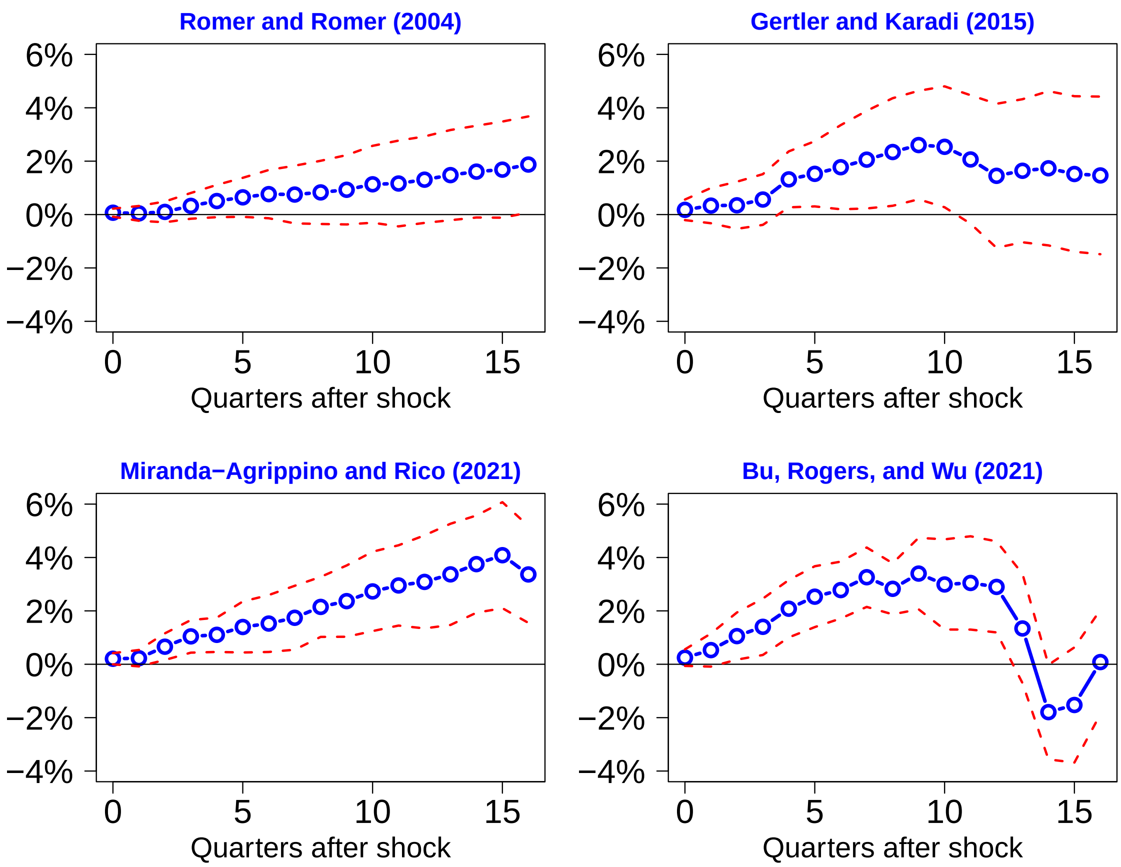

Figure A.11: IRFs excluding linear time trend

Note: This figure shows the response of the aggregate real capital stock for the manufacturing sector from the QFR to a variety of monetary policy shocks. The top left panel shows the response to a 100bp contractionary shock identified using the approach of Romer and Romer (2004) including data from 1970-2008 (I use the extended version of the shocks developed by Coibion (2012)). The upper right panel shows the response to a 100bp contractionary shock identified in Gertler and Karadi (2015) including data from 1975-2008. The lower left panel shows responses to a two standard deviation shock identified in Miranda-Agrippino and Ricco (2021) including data from 1991-2008. The lower right panel shows the response to a two standard deviation shock identified in Bu et al. (2021) including data from 1995-2008. All regressions include eight lags each of the dependent variable and the shock, but not a linear time trend. Dashed red lines show 90% confidence intervals calculated using Newey-West standard errors.

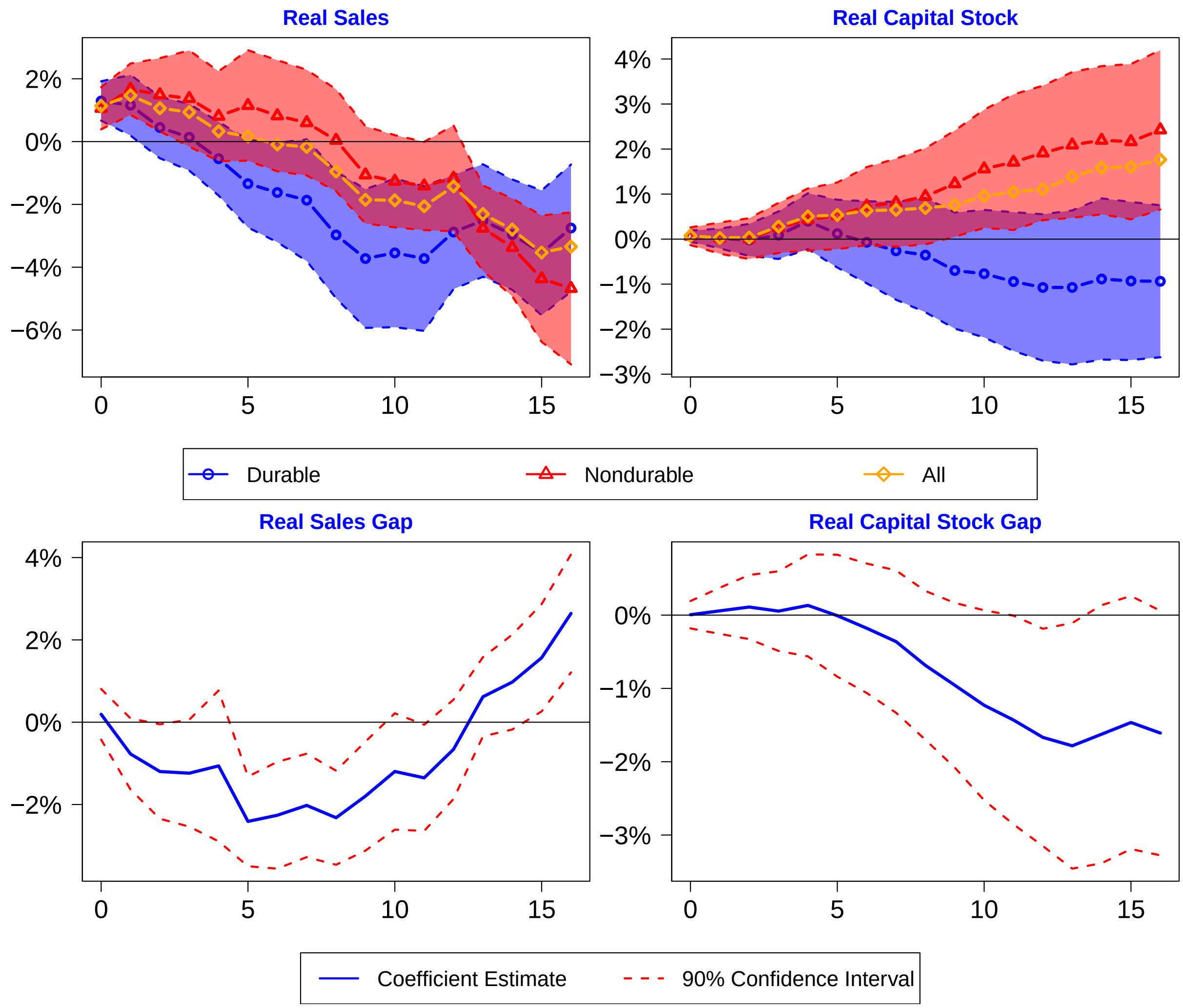

Figure A.12: IRFs excluding linear time trend

Note: This figure shows the effects of a 100bp contractionary monetary shock using a modified version of my baseline regression specification which replaces the linear time trend with eight lags of log real GDP. The horizontal axes correspond to quarters after the shock. The top row shows the responses of NPPE, which is measured by the QFR item "Stock of Property, Plant, and Equipment Net of Depreciation" and deflated using the NIPA nonresidential fixed investment price index, and sales, which is the QFR sales measure deflated by the NIPA manufacturing output price index for each sector. The bottom row shows the estimated effects on the log difference between each measure: $y_t \equiv \log(X_t^D) - \log(X_t^N)$. 90% confidence intervals are calculated using Newey-West standard errors. Regressions include data from 1970 through 2008.

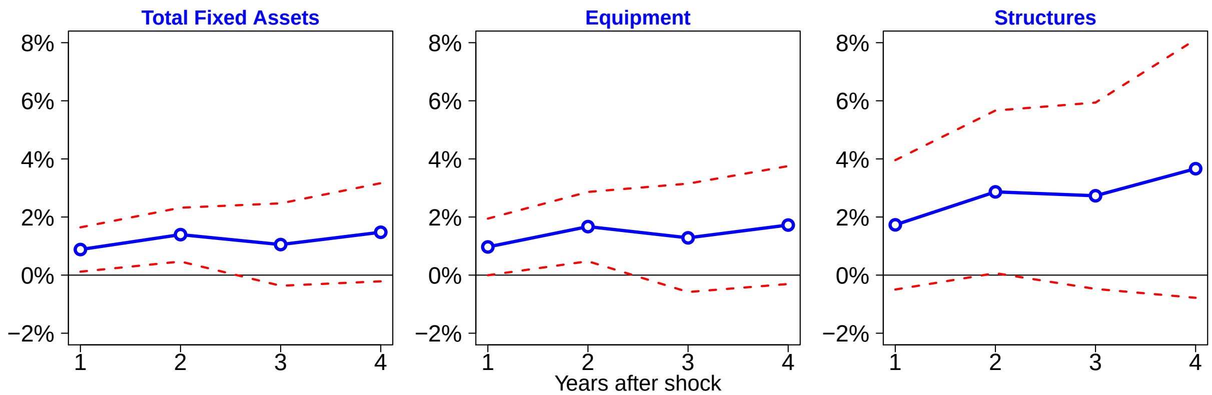

Figure A.13: Investment responses to monetary shocks using BEA fixed asset data (90% CI)

Note: This figure shows the same impulse responses of investment in total fixed assets, equipment, and structures for the manufacturing sector to a 100bp contractionary monetary shock as shown in Figure 4 of the main paper with the addition of 90% confidence intervals calculated using Newey-West standard errors. I add up the quarterly monetary shock series in each year to obtain an annual series to facilitate analysis of the BEA data (which is at the annual frequency). Regressions use a local projection specification that includes a linear time trend and four lags of the dependent variable as controls.

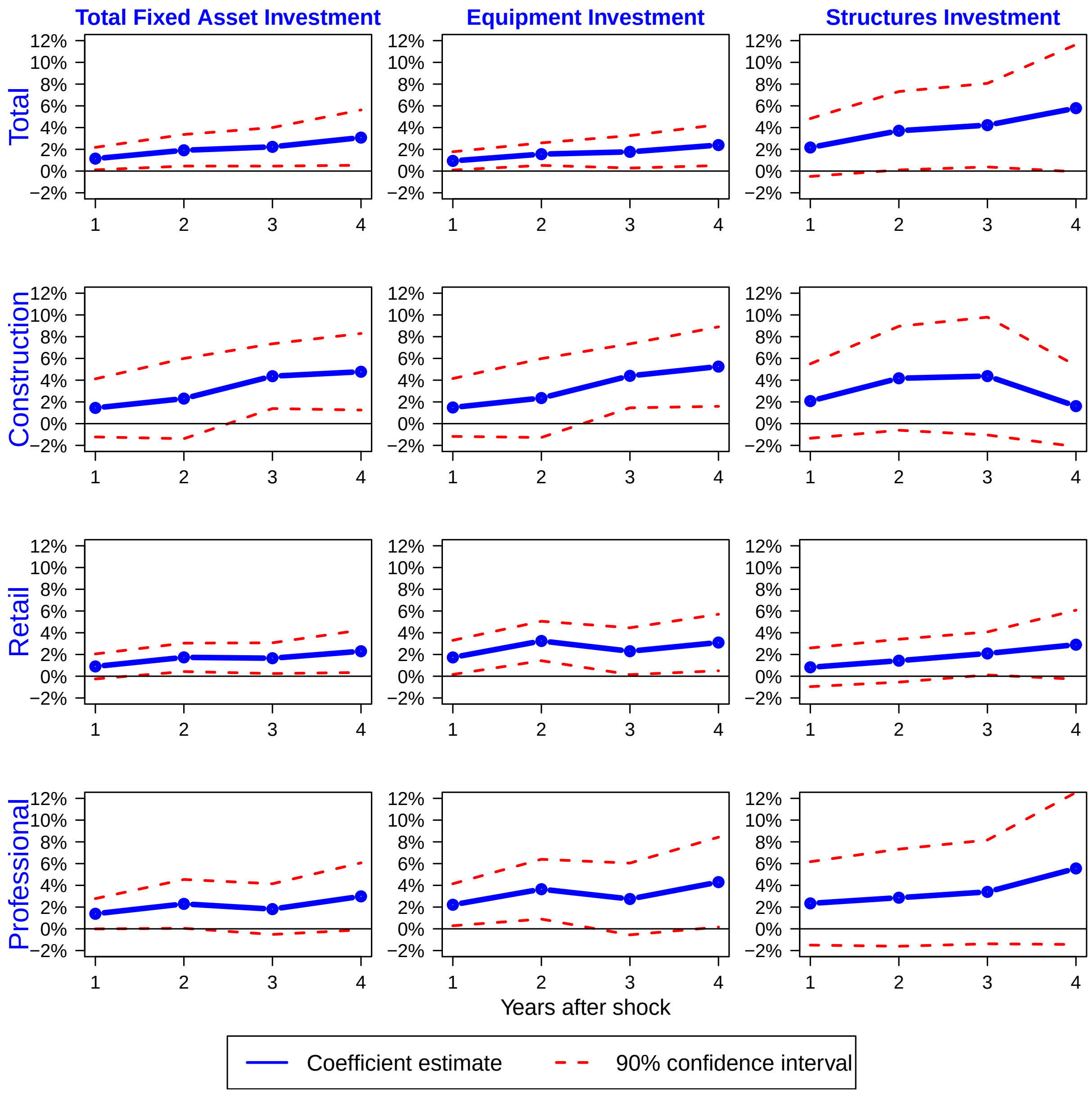

Figure A.14: Investment responses to monetary shocks using BEA fixed asset data (90% CI)

Note: This figure shows the impulse responses of the log difference between investment in the manufacturing sector and investment for the total economy as well as the construction, retail trade, and professional service sectors. I add up the quarterly monetary shock series in each year to obtain an annual series to facilitate analysis of the BEA data (which is at the annual frequency). Each row corresponds to the sector shown to the left, and each column corresponds to the asset category shown at the top. Regressions use a local projection specification that includes a linear time trend and four lags of the dependent variable as controls. 90% confidence intervals calculated using Newey-West standard errors.

B.2 Structures analysis

Structures, which according to the BEA's fixed asset data accounts represent about 80% of the capital stock across the entire economy and 35% of the capital stock for the manufacturing sector, provide detailed evidence that the cost of new investment falls in response to contractionary monetary shocks and that financially unconstrained firms take advantage of these lower prices. Buildings have much longer lifespans than most other types of capital goods, meaning that they should be particularly sensitive to price changes. The cost of new construction (including materials and wages) is strongly correlated with the residential housing market, which is known to deteriorate sharply following a monetary contraction (see for example Leamer (2015)). This reduced demand lowers building costs and leads to large estimated increases in manufacturing construction. Detailed commercial building permit data show that this investment response is driven by the intensive margin: the *number* of new manufacturing structures falls while the total *value* of new structures rises.

The inverse relationship between manufacturing and residential construction activity growth can be seen in the responses to monetary shocks in the top row of Figure A.15. While residential investment falls by almost 8% before returning to its baseline level, there is a much more muted effect in nonresidential structures investment. This is driven in part by manufacturing structures investment, which increases by up to 7.3%. Residential investment averaged about 58% of total structures investment from 1970-2008, meaning construction costs such as wages and building materials are driven to a large degree by activity in the housing market. This can be seen in the bottom row of Figure A.15, which shows the responses of construction employment, real building costs[23], and the NIPA real manufacturing structures price deflated by the GDP price index. These measures show that the relative cost of construction falls significantly in the wake of contractionary monetary shocks and can help explain why manufacturing firms increase their investment expenditure in response.

[23] This measure is the Engineering News-Record's Building Cost Index, which is calculated based on a variety of wages and materials in the construction industry and deflated using the GDP price index.

Figure A.16 shows the price indices for each component of total investment and highlights the fact that the decline in prices is not unique to manufacturing structures. While manufacturing-specific investment deflators are not available in the NIPA data, this exercise suggests that structures play an outsized role in driving the response of manufacturing investment to monetary shocks. The BEA fixed asset data do have manufacturing-specific investment price indices, and the responses of these are shown in Figure A.17. Because these data are only available at the annual level, the coefficient estimates are much noisier. Nonetheless, they are consistent with the idea that contractionary monetary policy has a persistently more negative effect on manufacturing structures prices relative to other types of investment.

Building permit data allow for more detailed analysis of structures investment at the "project" level. Dodge Analytics is a consulting firm that collects commercial building permits based on county-level filings. They generously shared aggregate data on commercial building permits dating back to 1967 for the total number and value of new (defined as those with a planned start date within 60 days) building permits split by type of structure. Details and definitions of the data can be found in Appendix A. These data are useful because they can distinguish between the extensive (more/fewer projects) and intensive (more/less costly projects) margins when analyzing changes in construction activity.

The results for manufacturing structures are shown in Figure A.18. The leftmost panel shows that the number of new permits drops following the shock before returning to its pre-shock level over four years. The total value of the projects, shown in the middle panel, closely matches the shape of the response of the NIPA measure of manufacturing construction value by increasing for about two years. The right panel shows that the increase in total value is driven by an increase in the average permit value. To the extent that larger and less financially constrained manufacturing firms undertake more valuable construction projects, these results are consistent with the idea that it is the subset of financially unconstrained firms which take advantage of declining construction costs and increase their investment.

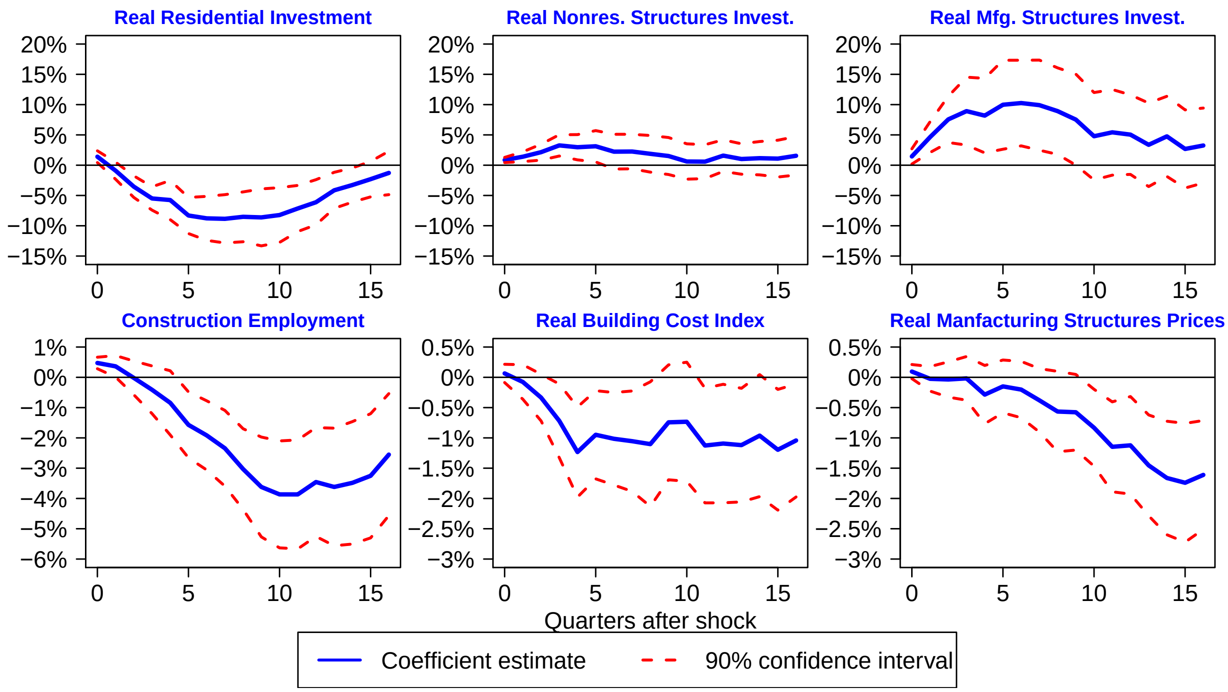

Figure A.15: Empirical Responses to 100bp Contractionary MP Shock (90% CI)

Note: Real residential investment, real nonresidential structures investment, and real manufacturing structures investment data come from the NIPA. Construction employment data are from the BLS establishment survey (CES). The Real Building Cost Index is calculated by dividing the nominal building cost index calculated by the Engineering News-Record, which is based on measures of material and labor costs, by the GDP price index. Real manufacturing structures prices are calculated by dividing the NIPA price index for manufacturing structures investment by the GDP price index. Regressions use the same specification as my baseline results (Equation 1 of the main paper), but without calendar quarter fixed effects since the data are already seasonally adjusted, and they include data from 1970-2008.

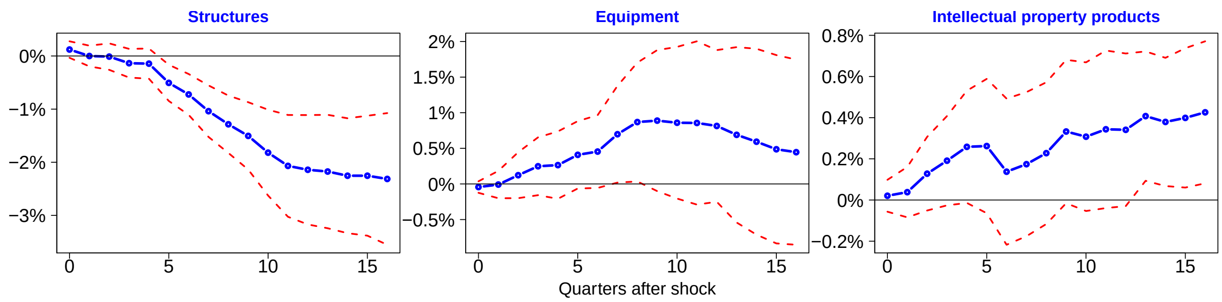

Figure A.16: Relative investment price response to monetary shocks (90% CI)

Note: This figure shows the estimated impulse response to a 100bp contractionary monetary shock for each component of the nonresidential fixed investment price index relative to the GDP price index. Data are quarterly and come from the National Income and Product Accounts. Regressions use the same specification as my baseline results (Equation 1 of the main paper), but without calendar quarter fixed effects since the data are already seasonally adjusted, and they include data from 1970-2008. Dashed red lines correspond to 90% confidence intervals calculated using Newey-West standard errors.

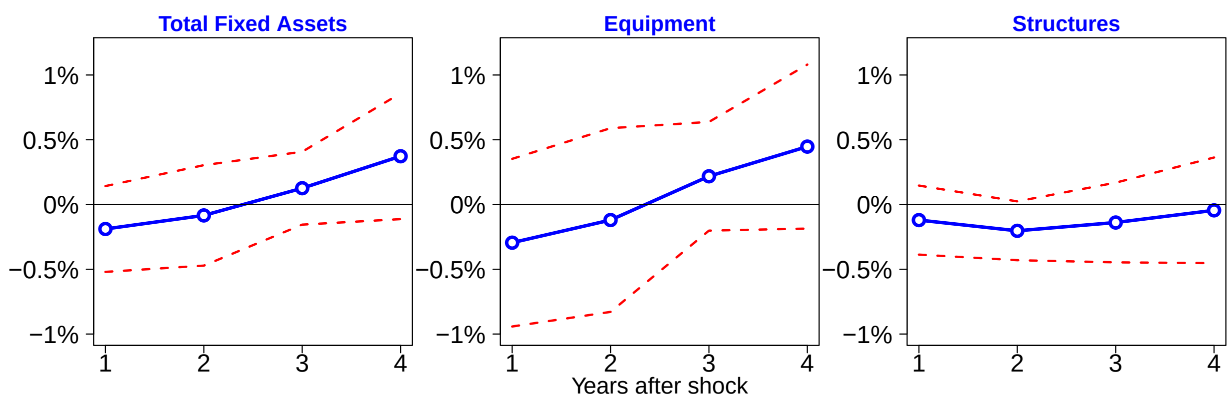

Figure A.17: Relative investment price response to monetary shocks (90% CI)

Note: This figure shows the impulse responses of investment price indices for total fixed assets, equipment, and structures for the manufacturing sector to a 100bp contractionary monetary shock. I add up the quarterly monetary shock series in each year to obtain an annual series to facilitate analysis of the BEA data (which is at the annual frequency). Regressions use a local projection specification that includes a linear time trend and four lags of the dependent variable as controls. Dashed lines represent 90% confidence intervals calculated using Newey-West standard errors.

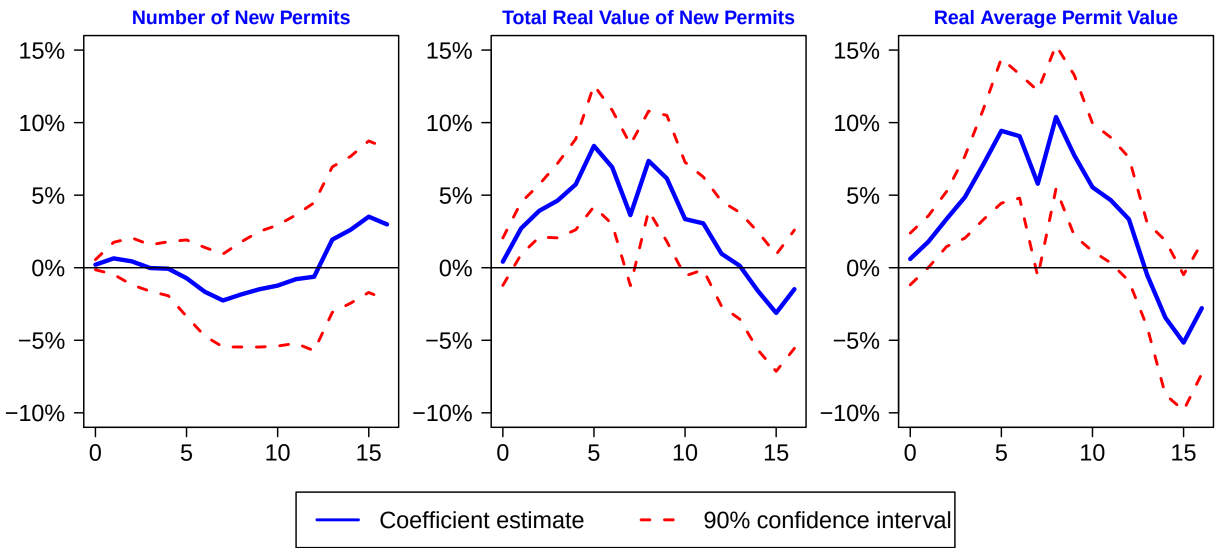

Figure A.18: Empirical Responses to 100bp Contractionary MP Shock (90% CI)

Note: This figure shows impulse responses of the number and value of new manufacturing building permits to a 100bp contractionary monetary policy shock. Building permit data were generously provided by Dodge Analytics and are smoothed using a four-quarter moving average. New permits are defined as those with a planned start date of within 60 days. Only permits for manufacturing structures are included. The real value of all permits is obtained by deflating the nominal value by the manufacturing structures investment price index. The real average permit value is obtained by dividing the real value of new permits by the number of new permits. The specification is the same as my baseline (shown as Equation 1 of the main paper). Regressions include data from 1970-2008.

C Compustat results

My main results showed that contractionary monetary policy shocks led to increases in investment driven by firms in the nondurable sector. This section shows that my results can also be seen using both aggregated and firm-level data from Compustat. Throughout this section, I construct capital stocks using the procedure outlined in Ottonello and Winberry (2020). This methodology takes as an initial value the earliest observation of the value of each firm's gross stock of property, plant, and equipment and then adds to this series the change in the *net* stock of property, plant, and equipment in each quarter. The process used to construct the data is described in detail in Appendix A.

C.1 Aggregate results

While firms in Compustat report capital stock measures that include international operations, firms in the QFR are specifically asked to restrict their responses to include only US operations. Thus to facilitate more accurate comparison, I use the geographical segment data in Compustat to restrict analysis to firms which are more likely to align with the QFR sample.

I create a set of "domestic" firms by dropping those that explicitly report a significant share of sales outside the US. Of US firms which report both total and foreign sales, a firm is classified as having foreign operations if the average share of foreign sales to total sales is greater than 20% over the quarters in which the company reports both. After dropping these firms with substantial foreign operations, the remaining group of domestic firms represents approximately 95% of the capital stock of the manufacturing sector in Compustat in the 1980s, though this share drops to just above 50% by 2012. The results of this approach are shown in Figure A.19. Nondurable manufacturers are estimated to increase their capital stock while durable producers show a decline, particularly toward the end of the response horizon. These results suggest that the primarily domestic firms in Compustat show very similar capital stock behavior to the patterns observed in the QFR.

These patterns are robust to alternative operational classification. This can be seen in Figure A.20 below, which shows several different approaches to classifying firms. The blue line shows results for firms which explicitly report making a majority of their sales in the US. Firms in the Compustat segments file report both country and a domestic indicator variable for each segment (so that the US operations of a foreign company will be classified as foreign while the US operations of a US company will be classified as domestic). Of firms who report both US domestic sales and total sales, a firm is classified as being "predominantly US" if the average share of US domestic sales to total sales is greater than 80% over the quarters in which the company reports both. The red line, which corresponds to the approach used in Figure A.19, excludes firms with an average share of foreign sales to total sales greater than 20% over the quarters in which a company reported both. These specifications are different conceptually in that not all firms report segment information in Compustat; as a result, the group that excludes explicitly foreign firms is much larger than the group that includes only explicitly US-focused firms. Finally, the orange line shows the results including all manufacturing firms in Compustat, regardless of the existence or scale of their international operations. These results are generally similar across specifications, particularly for durable producers, suggesting that the aggregate Compustat results are not sensitive to my choice of geographic classification.

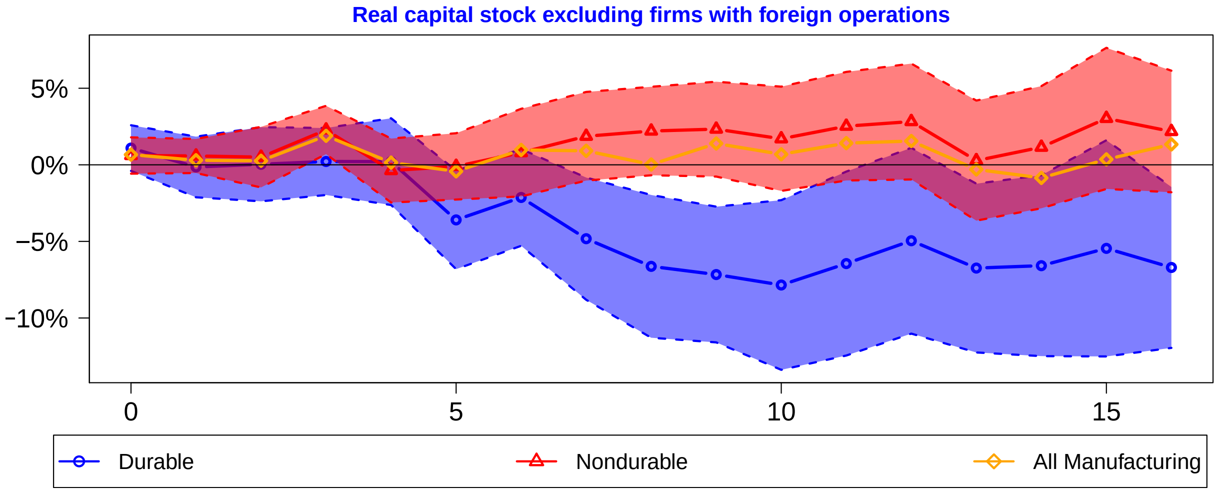

Figure A.19: IRFs for Aggregated Compustat Data, Excluding Foreign Operations (90% CI)

Note: This figure shows impulse responses to a 100bp contractionary monetary shock. The dependent variable is the four-quarter moving average of the aggregate capital stock across Compustat firms deflated by the NIPA nonresidential fixed investment price index. The "Nonforeign" set of firms excludes all firms with an average share of foreign sales to total sales greater than 20% over the quarters in which the company reports both. 90% confidence intervals are calculated using Newey-West standard errors. Regressions use the same specification as my baseline results (shown in Equation 1 of the main paper) and include data from 1987-2008.

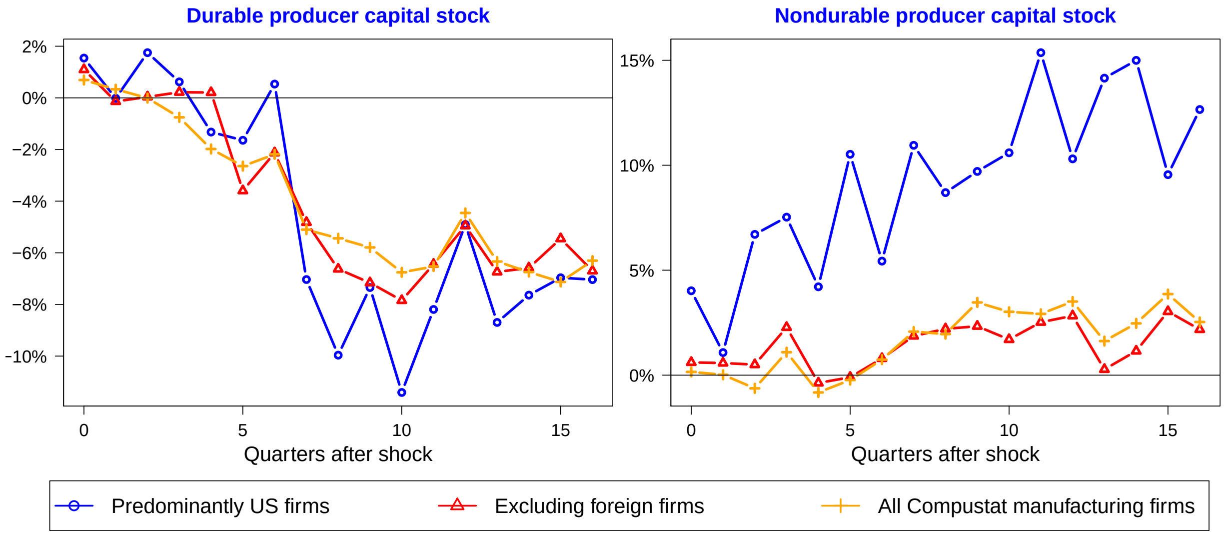

Figure A.20: Empirical responses to 100bp contractionary monetary shock

Note: This figure shows impulse responses to a 100bp contractionary monetary shock. The dependent variable is the four-quarter moving average of the aggregate capital stock across different groups Compustat firms deflated by the NIPA nonresidential fixed investment price index. The "Predominantly US" set of firms includes only those who report both US domestic and foreign sales and which have an average share of US domestic sales to total sales greater than 80% over the quarters in which companies reports both. The "Excluding foreign" group excludes all firms with an average share of foreign sales to total sales greater than 20% over the quarters in which the company reports both. Regressions use the same specification as my baseline results (shown in Equation 1 of the main paper) and include data from 1987-2008.

C.2 Firm-level results

In this section I use firm-level data from Compustat to analyze how firm financial constraints impact the investment response to monetary policy. I estimate the following panel specification:

$$\Delta k_{j,t+h} = \alpha_{j,h} + \delta_{t,h} + \sum_{k=1}^{4} \sigma_h Z_{j,t-k} + \Omega_h Lev_{j,t-1} + \sum_{i \in \{High, Low\}} \gamma_h^i \times Lev_{j,t-1}^i \times \epsilon_t^m + \nu_{j,t+h} \quad (17)$$

$\Delta k_{j,t+h}$ is the cumulative change in the log of the real capital stock between time $t-1$ and time $t+h$ so that $h=0$ corresponds to the same quarter at which the shock hits and $h=16$ corresponds to four years after. $\alpha_{j,h}$ is a firm fixed effect, $\delta_{t,h}$ is a time fixed effect, and Z_{t-1} is a vector of lagged firm-level controls including normalized leverage, log assets, sales growth, and the current share of assets. $Lev_{j,t}^i$ represents a set of indicator variables representing whether a firm was in the top ($High$) or bottom (Low) third of leverage ratios across all firms at time $t-1$. Finally ϵ_t^m is the same R&R-style monetary policy shock used in Section 2; because the shock is the same for all firms at each time, the average effect of the monetary shock across firms will be absorbed in the time fixed effects $\delta_{t,h}$. The main coefficient of interest is γ_h^i, which shows the differential effect of a monetary policy shock for a firm with high or low leverage relative to a firm in the middle of the leverage distribution. The estimates of γ_h^{High} and γ_h^{Low} for all horizons up to $h=16$ are shown in Figure A.21 below.

The left panel shows that firms with low leverage do in fact increase their capital stock following the contractionary monetary policy shock relative to the average firm, with the effect peaking at around 4% about two years after the shock. The right panel shows that firms with high leverage decrease their investment relative to the average firm by up to around 2%. Both of these magnitudes are similar to those shown in my baseline aggregate results, which provides supporting evidence that financial constraints are important for understanding the differences in investment responses to monetary shocks across different sectors.

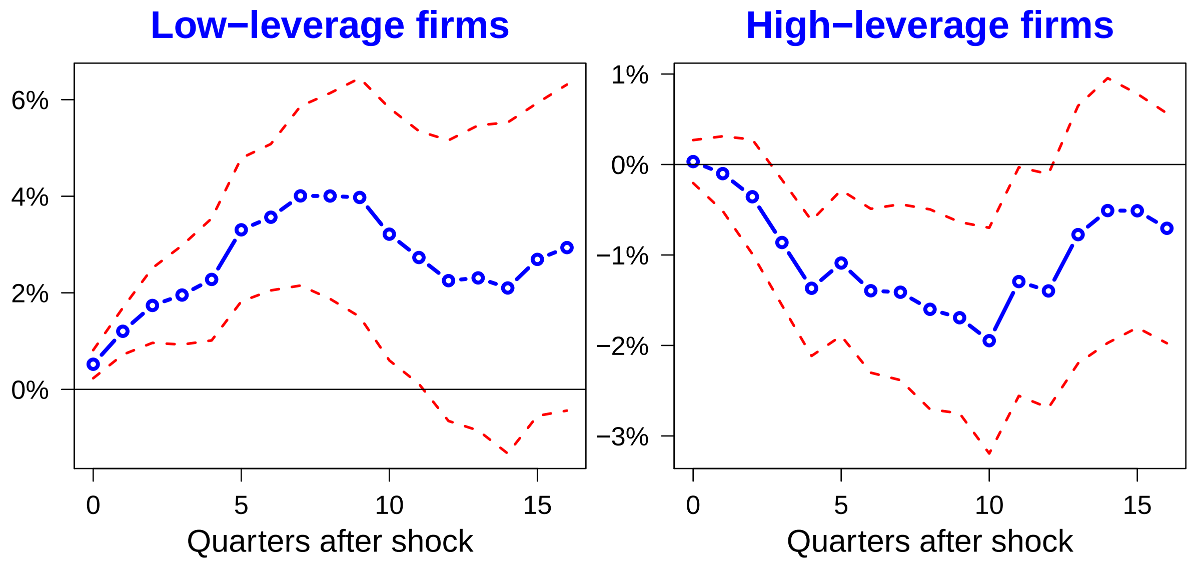

Figure A.21: Firm-level capital stock responses to contractionary monetary shocks (90% CI)

Note: This figure shows the estimated impulse response of the real stock of net property, plant, and equipment (NPPE) for firms in Compustat to a 100bp contractionary monetary shock using the regression specification described in Equation 17. The left panel shows the interaction coefficient between the monetary shock used in my baseline estimates and a dummy variable indicating whether a firm's leverage ratio was in the bottom third across all firms in the quarter prior to the shock. The right panel shows the interaction coefficient between the same shock and a dummy variable indicating whether a firm's leverage ratio was in the top third across all firms in the quarter prior to the shock. The dashed red lines show 90% confidence intervals calculated using Driscoll-Kraay standard errors.

C.3 Comparison to Existing Literature

In this section I compare my results to several recent papers which analyze the cyclical properties of investment. The first is Crouzet and Mehrotra (2020). While my results rely on the publicly available aggregate QFR data and Compustat, they use the QFR microdata. Their paper argues that the industry scope of a firm—that is, the number of industries in which a firm operates—can explain the difference in cyclical sensitivity between small and large firms. They use panel regressions to estimate the response of average firms in the top 1% and bottom 99% of the QFR firm size distribution to monetary policy shocks identified in a similar manner to those used in my paper. In their paper both types of firms decrease their investment in response to contractionary monetary shocks, but they use interactions between durable/nondurable industry dummies and monetary shocks in their specification. To the extent that my results are driven by the distinction between durable and nondurable producers, these interaction terms can reconcile these seemingly contradictory results. Even with this specification, they note that firm-level investment in the QFR microdata increases in response to monetary contractions starting in the 1990s.

The key mechanism in my paper is that investment increases for unconstrained firms in response to falling relative prices, even in the presence of reduced demand. To the extent that the relative price of investment goods also moves in response to other drivers of business cycles, several other findings in their paper provide further support the mechanism at the heart of my paper. Crouzet and Mehrotra (2020) show that while the average marginal effect of GDP growth on fixed investment is positive, the conditional average marginal effect for the largest 0.5% of QFR firms is negative and statistically significant. Furthermore, they find that dividend-paying firms increase their investment during the three years following the onset of a recession; in contrast, investment falls for firms which do not pay dividends. While these empirical results are based on business cycles caused by both monetary and non-monetary shocks, they are consistent with the idea that periods of reduced demand can be attractive times to invest for unconstrained firms.

Several other recent papers also analyze firm-level investment patterns in response to monetary shocks using panel regressions. These include Jeenas (2019), Ottonello and Winberry (2020), and Greenwald et al. (2021). While these papers do not focus explicitly on the heterogeneity of firm responses across sectors, they are both consistent with my findings that it is the *least* financially constrained firms which are most responsive to monetary policy. In addition, Guo (2020), who focuses on financial rather than monetary shocks, provides evidence from Compustat that the firms which are least financially constrained demonstrate countercyclical investment patterns, which dampens the aggregate response to economic shocks through general equilibrium effects.

D Model

This section shows the parameter values used in the model and the entire set of equilibrium conditions along with several robustness checks and extensions. I show that the main results are robust to forcing durable producers to borrow at the risk-free rate instead of at zero net interest and that the model is still able to generate qualitatively similar results even in the case of equally sticky prices in both sectors. Finally, a simple corporate finance model is used to provide theoretical justification for the fact that durable producers are more financially constrained, and I show that the solution to this model is an "investment multiplier" that takes on the same functional form as the one used in the paper's New Keynesian model.

D.1 Full Set of Equilibrium Conditions

This section shows the set of equations which fully characterize the solution to the model. After plugging in the household's demand curve, the full Lagrangian can be formulated as below. ξ^N is set sufficiently high such that the borrowing constraint does not bind for nondurable producers and thus $\mu_t^N = 0$; as a result, the sector-specific superscripts are omitted in the body of the paper.

$$\mathcal{L} = E_0 \sum_{t=0}^{\infty} \beta_S^t \frac{\lambda_{S,t}}{\lambda_{S,0}} \Bigg\{ p_t^j(i) \left(\frac{p_t^j(i)}{P_t^j} \right)^{-\epsilon_j} Y_t^j - w_t N_t^j - p_t^D I_t^j - \frac{\phi_j}{2} \left(\Pi_t^j(i) - 1 \right)^2 Y_t^j(i)$$
$$+ mk_t^j \left[I_t^j \left(1 - \frac{\theta_j}{2} \left(\frac{I_t^j}{I_{t-1}^j} - 1 \right)^2 \right) + (1-\delta_j) K_t^j - K_{t+1}^j \right] + \mu_t^j \left[\xi^j p_t^D K_t^j - w_t N_t^j - p_t^D I_t^j \right]$$
$$+ mc_t^j \left[A_t (K_t^j)^{\alpha_j} (N_t^j)^{1-\alpha_j} - Y_t^j(i) \right] \Bigg\} \tag{18}$$

The full set of equilibrium conditions are as follows:

$$\eta \left(\frac{1}{C_{B,t}^N - hC_{B,t-1}^N} - h\beta_B E_t \left[\frac{1}{C_{B,t+1}^N - hC_{B,t}^N} \right] \right) = \lambda_{B,t} p_t^N \tag{19}$$

$$w_t = \left(\frac{\nu H_{B,t}^{\chi}}{\lambda_{B,t}} (1 + \mu^w) \right)^{1-\rho_w} \left(\frac{w_{t-1}}{\Pi_t} \right)^{\rho_w} \tag{20}$$

$$\lambda_{B,t} p_t^D = \frac{(1-\eta)}{D_{B,t}} + m\psi_t p_t^D \lambda_{B,t} + \beta_B E_t \left[\lambda_{B,t+1} p_{t+1}^D (1 - \delta_D) \right] \tag{21}$$

$$(1 + i_t)\psi_t = 1 - \beta_B E_t \left[\frac{\lambda_{B,t+1}(1 + i_t)}{\lambda_{B,t} \Pi_{t+1}} \right] \tag{22}$$

$$D_{B,t} = C_{B,t}^D + (1 - \delta_D) D_{B,t-1} \tag{23}$$

$$(1 + i_t) B_{B,t} = m p_t^D D_{B,t} \tag{24}$$

$$p_t^N C_{B,t}^N + p_t^D C_{B,t}^D + \frac{(1 + i_{t-1}) B_{B,t-1}}{\Pi_t} = B_{B,t} + w_t H_{B,t}^D + w_t H_{B,t}^N \tag{25}$$

$$\eta \left(\frac{1}{C_{S,t}^N - hC_{S,t-1}^N} - h\beta_S E_t \left[\frac{1}{C_{S,t+1}^N - hC_{S,t}^N} \right] \right) = \lambda_{S,t} p_t^N \tag{26}$$

$$w_t = \left(\frac{\nu H_{S,t}^{\chi}}{\lambda_{S,t}}(1+\mu^w)\right)^{1-\rho_w} \left(\frac{w_{t-1}}{\Pi_t}\right)^{\rho_w} \tag{27}$$

$$\lambda_{S,t} p_t^D = \frac{(1-\eta)}{D_{S,t}} + \beta_S E_t \left[\lambda_{S,t+1} p_{t+1}^D (1-\delta_D)\right] \tag{28}$$

$$D_{S,t} = C_{S,t}^D + (1-\delta^D) D_{S,t-1} \tag{29}$$

$$\lambda_{S,t} = \beta_S E_t \left[\frac{\lambda_{S,t+1}(1+i_t)}{\Pi_{t+1}}\right] \tag{30}$$

$$w_t(1+\mu_t) = (1-\alpha^D) mc_t^D A_t (K_t^D)^{\alpha_D} (H_t^D)^{-\alpha_D} \tag{31}$$

$$w_t = (1-\alpha^N) mc_t^N A_t (K_t^N)^{\alpha_N} (H_t^N)^{-\alpha_N} \tag{32}$$

$$\begin{aligned}(1+\mu_t) p_t^D = mk_t^D &\left[1 - \frac{\theta_D}{2}\left(\frac{I_t^D}{I_{t-1}^D} - 1\right)^2 - \theta_D \left(\frac{I_t^D}{I_{t-1}^D} - 1\right)\left(\frac{I_t^D}{I_{t-1}^D}\right)\right] \\ &+ \beta_S E_t \left[mk_{t+1}^D \theta_D \left(\frac{I_{t+1}^D}{I_t^D} - 1\right)\left(\frac{I_{t+1}^D}{I_t^D}\right)\right]\end{aligned} \tag{33}$$

$$\begin{aligned}p_t^D = mk_t^N &\left[1 - \frac{\theta_N}{2}\left(\frac{I_t^N}{I_{t-1}^N} - 1\right)^2 - \theta_N \left(\frac{I_t^N}{I_{t-1}^N} - 1\right)\left(\frac{I_t^N}{I_{t-1}^N}\right)\right] \\ &+ \beta_S E_t \left[mk_{t+1}^N \theta_N \left(\frac{I_{t+1}^N}{I_t^N} - 1\right)\left(\frac{I_{t+1}^N}{I_t^N}\right)\right]\end{aligned} \tag{34}$$

$$mk_t^D = \beta_S E_t \left[\left(\frac{\lambda_{S,t+1}}{\lambda_S}\right)\left(A_{t+1} \alpha_N {K_{t+1}^D}^{\alpha_D - 1} {H_{t+1}^D}^{1-\alpha_D} mc_{t+1}^D + mk_{t+1}^D (1-\delta_K)\right) + \xi p_{t+1}^D \mu_{t+1}\right] \tag{35}$$

$$mk_t^N = \beta_S E_t \left[\left(\frac{\lambda_{S,t+1}}{\lambda_S}\right)\left(A_{t+1} \alpha_N {K_{t+1}^N}^{\alpha_N - 1} {H_{t+1}^N}^{1-\alpha_N} mc_{t+1}^N + mk_{t+1}^N (1-\delta_K)\right)\right] \tag{36}$$

$$w_t H_t^D + p_t^D I_t^D = \xi p_t^D K_t^D \tag{37}$$

$$\left[(1-\epsilon_D)p_t^D+\epsilon_D mc_t^D\right]-\phi_D\left(\Pi_t^D-1\right)\Pi_t^D+\beta_S\phi_D E_t\left[\left(\frac{\lambda_{S,t+1}}{\lambda_{S,t}}\right)\left(\Pi_{t+1}^D-1\right)\Pi_{t+1}^D\left(\frac{Y_{t+1}^D}{Y_t^D}\right)\right]=0 \tag{38}$$

$$\left[(1-\epsilon_N)p_t^N+\epsilon_N mc_t^N\right]-\phi^N\left(\Pi_t^N-1\right)\Pi_t^N+\beta_S\phi_N E_t\left[\left(\frac{\lambda_{S,t+1}}{\lambda_{S,t}}\right)\left(\Pi_{t+1}^N-1\right)\Pi_{t+1}^N\left(\frac{Y_{t+1}^N}{Y_t^N}\right)\right]=0 \tag{39}$$

$$Y_t^D=A_t\left(K_t^D\right)^{\alpha_D}\left(H_t^D\right)^{1-\alpha_D} \tag{40}$$

$$Y_t^N=A_t\left(K_t^N\right)^{\alpha_N}\left(H_t^N\right)^{1-\alpha_N} \tag{41}$$

$$K_{t+1}^D=(1-\delta_K)K_t^D+I_t^D\left[1-\frac{\theta_D}{2}\left(\frac{I_t^D}{I_{t-1}^D}-1\right)^2\right] \tag{42}$$

$$K_{t+1}^N=(1-\delta_K)K_t^N+I_t^N\left[1-\frac{\theta_N}{2}\left(\frac{I_t^N}{I_{t-1}^N}-1\right)^2\right] \tag{43}$$

$$\omega H_{S,t}^D+(1-\omega)H_{B,t}^D=H_t^D \tag{44}$$

$$\omega H_{S,t}^N+(1-\omega)H_{B,t}^N=H_t^N \tag{45}$$

$$\omega C_{S,t}^D+(1-\omega)C_{B,t}^D=C_t^D \tag{46}$$

$$\omega C_{S,t}^N+(1-\omega)C_{B,t}^N=C_t^N \tag{47}$$

$$\omega D_{S,t}+(1-\omega)D_{B,t}=D_t \tag{48}$$

$$\omega B_{S,t} + (1-\omega) B_{B,t} = 0 \tag{49}$$

$$K_t^D + K_t^N = K_t \tag{50}$$

$$C_t^D + I_t^D + I_t^N + \frac{\phi_D}{2}\left(\Pi^D - 1\right)^2 Y_t^D = Y_t^D \tag{51}$$

$$C_t^N + \frac{\phi_N}{2}\left(\Pi^N - 1\right)^2 Y_t^N = Y_t^N \tag{52}$$

$$A_t = A_{t-1}^{\rho^A} \exp\left(e_t^A\right) \tag{53}$$

$$\beta_S(i + i_t) = (\beta_S(i_{t-1}))^{\rho} \left(\Pi_t^{\phi_\Pi}\right)^{1-\rho} \exp(e_t^M) \tag{54}$$

$$\Pi_t^D = \frac{p_t^D}{p_{t-1}^D} \Pi_t \tag{55}$$

$$\Pi_t^N = \frac{p_t^N}{p_{t-1}^N} \Pi_t \tag{56}$$

$$1 = (p_t^N)^{\eta} (p_t^D)^{1-\eta} \tag{57}$$

D.2 Model extensions

This section considers several extensions to my baseline model. First, I show the results are robust to using sticky prices in both sectors. Even though the assumption that durable prices are more flexible is supported by existing empirical work, my results do not depend on it. Calibrations which use the baseline nondurable price stickiness for both sectors ($\phi_D = \phi_N = 58.25$) lead to an increase in investment in both sectors in response to the contractionary shock, but this depends on the calibration of the other parameters. Even with this higher degree of price stickiness, the model is able to generate the appropriate responses of investment in the case of tighter financial constraints (setting $\xi = 0.04$ instead of its baseline value of 0.1). The IRFs are shown in the left panel of Figure A.22. This suggests that imposing equal degrees of price stickiness will not automatically lead to behavior inconsistent with the main mechanisms described in my paper.

Next, I consider how the model results change if I assume that financially constrained firms borrow intertemporally at the risk-free rate instead of intratemporally without paying interest. In this alternate setup, the equilibrium conditions for households and nondurable producers are unchanged; the only difference is that durable producers now have to pay interest (at the risk-free rate) on the funds they borrow to purchase capital and labor. The modified equations are:

$$w_t(1+\mu_t)(1+i_t) = (1-\alpha^D) mc_t^D A_t (K_t^D)^{\alpha^D} (H_t^D)^{-\alpha^D} \tag{58}$$

$$\begin{aligned}(1+\mu_t)p_t^D(1+i_t) = mk_{D,t}&\left[1 - \frac{\theta_D}{2}\left(\frac{I_{D,t}}{I_{D,t-1}} - 1\right)^2 - \theta_D\left(\frac{I_{D,t}}{I_{D,t-1}} - 1\right)\left(\frac{I_{D,t}}{I_{D,t-1}}\right)\right] \\ &+ \beta_S E_t\left[mk_{t+1}^D \theta_D\left(\frac{I_{D,t+1}}{I_{D,t}} - 1\right)\left(\frac{I_{D,t+1}}{I_{D,t}}\right)\right]\end{aligned} \tag{59}$$

$$(1+i_t)\left(w_t H_t^D + p_t^D I_t^D\right) = \xi p_t^D K_t^D \tag{60}$$

The impulse responses incorporating these modifications are shown in the right panel of Figure A.22 and are virtually indistinguishable from the baseline results because, as in the data, interest rates are relatively small drivers of user cost compared to the relative price of investment.

Finally, I show that the assumption of a homogenous durable good that functions both as productive capital and as a consumption good for the household is not crucial to the model's main results. To show this, I modify the baseline model to include two durable sectors: one that produces capital, and another that produces household goods. Both durable sectors have the same production and price setting parameters. They also face the same financial constraints as the durable producers in the baseline model, which restrict their total input expenditure to a fraction of the value of their productive capital stock. The impulse responses for the capital stocks in each sector, as well as the aggregate, are shown in Figure A.23. The durable sector in this figure combines producers of household durable goods and capital goods to make it comparable to the baseline model. These figures show that the main three facts from my baseline model still hold. In response to a contractionary monetary shock: 1) investment declines for durable producers (after a small and short-lived and increase in the version with separate pricing), 2) investment increases for nondurable producers, and 3) on balance, the total combined capital stock of the manufacturing sector increases.

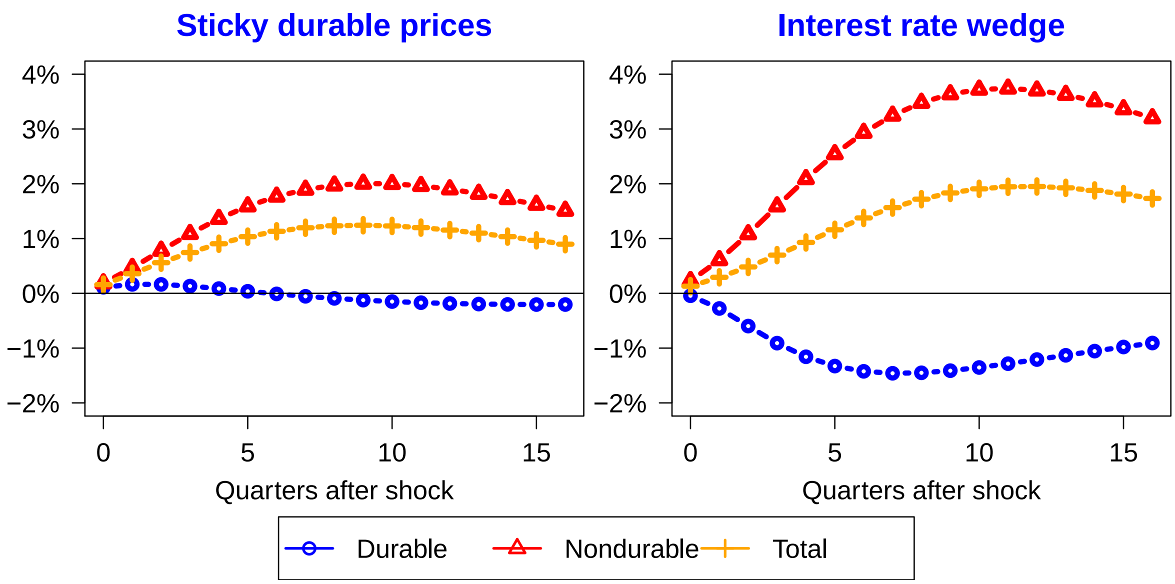

Figure A.22: Capital stock responses under alternative modeling assumptions

Note: This figure shows the impulse responses of the model capital stocks in each sector to a 100bp contractionary monetary shock under several alternative modeling assumptions. The left panel shows results when the price stickiness of both sectors is set to be $\phi_N = \phi_D = 58.25$ and the financial constraint parameter is set to $\eta = 0.04$ while all other parameters remain the same as in Table 1. The right panel shows results when durable producers must pay the risk-free rate on their loans.

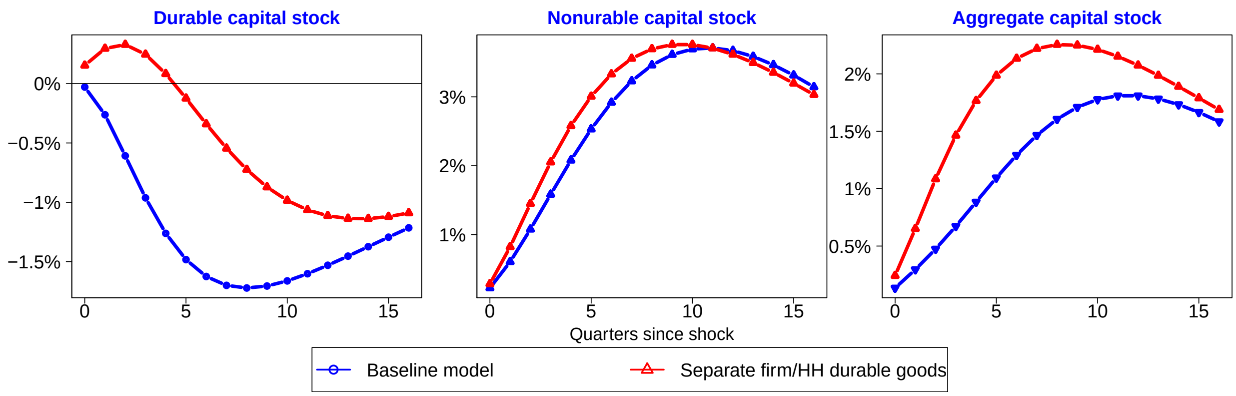

Figure A.23: Model IRFs with distinct household durables and capital goods

Note: This figure shows impulse responses for capital stocks to a 100bp monetary contraction for two different versions of the model. The blue lines correspond to the baseline model. The red lines correspond to a modified version of the model that includes two durable sectors: one that produces capital, and another that produces household goods. Both durable sectors have the same production and price setting parameters. They also face the same financial constraints as the durable producers in the baseline model, which restrict their total input expenditure to a fraction of the value of their productive capital stock.

D.3 Theoretical Basis for Lending Frictions

The New Keynesian model used in the paper treated durable goods producers as exogenously subject to financing constraints. This section outlines a plausible theoretical mechanism that would endogenously lead to such frictions: the fact that durable producers face more volatile demand for their product due to its longevity.

I use the workhorse model developed in in Tirole (2010) to analyze this mechanism for several reasons. First, the model is simple, tractable, and allows for analytic results. Second, the model is flexible enough to easily incorporate a stylized type of demand volatility. Finally, the solution to the model is an "investment multiplier" which says that the amount of funds that a firm is able to raise is a linear function of the value of its assets, which is the same functional form as the one found in the paper's more elaborate New Keynesian model. While not all of the parameters which determine the investment multiplier in this simplified context have direct counterparts in the larger model, this section provides justification for my choice of working capital constraint and allows for some insightful comparative static exercises.

D.3.1 The Simple Model

There is a risk-neutral entrepreneur with sole access to the technology to produce their good. The production of the project is a function of the investment X and effort $e \in \{l, h\}$ put into it. The entrepreneur has net worth A that can be invested in the project; if he wishes to invest $X > A$, he must borrow $L = X - A$ from the banking sector, which is perfectly competitive and risk neutral.

The financing of the projects is non-trivial due to the presence of a moral hazard problem. If the entrepreneur exerts high effort e_h, the project succeeds with probability p_h and produces according to the linear "production" function RX where R is the productivity or return of the project and $X \in [0, \infty)$. If the entrepreneur exerts low effort, the project succeeds with probabilty $p_l < p_h$ and the entrepreneur receives private benefits proportional to the level of investment BX. I assume that $p_h R > 1 > p_l R + B$, which tells us that the project is only NPV positive on a per-unit basis in the case of high effort, and $p_h R < 1 + \frac{p_h B}{\Delta p}$, which leads to a bounded quantity of investment.

Because effort is not observable the contract cannot directly reward the entrepreneur for working hard, so it must be set up in an incentive-compatible manner to prevent them from running away with the money. This means that the entrepreneur must have enough "skin in the game" such that their private benefit from working hard exceeds their gains from shirking. The contracting problem will have individual rationality (IR) constraints for both the borrower and lender and an incentive compatibility (IC) constraint for the borrower.

Formally, their problem will be to split the investment X and total expected successful return R into separate pieces for both the lenders and borrowers. Incentive compatibility will require that the expected gain for the producer exceeds the private benefit of shirking:

$$R_b(e_h)X \geq R_b(e_l)X \implies p_h R_b X \geq p_l R_b X + BX \implies R_b X \geq \frac{BX}{\Delta p} \tag{61}$$

Here I've defined $\Delta p \equiv (p_h - p_l)$ to be the improvement in success probability that results from hard work. Because the per-unit net return of the project $(p_h R - 1)$ is greater than 1, the constrained investors will always have incentives to invest more in the project and they will only be limited by the set of contracts agreeable to the bank. Thus, their IC constraint will bind ($R_b X = \frac{BX}{\Delta p}$) and their IR constraint will be slack. The positive net return will result in constrained investors optimally pledging their full wealth A to the project so that $L = X - A$.

I now write the IR constraint for the bank knowing that the optimal contract will induce high effort on the part of the firm and that shirking will not be observed in equilibrium. I also allow for an outside option of investing their funds to earn a risk-free gross interest rate of $(1 + i)$:

$$(1+i)L \geq p_h R_l X \implies (1+i)(X - A) \geq p_h \left[RX - R_b X \right] \tag{62}$$

The second inequality holds because the lender's return can be written as the total return minus the portion promised to the borrower. Because the entrepreneurs have market power in this setup, the IR constraint will bind for the bank and they will receive expected net returns of zero in equilibrium. Thus, combining Equations 61 and 62 leads to following condition:

$$(1+i)(X-A) = p_h\left[RX - R_b X\right] \implies (1+i)(X-A) = p_h\left[RX - \frac{BX}{\Delta p}\right]$$

$$\implies X\left[1 - \frac{p_h}{1+i}\left(R - \frac{B}{\Delta p}\right)\right] = A \implies X = \left(\frac{1}{1 - \frac{p_h}{1+i}\left[R - \frac{B}{\Delta p}\right]}\right)A \tag{63}$$

Re-write the utility function as a linear function of X and then plug in the investment multiplier derived above to write the borrower's net utility as follows:

$$U^B = (p_h R - 1)X = \left(\frac{p_h R - 1}{1 - \frac{p_h}{1+i}\left[R - \frac{B}{\Delta p}\right]}\right)A \tag{64}$$

Because all firms have constant returns to scale and the project has positive NPV, they will always want to invest as much as possible. The model solution will be an "investment multiplier" k that reflects the return of the project, the outside interest rate, the project's probaiblity of success, and the severity of the moral hazard problem. In this setup, because R is known by both parties before the investment is sunk, the contract can be interpreted as either debt or equity.

D.3.2 Implications of Demand Volatility

A simple way to extend the model to allow for durable goods to have more volatile demand is to treat the parameter R as a random variable that is realized after financing is obtained but prior to effort being exerted. In this setup the per-unit returns to investment can be thought of as the price of the good being sold; in this context, durable producers face more volatile returns because their good is longer-lived, and this longevity makes intertemporal substitution easier and leads to a more volatile price. In this section I show that the combination of volatile returns and equity contracts will cause the investment multiplier to decrease in the case of a mean-preserving spread in the return.

The simplest illustration of how demand volatility can influence terms of equity is in the discrete case. Instead of being deterministic as in the previous section, the return $\tilde{R}$ is now a random variable that is realized after investment has been sunk but before effort has been exerted. It takes on a value of R_0 with probability θ and R_1 with probability $1-\theta$. Define the expected return $\bar{R} \equiv \theta R_0 + (1-\theta)R_1$. In expectation the investment project is NPV positive in the case of high effort: $p_h\bar{R} > 1 > p_l\bar{R} + B$. As a result, the entrepreneur will want to exert effort when the high return R_h is realized. If R_0 is realized, there is no surplus to be gained from exerting effort since $p_l R_0 + B > p_l R_0$, so the entrepreneur will slack.[24]

If the borrower could credibly commit to working hard regardless of the realization of $\tilde{R}$, then they would be able to promise a higher return to the lender and receive more financing. However, because the bank knows that the entrepreneur will not exert effort if R_0 is realized, they will internalize this outcome when making their lending decision and subsequently reduce the available quantity of funds. In this sense it is the bank who bears the downside risk to bad realizations of $\tilde{R}$ while the entrepreneur captures the upside. It is this fundamental asymmetry that allows volatility to exacerbate financial constraints even when all agents are risk neutral.

The optimal equity contract will involve the borrower receiving a share γ of the proceeds of the project regardless of outcome. If R_0 is realized, the borrower will find it optimal not to exert effort, and the gross expected return will be $p_l R_0$. If R_1 is realized, the borrower will find it optimal to exert effort, and the gross return will be $p_h R_1$. The incentive compatibility

[24] Once financed, the funds can only be allocated toward the project. This prevents the entrepreneur from simply "running away with the money" and earning a net return of 1 if R_0 is realized, which would be higher than the expected value of shirking on the project.

condition requires $\gamma p_h R_1 \geq \gamma p_l R_1 + B \implies \gamma = \frac{B}{R_1 \Delta p}$.

The lender will receive a per-unit share of $1-\gamma$ of the per-unit return of the project, which can be written $\hat{R} \equiv \theta p_l R_0 + (1-\theta) p_h R_1$. Their IR constraint requires that they receive in expectation enough to keep them indifferent between investing and earning the risk-free rate: $(1+i)(X-A) = X(1-\gamma)\hat{R}$. Plugging in the borrower's IC constraint yields the model's solution:

$$(1+i)(X-A) = X\left(1 - \frac{B}{\Delta p R_1}\right)\hat{R} \implies X = \left[\frac{1}{1-\left(\frac{1-\frac{B}{\Delta p R_1}}{(1+i)}\hat{R}\right)}\right] A \tag{65}$$

If $\theta = 0$, then $\hat{R} = p_h R_1$, and the solution collapses to that of the previous section. In this deterministic case, the borrowers would expect to receive $(1-\gamma) p_h \bar{R}$. In the presence of moral hazard, however, the fact that the borrowers will not exert effort if R_0 is realized prevents the lender from earning this return. Instead, they earn $(1-\gamma)\hat{R}$. This difference can be written:

$$p_h \bar{R} - \hat{R} = p_h\left(\theta R_0 + (1-\theta) R_1\right) - \left(\theta p_l R_0 + (1-\theta) p_h R_1\right) = \theta \Delta p R_0 \tag{66}$$

As long as $R_0 > 0$, this difference will be positive, which means that the investment multiplier will be larger in the deterministic case even when the expected returns are the same. The fact that the benefits of shirking only accrue to the borrower and not the lender lead to a lower investment multiplier for more volatile projects.

D.3.3 Relationship to DSGE Model

In these models the solution is an investment multiplier of the form $X = \xi A$ where X was the amount of funds obtained by the entrepreneur and invested in the project, A is the value of the entrepreneur's assets pledged toward the project, and ξ is the multiplier that links the two. If $\xi_i > \xi_j$, then firm i is able to obtain a greater amount of financing for the same initial level of assets, and thus firm i can be interpreted as less financially constrained than firm j. The previous section showed that $\xi_{baseline} > \xi_{volatile}$, showing that firms facing a mean-preserving spread in the volatility of their expected returns would be able to obtain a smaller financing multiplier:

$$\left(\frac{1}{1-\frac{p_h}{1+i}\left[\bar{R}-\frac{B}{\Delta p}\right]}\right) > \left(\frac{1}{1-\left(\frac{1-\frac{B}{\Delta p R_1}}{(1+i)}\hat{R}\right)}\right) \tag{67}$$

The conceptual link between this simple model and the more complex DSGE model in the body of the paper is quite clear. In that model, the main borrowing constraint for durable producers was:

$$w_t H_t^D + p_t^D I_t^D = \xi p_t^D K_t^D \tag{68}$$

The total amount invested in the "project" each period—which in this case corresponds to the production of durable goods—is simply the total expenditure on labor and capital, so $X = w_t H_t^D + p_t^D I_t^D$. The total amount of assets available to the producer each period is simply the value of their capital stock, so $A = p_t^D k_t^D$. Putting these together, this becomes $X = \xi A$, which is precisely the same functional form as in the baseline model.