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 manufacturing 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 responds *countercyclically* to 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 manufacturing 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 dating back to 1966 from the Quarterly Financial Report for Manufacturing Corporations (QFR), which contain detailed income and balance sheet information for the entire US manufacturing sector. 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 necessarily for 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. Durable goods tend to have more flexible prices, meaning that their relative price will fall in response to contractionary demand shocks. 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, financing costs, 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 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 with distinct durable and nondurable sectors generate countercyclical investment. Counterfactual exercises show that eliminating firm financial constraints reduces the volatility of manufacturing output and inflation coming from monetary shocks by around 25% and 10%, respectively.

These results 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 economy's sensitivity to monetary policy shocks.

This paper builds on recent work analyzing how firm and industry characteristics can influence the transmission of shocks through the lens of financial frictions, including Gertler and Gilchrist (1994), Cloyne et al. (2023), Crouzet and Mehrotra (2020), Durante et al. (2022), Guo (2022), Jeenas (2019), and Ottonello and Winberry (2020). Relative to these papers, my results emphasize monetary policy's effect on the relative price of investment as a key mechanism in explaining heterogeneous responses of different types firms to monetary shocks. I also contribute to past work analyzing the role of durable goods in New Keynesian models, such as Barsky et al. (2007), Monacelli (2009), Carlstrom and Fuerst (2010), Kim and Katayama (2013), and Chen and Liao (2014). By incorporating the insights of past studies such as Almeida and Campello (2007) and Banerjee et al. (2008), who show that the durable goods sector displays a greater degree of financial constraint than the nondurable sector, my model is able to more accurately reflect sector-level investment dynamics in the data.

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,

[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.

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 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 1966 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 the appendix.

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 as in Tenreyro and Thwaites (2016), though I show in the appendix that its inclusion does not drive my main findings, and calendar quarter fixed effects q^i_h to account for potential 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 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

[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.

[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.

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 2.4% on the part of nondurable producers. However, the capital stock of durable producers, shown as the blue line, declines by up to 1.5% 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 (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 non-durable 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. (2022), 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 shocks for durable producers than for nondurable producers, and argue that this is the result of fundamental differences in the properties of the goods produced by each sector. One distinction 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 appendix, I consider several extensions and robustness checks that support these findings. First, I show that my 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 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

[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.

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.

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 net income 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 areas; 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,

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

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 exhibit larger equity risk premia 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.

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

[6]The appendix 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.

current and expected future prices. In models in which firms own their 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 expected changes in investment prices, 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.

[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 annualized average GDP price index inflation rate from 1970-2008 (approximately 4%), 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.

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]

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 about 2% following the shock. In Section 2.2, I estimated an increase in the capital stock of almost 1.7%. This implies a back-of-the-envelope user cost elasticity of -0.85, which aligns closely with past estimates of between -0.5 and -1.0 according to Hassett and Hubbard (2002), though it is a bit smaller than the estimates in Zwick and Mahon (2017). It is also in line with the manufacturing-specific estimates of Caballero et al. (1995), who estimate values 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.

[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.

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, the appendix 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] Investment in most other industries (including the aggregate, which is shown as the solid black line) declines. 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 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

[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 the appendix.

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 by industry. This share currently stands at about 37% across all sectors and has been increasing since the mid-1990s.[10] However, it is much higher for manufacturing firms, and has increased 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, this share has remained between 40-50% throughout the sample period. 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

[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 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*.

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 the appendix. 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 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, I replicate my analysis using Compustat data. I find that the aggregate capital stock for publicly traded nondurable producers in Compustat increases relative to that of durable producers, mirroring the findings from the QFR data. I also exploit firm-level variation to show that less-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 $C_{i,t}^N$ with habit formation, stocks $D_{i,t}$ and flows $C_{i,t}^D$ of durable consumption, labor $H_{i,t}$, and nominal bonds $B_{i,t}$:

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

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

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

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_t^j 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.

$$p_t^N C_{B,t}^N + p_t^D C_{B,t}^D + B_{B,t} = \frac{(1+i_{t-1})B_{B,t-1}}{\Pi_t} + w_t H_{B,t}^D + w_t H_{B,t}^N, \tag{5}$$

$$p_t^N C_{S,t}^N + p_t^D C_{S,t}^D + B_{S,t} = \frac{(1+i_{t-1})B_{S,t-1}}{\Pi_t} + w_t H_{S,t}^D + w_t H_{S,t}^N + \frac{1}{\omega}\left(Profits_t\right). \tag{6}$$

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

[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).

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 investment adjustment costs[13] in the manner of 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.[14] 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:[15]

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

For simplicity, I model durable producers as being financially constrained and nondurable producers as being unconstrained. This modeling choice is consistent with the empirical

[13] The appendix shows similar results using adjustment costs on K_t rather than I_t.

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

[15] 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 the appendix I show that forcing durable producers to borrow at the risk-free interest rate does not change the results.

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 the appendix 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.

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:

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

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. The appendix 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).[16] I also use their values for price stickiness for each sector

[16] 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

($\phi_D = 0, \phi_N = 58.25$).[17]

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 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

of investment.

[17]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.

($\delta_D = 0.02, \delta_K = 0.03$), 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.[18]

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.

[18] 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.

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 their ability to 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 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 in response to other types of shocks and for 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 model is able to match the quantitative magnitudes in the data quite well. The left two panels of the middle row show the behavior of flow investment, which display peak effects about four quarters after the shock hits. The remaining panels shows the responses for consumption, the relative price of durables, total inflation, and total output. As in the data, all decline in response to a monetary contraction. The fact that the magnitudes are larger than in the data is primarily a result of choosing parameter values to match the sector-specific investment facts described in Section 2. Overall, 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 aggregate productivity (A_t), labor disutility (ν), risk aversion (σ), financial frictions (ξ), depreciation (δ), and government spending.[19] 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

[19] 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.

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 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 leads to a manufacturing sector that is, on aggregate, less responsive to monetary shocks; I find removing financial frictions for durable producers reduces the volatility of real manufacturing output coming from monetary shocks by approximately 25%, and reduces 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. This is consistent with the idea that removing the collateral constraints, which tie the prices of capital goods to real outcomes, allows manufacturers to be more flexible in their deployment of capital goods and allows for a net reduction in volatility. While my model focuses on the manufacturing sector in order to match the stylized facts I document in the QFR, Jermann and Quadrini (2009) provide both empirical and theoretical evidence that deepening financial markets allow for greater financial flexibility and less volatile real activity at the aggregate level.

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 attenuates manufacturing output and inflation responses to monetary shocks and reduces 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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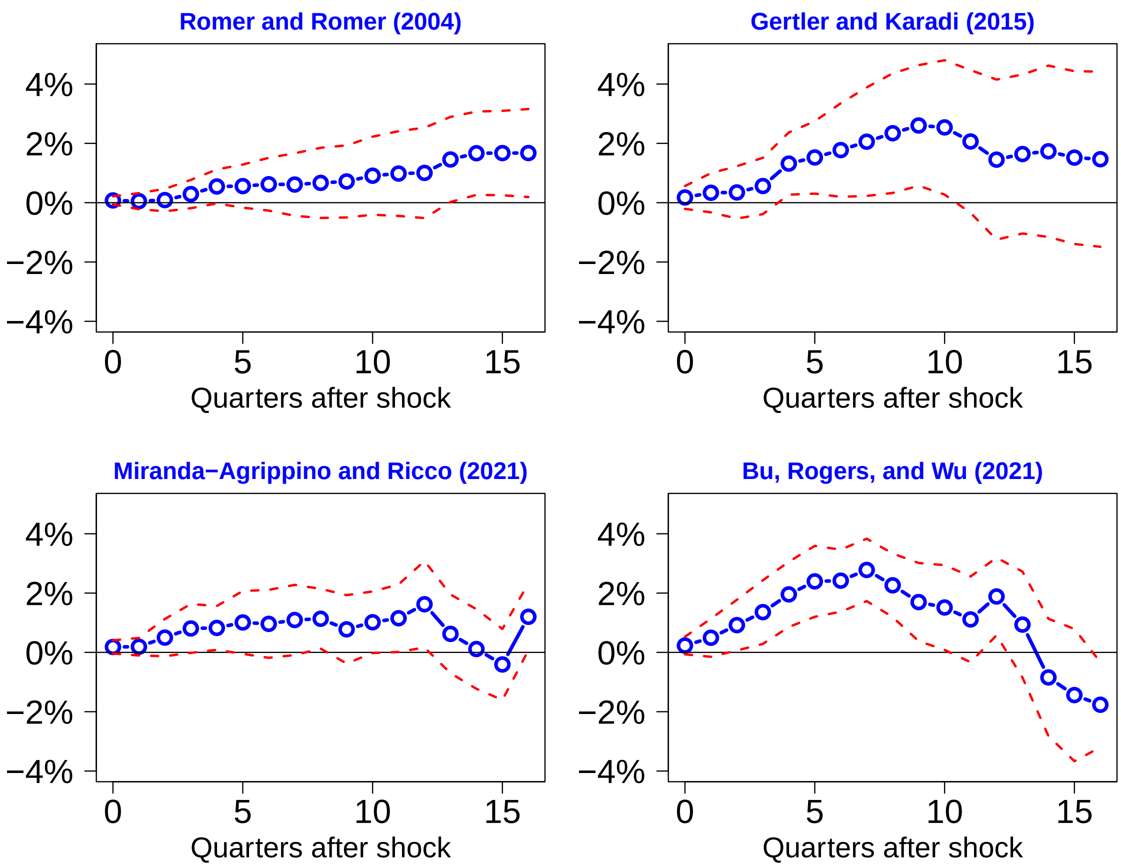

Figure 1: Responses of aggregate manufacturing NPPE to contractionary monetary shocks

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.

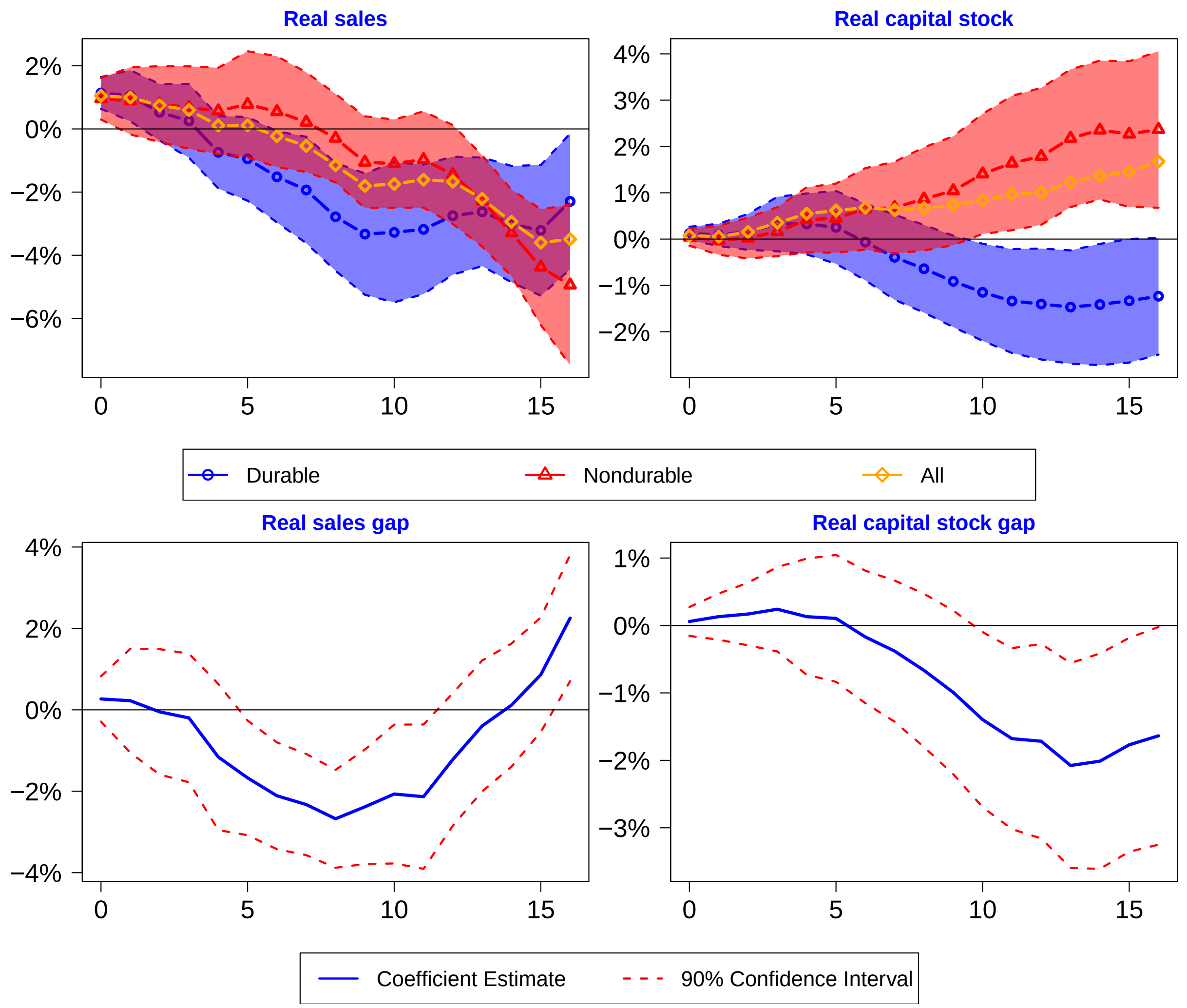

Figure 2: Responses of manufacturing subsector NPPE to contractionary monetary shock

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.

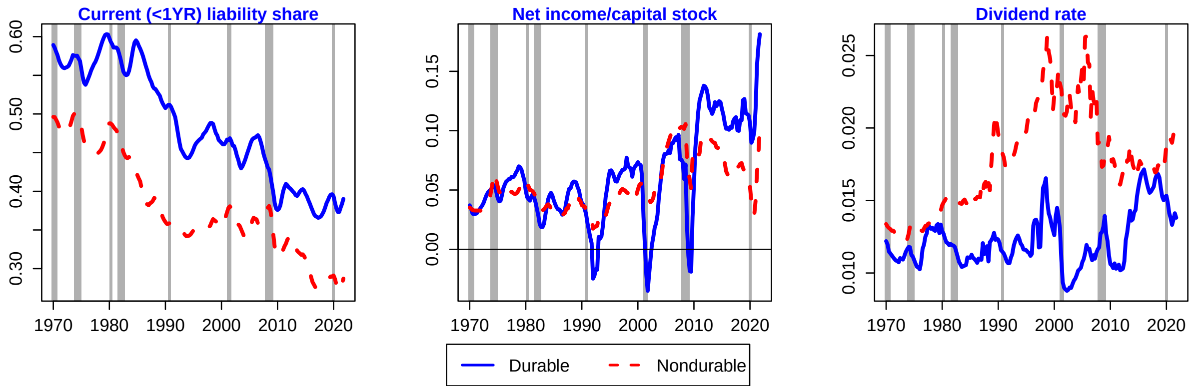

Figure 3: Financial constraint measures

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.

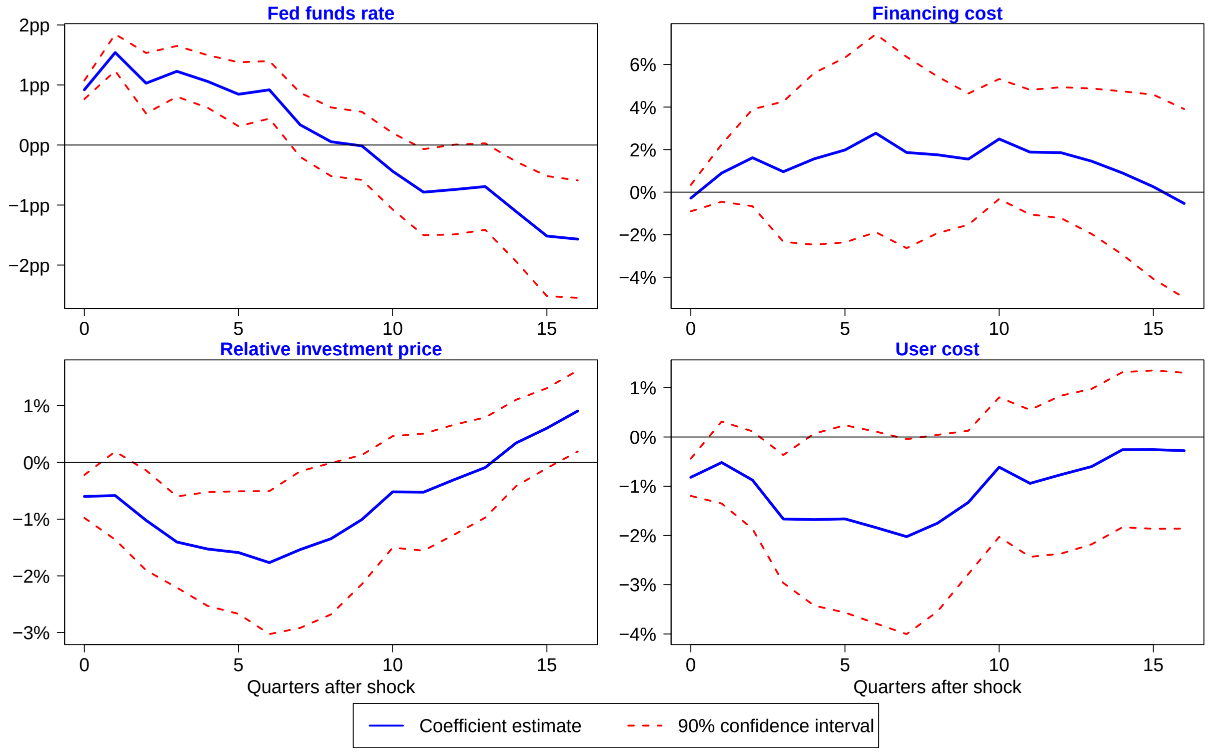

Figure 4: Response of user cost and its components to contractionary monetary shock

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 and GDP growth replacing the linear time trend. 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 annualized average GDP price index inflation rate from 1970-2008 (approximately 4%), with a weight of 0.33. These interest rates are derived by first dividing interest expenses by total debt using the WRDS financial ratio suite, multiplying by 4 to obtain an annual rate, winsorizing the top and bottom 1% of observations, and calculating a mean in each quarter weighted by total debt. Because these observations are sparsely populated prior to 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).

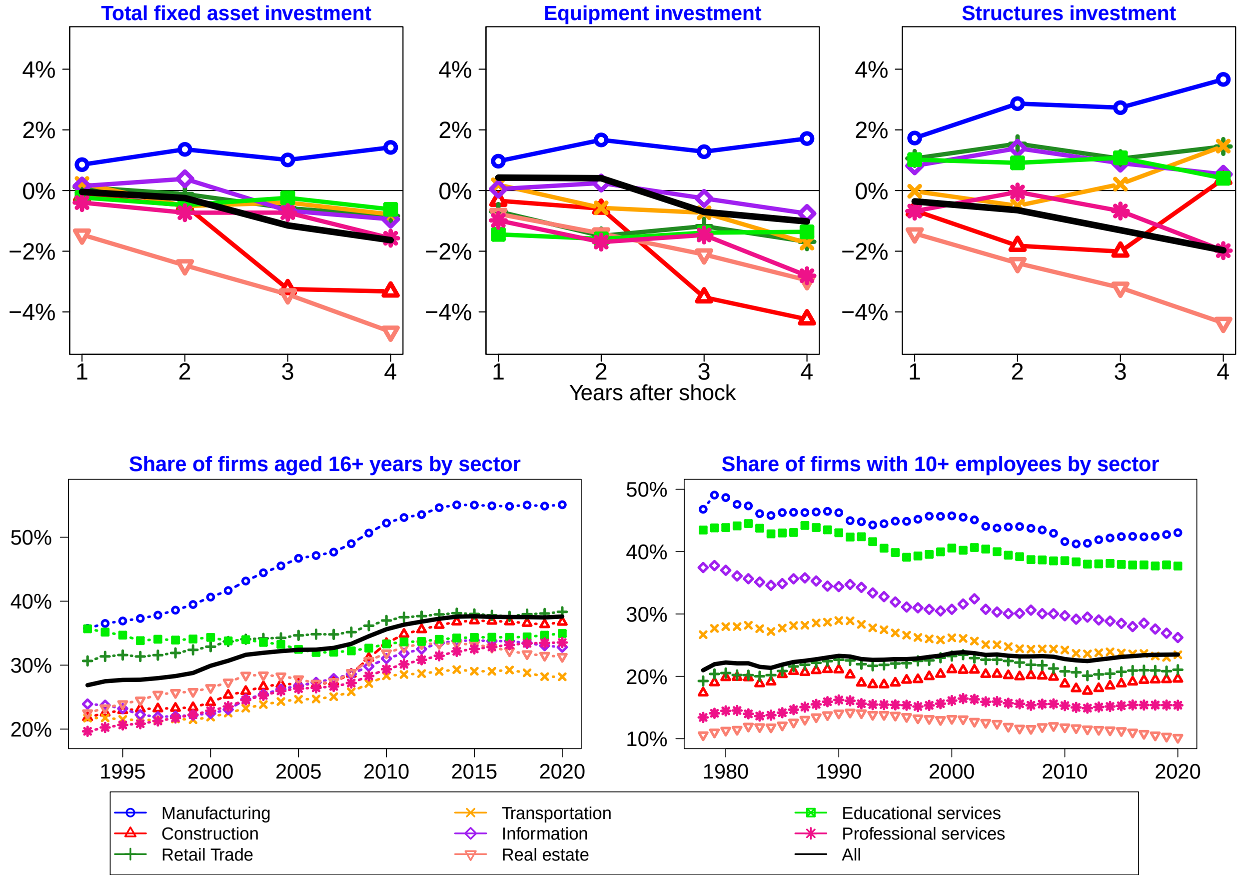

Figure 5: Investment responses and financial constraints by sector

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

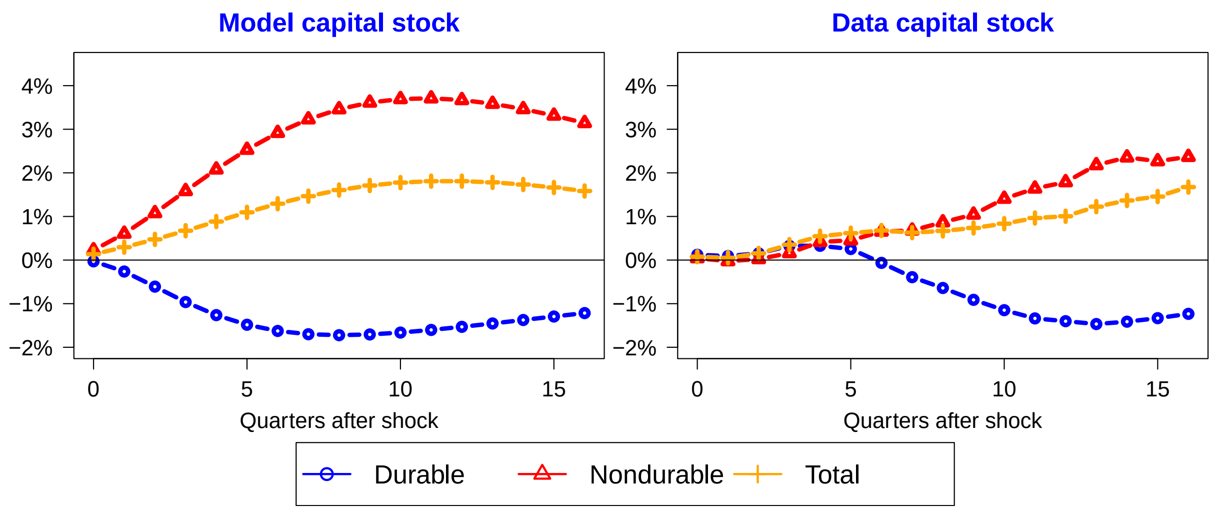

Figure 6: Model and data responses to contractionary MP shock

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.

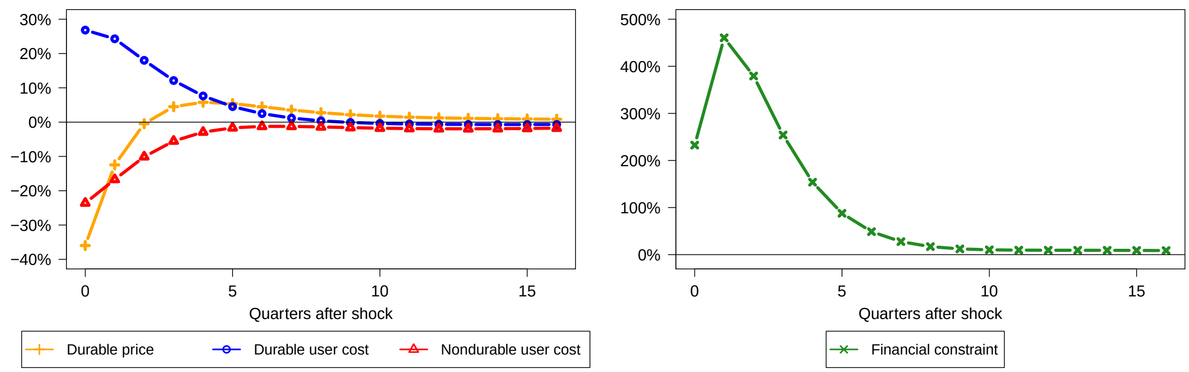

Figure 7: Model user cost responses to contractionary MP shock

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.

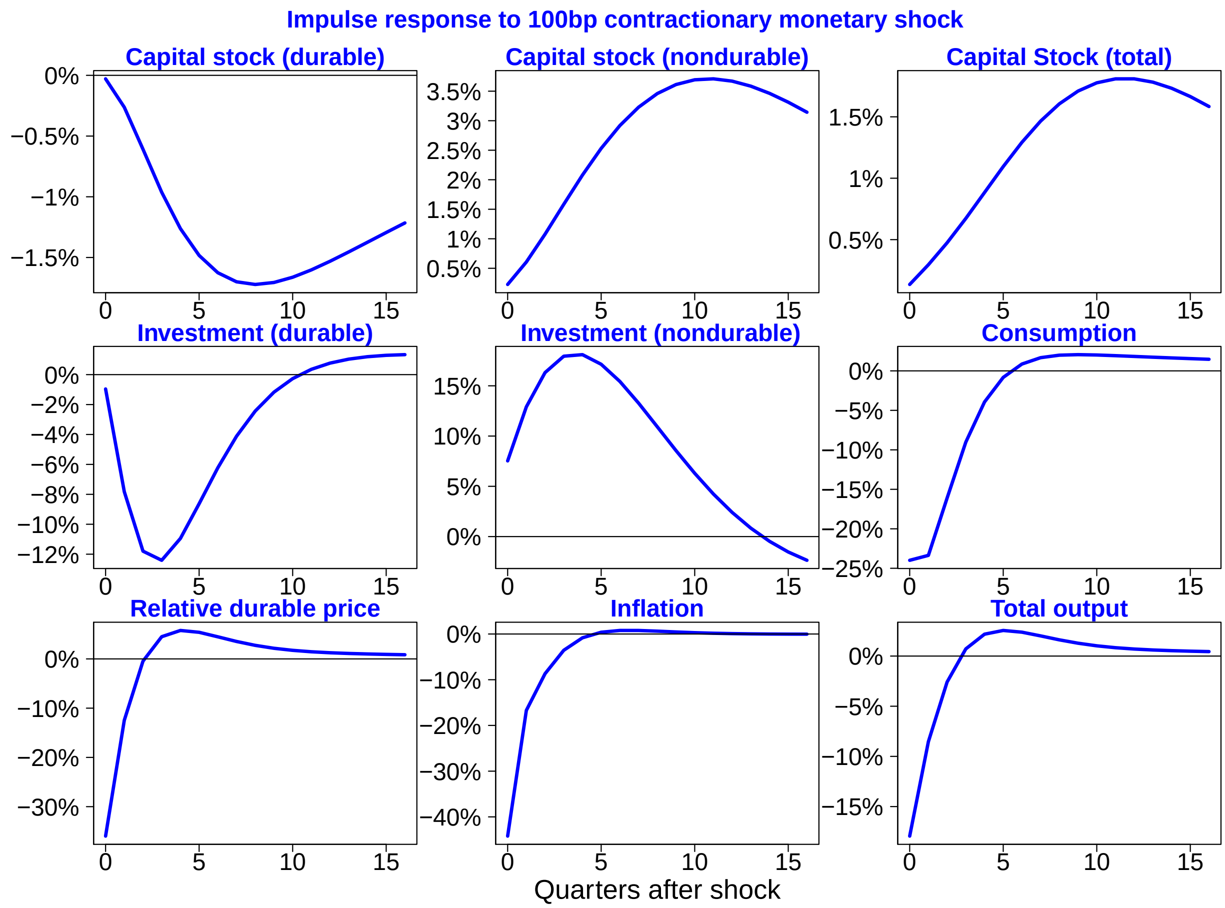

Figure 8: Model impulse responses to contractionary MP shock

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

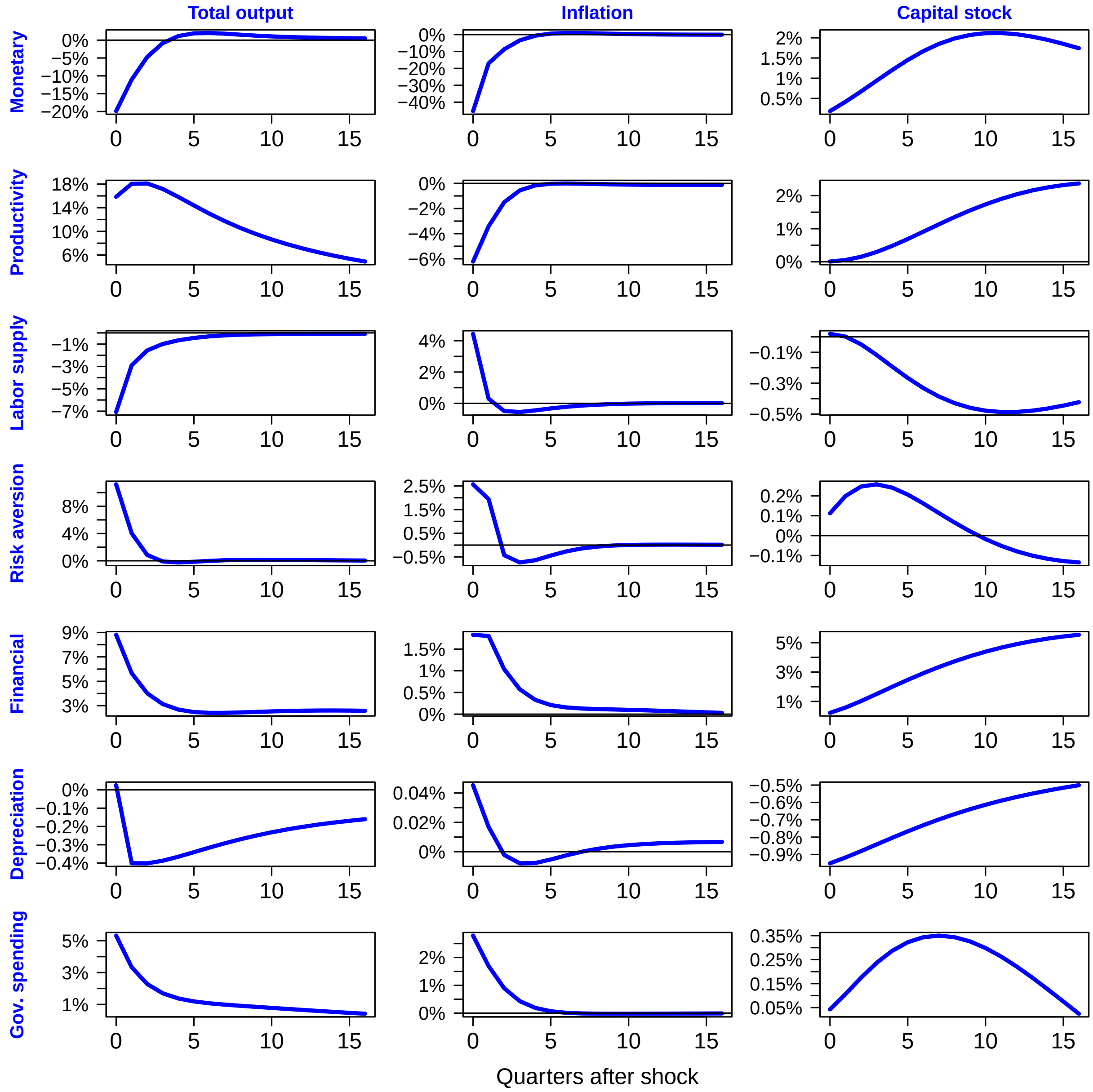

Figure 9: Model impulse responses to a range of shocks

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.

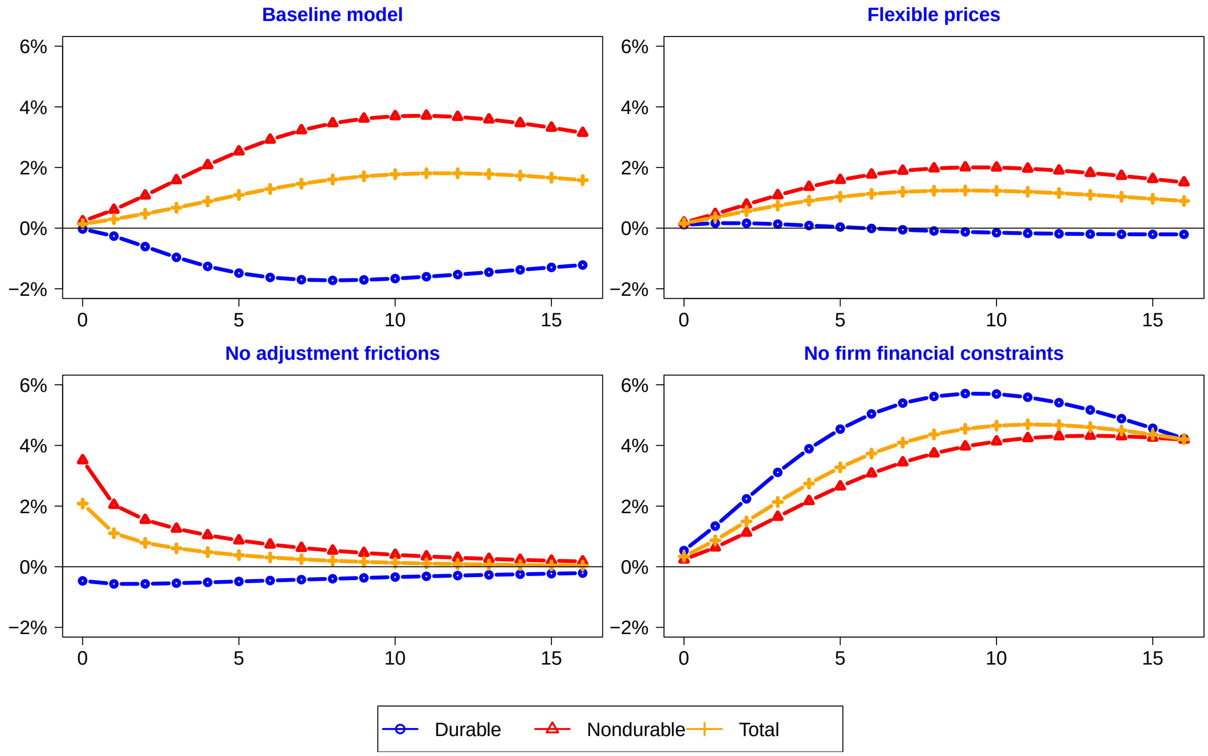

Figure 10: Capital stock responses to MP shock under alternative model assumptions

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.