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Sectoral comovement, monetary policy and the credit channel

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Abstract

Using a structural vector autoregression, we document that a contractionary monetary policy shock triggers a decline in durable and non-durable outputs as well as a contraction in bank equity and a rise in the excess bond premium. The latter points to an important transmission channel of monetary policy via financial markets. It has long been recognized that a standard two-sector New Keynesian model, where durable goods prices are flexible and non-durable and services sticky, does not generate the empirically observed sectoral comovement across expenditure categories in response to a monetary policy shock. We show that introducing financial frictions in a two-sector New Keynesian model can resolve its disconnect with the empirical evidence: a monetary tightening generates not only comovement, but also a rise in credit spreads and a deterioration in bank equity.

Key words: Financial intermediation, sectoral comovement, monetary policy, financial frictions, credit spreads.

JEL classification: E22, E32, E44, E52.

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1 Introduction

A contractionary monetary policy shock, identified using a structural vector-autoregression, triggers a decline in investment and consumption. As shown by Barsky, House, and Kimball (2007) the standard two-sector New Keynesian model with sticky non-durable goods prices and flexible durable goods prices fails to replicate this sectoral comovement in response to a monetary contraction.[1] Our empirical exercise also points towards a transmission mechanism of monetary policy operating through the credit market, as a policy tightening triggers a rise in the excess bond premium. This is important since accounting for frictions in financial markets can resolve the disconnect between theory and evidence. We show that in response to a contractionary monetary policy shock, a two-sector New Keynesian framework with financial frictions can generate a decline in sectoral outputs as well as a tightening in credit conditions, through a rise in credit spreads, as is observed in the data.

We estimate a six-variable SVAR-IV model on US data and employ the monthly external instrument recently proposed by Miranda-Agrippino and Ricco (2017) to identify unexpected (conventional) monetary policy shocks. Using disaggregated industrial production indices, we construct measures for durable and non-durable production. We find that a hike in the policy rate leads to a persistent decline in both expenditure components, a rise in the excess bond premium and a contraction in bank equity. The latter are indicative of frictions in the supply of credit. Our results on sectoral co-movement and the transmission of monetary policy through the credit market are also evident when using quarterly data for aggregate consumption and investment, and identifying the monetary policy shock via standard recursive or sign restrictions.[2]

As argued above, standard two-sector New Keynesian models find it difficult to accommodate for sectoral co-movement. We employ a model, developed in Görtz and Tsoukalas (2017), where frictions in financial intermediation are key to generate responses that are in line with the empirically documented patterns.[3] There are two notable features of this model which distinguish it from the standard New Keynesian framework. First, it has two distinct sectors for the production of investment and consumption goods, respectively. Second, firms

[1]This assumption about pricing is consistent with evidence provided by Bils and Klenow (2004) and Klenow and Kryvtsov (2008) who document that durable prices are more flexible than non-durable prices. In a recent paper, Di Pace and Hertweck (2019) demonstrate that the disconnect with the empirical evidence on co-movement across expenditure categories also occurs in models featuring distinct consumption and investment producing sectors (as opposed to durable and non-durable sectors).

[2]For further empirical evidence on sectoral co-movement, see e.g. Erceg and Levin (2006), Monacelli (2009) or Di Pace and Hertweck (2019). Evidence for a countercyclical response of credit spreads is documented e.g. in Gertler and Karadi (2015), Cesa-Bianchi and Sokol (2017) and Bu, Rogers, and Wu (2021).

[3]Görtz and Tsoukalas (2017) use the model to study the propagation of anticipated technology shocks, but do not discuss the transmission of monetary policy shocks.

in each sector face frictions in the supply of credit as in Gertler and Karadi (2011) which give rise to positive credit spreads. The model consists of standard components and nests for example frameworks such as Justiniano, Primiceri, and Tambalotti (2011), Gertler and Karadi (2011), or the multi-sector model by Huffman and Wynne (1999). Following the evidence in Bils and Klenow (2004) and Klenow and Kryvtsov (2008), we assume that prices in the investment sector are more flexible than in the consumption sector.

In a model version without financial frictions, a contractionary monetary policy shock triggers a decline in inflation which, via the New-Keynesian Phillips curve, implies a reduction in consumption sector output. This reduction in production comes about as the firms in the consumption sector that cannot adjust their prices, have to reduce output to keep pace with the decline in the price level. The drop in consumption dampens demand for factor inputs in that sector, putting downward pressure on the real wage and real marginal cost. Since labor is perfectly mobile, and hence the real wage is common across sectors, this translates into lower marginal costs in the investment sector.[4] For this reason, the real price of investment — as a function of sectoral marginal cost and factor shares — falls, which in turn stimulates the accumulation of capital, and yields a counterfactual response in investment.

Allowing for frictions in financial markets introduces an effect that more than offsets the motive for capital accumulation. The contractionary monetary policy shock implies a drop in the price of capital. This in turn harms equity of financial intermediaries and results in lower lending to finance investment projects. Banks' reduced demand for capital assets, as a result of their poor capitalization, leads to a second round effect that dampens capital prices and lending even further. To rebuild their balance sheets, banks increase credit spreads. In comparison to the model with frictionless financial intermediation, the additional channel that limits lending induces a fall in the production of investment goods. Consistent with the empirical evidence, a contractionary monetary policy shock in the model with financial frictions triggers a decline in sectoral outputs, a rise in credit spreads and a contraction in bank equity.

It has long been recognized that structural models have a hard time generating co-movement across expenditure categories in response to monetary policy shocks. Carlstrom and Fuerst (2010) for example document the co-movement puzzle between durable and non-durable outputs and show that it can be resolved in a model with nominal wage stickiness and durable (housing construction) adjustment costs. In a similar vein, DiCecio (2009) shows that nominal wage rigidities in a New Keynesian model featuring consumption and investment producing sectors can address the co-movement puzzle. Katayama and Kim (2013) and Dey

[4] The assumption of perfect labor mobility and sector-specific capital is standard in multi-sector models. For a discussion see e.g. Huffman and Wynne (1999).

and Tsai (2017) demonstrate that adopting particular preference specifications can help to generate co-movement between expenditure categories.[5]

Another strand of the literature puts emphasis on demand-side collateral constraints in two-sector economies featuring durable and non-durable production (see e.g. Monacelli (2009) and Iacoviello and Neri (2010)). A monetary tightening in such a setting triggers a rise in durable assets trade between borrowers and lenders. As durable prices fall, borrowers attach less value to durable assets, which in turn depresses the collateral value even further. Collateral constraints however render durable prices more sensitive to monetary policy shocks, which, as shown by Sterk (2010), tends to exacerbate the comovement problem (by increasing the demand for durables and giving more incentive to firms to expand durable production due to the fall in real marginal costs). In order to restrict the fluctuations in durable prices, nominal price and wage rigidites are layered to limit the movements in the real marginal cost of production in the durable sector. In contrast to this literature with demand-side collateral constraints, and guided by the empirical evidence of a severe contraction in bank equity, we instead focus on frictions in the supply of credit. In addition, our model can explain the positive credit spread between the lending and the deposit rates which does not feature in the frameworks mentioned above.

We view the supply-side financial channel as an important mechanism to resolve the co-movement puzzle which can be complemented by other mechanisms suggested in the literature. We show explicitly that the effect of the financial channel is strengthened through the introduction of nominal wage rigidities, and we discuss variations in the degree of investment sector price stickiness. However, our work goes beyond earlier suggestions in an important dimension. As a distinguishing feature, the financial channel we highlight does not only allow us to resemble the empirical movements of real expenditure categories, but also the patterns of financial variables such as the excess bond premium and bank equity. As such, our work links to a large literature that emphasizes the importance of financial frictions for the transmission of a variety of economic shocks.[6] In a recent paper, Caldara and Herbst (2019) stress in particular the importance of accounting for movements in the excess bond premium when investigating the effects of monetary policy shocks.

[5]Other real frictions are considered in the literature to solve the comovement problem. Di Pace and Hertweck (2019) argue that allowing for search and matching frictions (and habits in consumption) can match the observed co-movement patterns as well as the persistent decline of sectoral outputs. Di Pace (2008), Sudo (2012), Bouakez, Cardia, and Ruge-Murcia (2011) and Petrella, Rossi, and Santoro (2019) show that inter-sectoral linkages result in greater inertia in the real marginal cost of the durable sector which helps restoring co-movement.

[6]See e.g. Kiyotaki and Moore (1997), Gertler and Kiyotaki (2010), Gertler, Kiyotaki, and Queralto (2012), Christiano, Motto, and Rostagno (2014), Gertler, Kiyotaki, and Prestipino (2016a,b), Gertler, Kiyotaki, and Prestipino (2020) and Görtz, Tsoukalas, and Zanetti (2021).

The remainder of this paper is organized as follows. Section 2 presents the empirical model and results. Section 3 outlines the structural model and inspects the transmission mechanism. Section 4 concludes.

2 Empirical Evidence

2.1 SVAR-IV Identification and Data

We adopt a Vector Autoregressive (VAR) model to study the transmission of monetary policy innovations. In particular, we assume that the dynamics of the variables of interest can be described by a reduced form VAR of order p which takes the form:

$$y_t = \Phi_0 + \Phi_1 y_{t-1} + ... \Phi_p y_{t-p} + \epsilon_t \quad \text{with} \quad \epsilon_t \sim \mathbb{N}\left(0, \Sigma\right),$$

where ϵ_t is a vector of i.i.d. innovations with mean zero and variance $\Sigma = \mathbb{E}\left(\epsilon_t \epsilon_t^{'}\right)$. Φ_0, Φ_1, ...,Φ_p are matrices of appropriate dimensions capturing the dynamics of the system. y_t is a $N \times 1$ vector that contains the observations for N variables at monthly frequencies for the US.

The set of observable variables include the log of the consumer price index (CPI), the log of real industrial production (IP) durable investment, the log of real IP non-durable consumption goods, the log of real industrial production, the monthly 1-year Treasury Bill (TB) constant maturity rate, and the excess bond premium (EBP). The monthly investment and non-durable consumption series have been constructed using the Industrial Production and Capacity Utilization tables published by the Federal Reserve Board. Monthly (gross value) industrial production for investment is computed by removing non-durable consumption and defense spending through the adoption of relative importance weights. Details on the sources and construction of all variables used in this section can be found in Appendix A. We consider a sample from $1973M1$ to $2009M12$, as EBP data is only available from $1973M1$. We exclude the period when the policy rate hits the zero lower bound as our focus is on conventional monetary policy. We set the lag length of the VAR to 12 as is standard when employing monthly data. The reduced form VAR is estimated using Bayesian techniques. We adopt Jeffrey (non-informative) priors, and $5,000$ draws are generated from the posterior distribution of the parameters using a Gibbs sampler algorithm.[7]

Miranda-Agrippino and Ricco (2017) construct an informationally-robust high-frequency instrument for monetary policy shocks by projecting market-based monetary surprises on

[7] We facilitate the estimation using the Toolbox developed by Canova and Ferroni (2020).

their own lags and on the central bank's information set.[8] The external instrument is available for the period $1991M1$ to $2009M12$ and Miranda-Agrippino and Ricco (2017) show that the identification approach is not subject to either price or output puzzles. We employ this instrument to identify monetary policy shocks in an SVAR-IV (see Stock and Watson (2012, 2018); Mertens and Ravn (2013)). The idea behind this approach is that the disturbance of interest is identified by the predicted value in the regression of a reduced form VAR innovation on the instrument. For the approach to provide valid inference we need the instrument to be relevant (i.e. correlated with the disturbance of interest) and exogenous (uncorrelated with the other disturbances).[9]

2.2 SVAR-IV Results

Figure 1 reports the impulse responses to a one standard deviation unexpected contractionary monetary policy shock. We report the median response from the posterior distribution as well as the 68% and 90% confidence sets. In response to an interest rate hike output, measured by industrial production, falls persistently. This, as well as the decline in CPI, is in line with the findings in Miranda-Agrippino and Ricco (2017). What our exercise adds is that we document co-movement across expenditure categories alongside a significant rise in the excess bond premium. Both, durable investment and non-durable consumption decline. In particular, the former responds more strongly to the monetary tightening than the latter. Gilchrist and Zakrajsek (2012) argue that the excess bond premium captures credit supply conditions in the economy, so that the significant increase in this measure, shown in Figure 1, indicates a tightening in credit supply.[10]

The results above point towards a transmission mechanism of monetary policy operating through the credit channel. The tightening in credit conditions can, in the context of a

[8]The market based surprises are high-frequency price revisions in traded interest rates futures triggered by a policy announcement. The central bank's information set is captured by Greenbook forecasts.

[9]For a correctly specified VAR being able to capture the data generating process, and under the assumption of invertibility in the structural shocks, the validity of an instrument z_t to identify a shock of interest – e.g. a monetary policy shock ν_t^{mp} – depends on the following set of conditions:

$$(i) \quad \mathbb{E}\left[\nu_t^{mp} z_t^{'}\right] = \phi,$$
$$(ii) \quad \mathbb{E}\left[\nu_t^{\not{mp}}\right] = 0,$$

where ν_t^{mp} and $\nu_t^{\not{mp}}$ denote the monetary policy shock and any other shock in the system respectively. The structural shocks ν_t are invertible if $\epsilon_t = \Omega \nu_t$, where Ω identifies the mapping between the structural shocks and the reduced-form one-step-ahead forecast errors.

[10]These results are robust to using the Federal Funds Rate instead of the 1-year Treasury Bill rate. The same holds if we extend the sample up to $2019M12$, which also includes times of unconventional monetary policy and policy rates at the zero lower bound. Details are provided in Appendix B.

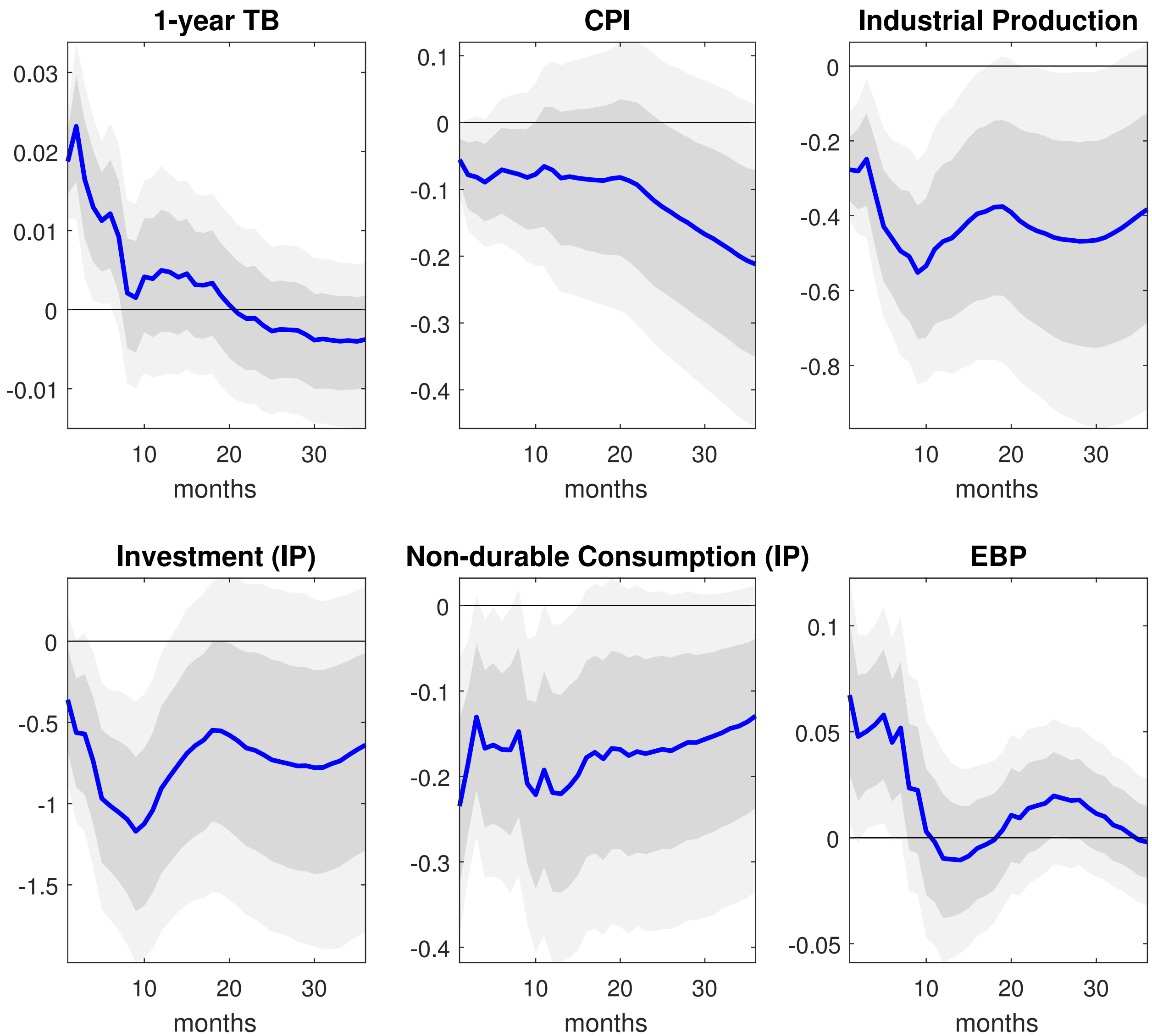

Figure 1: Impulse responses to an unexpected monetary tightening

Notes: This figure shows the (monthly) empirical impulse responses to a (one standard deviation) monetary policy shock. The median monthly response is shown in solid blue, with the dark and light grey areas denoting the 68% and 90% confidence bands respectively. With the exception of the 1-year Treasury Bill (TB) rate and the Excess Bond Premium (EBP), responses are expressed in percentage deviations. Rates and premiums are expressed in percentage points.

structural model, in principle be helpful to facilitate co-movement of sectoral outputs. To further understand the workings of the financial channel and thereby inform the mechanism in the structural model considered below, we inspect the response of commercial bank's equity to the monetary policy shock.[11] Figure 2 shows the responses to a contractionary

[11] We obtain the market value of commercial bank's equity from the Center for Research in Security Prices (CRSP). Details are provided in Appendix A.

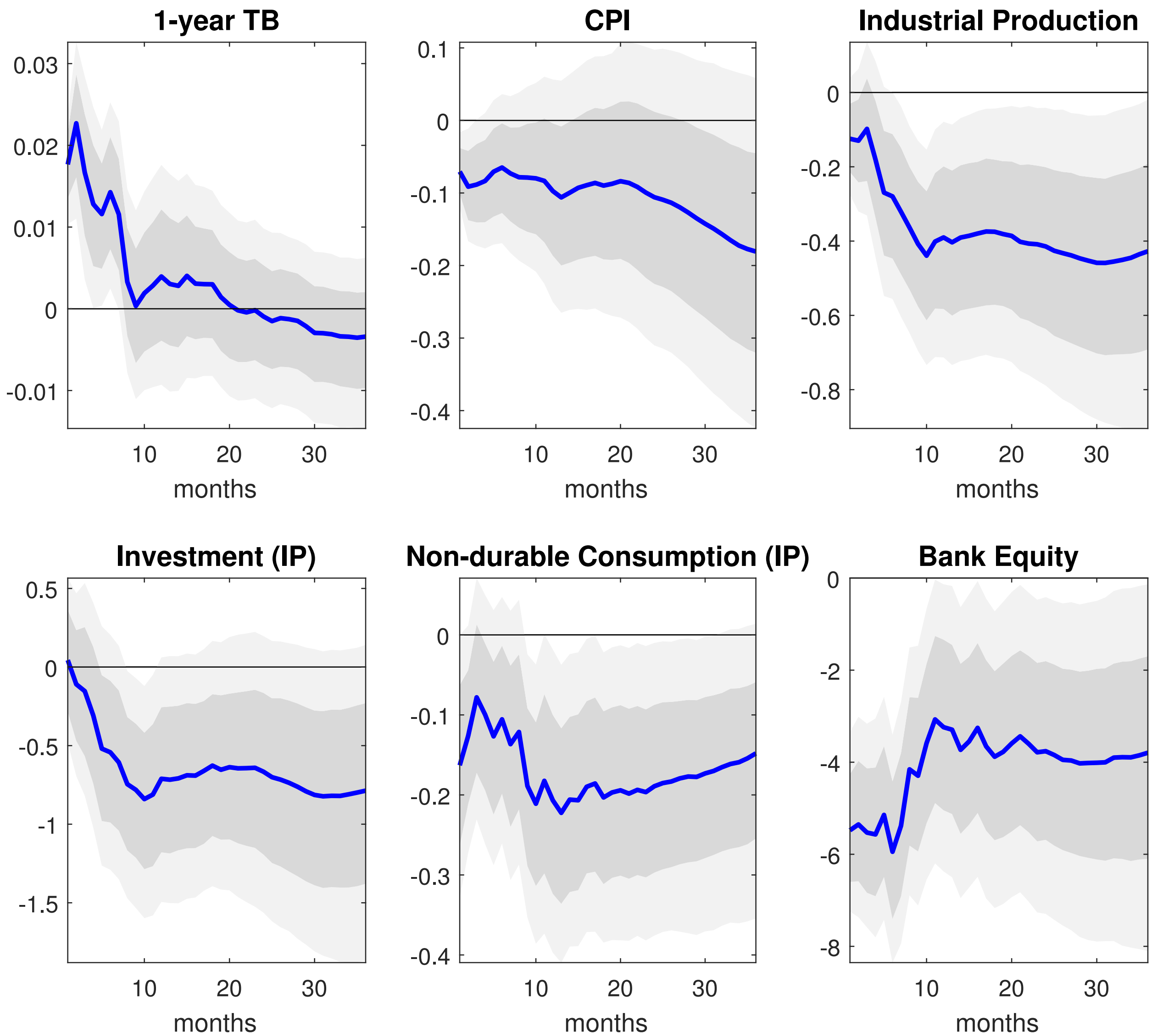

Figure 2: Impulse responses to an unexpected monetary tightening

Notes: This figure shows the (monthly) empirical impulse responses to a (one standard deviation) monetary policy shock. The median monthly response is shown in solid blue, with the dark and light grey areas denoting the 68% and 90% confidence bands respectively. With the exception of the 1-year Treasury Bill (TB), responses are expressed in percentage deviations. The policy rate is expressed in percentage points.

monetary policy shock when we replace the excess bond premium with bank equity in our VAR system. The responses of CPI and the activity variables are very similar to the ones reported in Figure 1. The important takeaway from Figure 2 is that bank equity contracts substantially in response to a monetary tightening which is indicative of severe frictions in the supply of credit, generating greater persistence in the responses of all variables.

Our results are relevant also insofar as the (conditional) procyclicality of sectoral outputs and the countercyclical response of the excess bond premium are consistent with variables' respective unconditional correlations with aggregate output. After detrending, using the methodology proposed by Hamilton (2018), we find that unconditional correlations between the aggregate IP index and (IP) non-durable consumption, (IP) durable investment and the excess bond premium are 0.71, 0.93 and -0.28 respectively. The correlation between the durable and non-durable measures is 0.40. These unconditional statistics support the notion that our identified monetary policy shocks are potentially relevant driving forces of aggregate fluctuations.

2.3 Robustness on Shock Identification and Data Frequency

The use of industrial production for the identification of monetary policy shocks at monthly frequency is appealing, yet our constructed measure for (IP) non-durable consumption excludes services which is not available at monthly frequency. This implies that in the above exercise we may miss large part of the variation in aggregate consumption. Other studies, such as e.g. Justiniano, Primiceri, and Tambalotti (2010), use a quarterly measures of aggregate consumption, that consist of chain-linking non-durable consumption and services, and also an aggregate investment measure, which is computed by combining fixed investment and durable consumption. We therefore adopt these more conventional measures of aggregate consumption and investment to evaluate co-movement patterns in response to monetary policy shocks at quarterly frequencies. We further scrutinize the robustness of our findings by identifying a monetary policy shock using recursive schemes and sign restrictions.

In our quarterly VAR specifications the observable variables are the log of the consumption deflator, the log of investment, the log of consumption, the log of gross domestic product (GDP), the quarterly 1-year treasury bill constant maturity rate, and the excess bond premium. Investment, consumption and GDP are all expressed in real per-capita terms. Details on the variable construction and data sources are provided in Appendix A. Consistent with the monthly VAR, the sample size ranges from $1973Q1$ until $2009Q4$.

Using the quarterly VAR, we first apply a recursive identification scheme. The identification strategy to retrieve the monetary policy innovation from the rotation matrix consists of assuming a recursive timing restriction on the variables in the VAR. Our identification is such that a shock to the policy rate only has an instantaneous effect on the excess bond premium (i.e., the assumption that financial variables respond on impact to the monetary shock). This implies that all the other variables do not react contemporaneously to changes in the 1-year treasury bill rate. The rate instead responds contemporaneously to all the

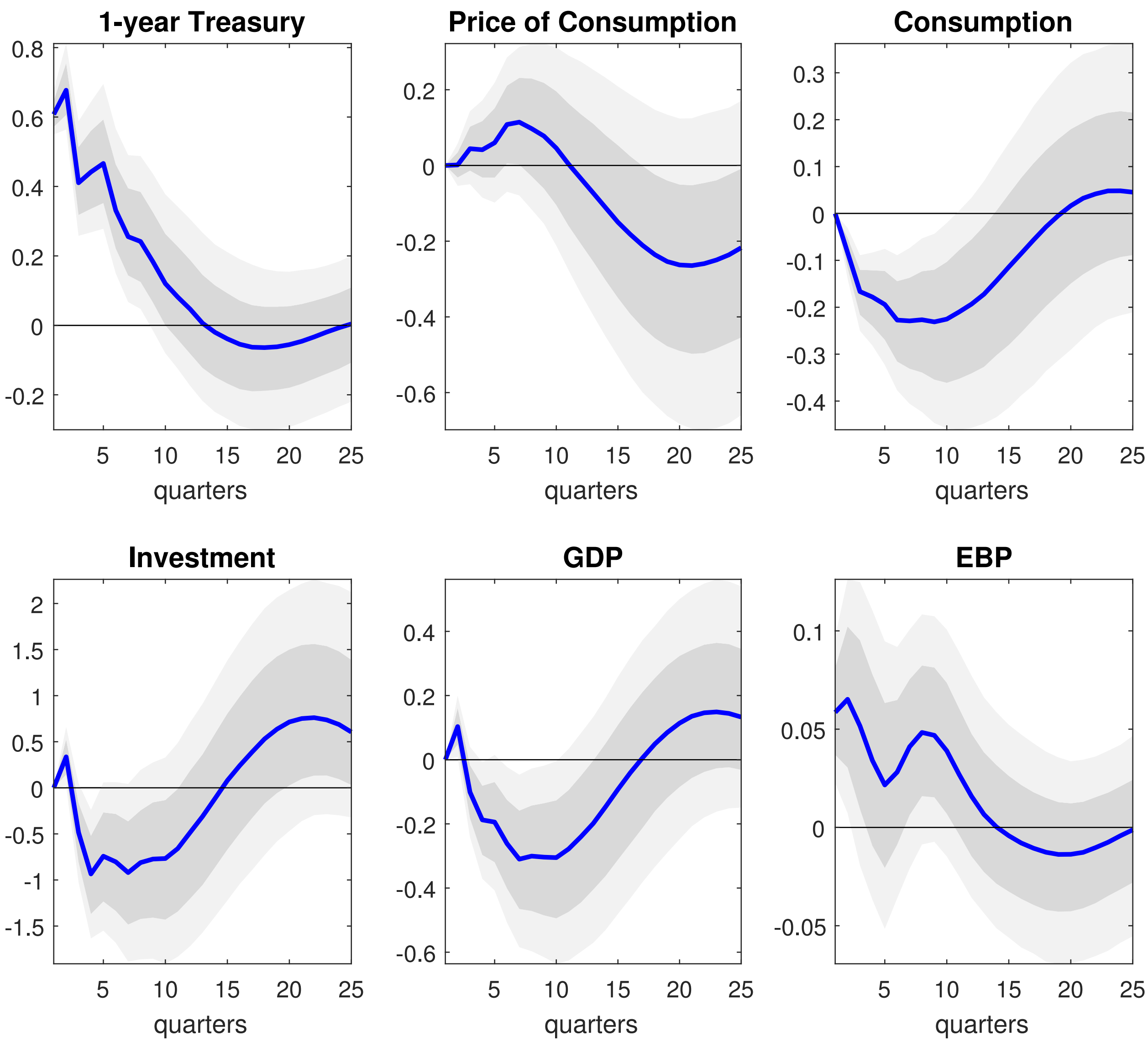

Figure 3: Impulse responses to an unexpected monetary tightening: recursive identification scheme

Notes: This figure shows the (quarterly) empirical impulse responses to a (one standard deviation) monetary policy shock identified under a recursive identification scheme. The median (quarterly) response is shown in solid blue, with the dark and light grey areas denoting the 68% and 90% confidence bands respectively. With the exception of the 1-year Treasury (Bill) rate and the Excess Bond Premium (EBP), responses are expressed in percentage deviations. Rates and premiums are expressed in percentage points.

Figure 3 shows impulse responses to a (one standard deviation) monetary policy shock (tightening). In line with the findings in Section 2.2 above, an unexpected rise in the interest

[12]We estimate the VARs using Bayesian methods with non-informative priors. We set the lag length to four.

rate leads to a contraction in GDP, consumption and investment. Also the rise in the excess bond premium is in line with results obtained under the high frequency identification. Note that consumption prices increase in the short term (yet not significantly), exhibiting the well known price puzzle, before they decline in the long run.[13]

Since the price puzzle in Figure 3 may be of concern, we further identify monetary policy shocks using sign restrictions in the quarterly VAR as in Faust (1998), Canova and Nicolo (2002), and Uhlig (2005). The advantage of this approach is that the sign restrictions are in line with the predictions of a wide range of general equilibrium models and also with prior beliefs accepted by researchers. The sign restrictions are specified such that price and quantities fall for five quarters after an expected monetary tightening. We leave the sign of the excess bond premium unrestricted. The sign restrictions for the monetary policy shock are summarized in Table 1.

Table 1: Sign Restrictions

Shock/Variable	1-year TB	Prices	Consumption	Investment	GDP	EBP
MP	+	-	-	-	-	

Notes: Blank entries denote that no sign restriction is imposed. The sign restrictions are imposed for five quarters.

Based on this identification, Figure 4 exhibits the impulse responses to a (one standard deviation) monetary tightening. The figure shows patterns consistent with the results using the instrumental variable approach in that the monetary policy shock is deflationary. Also the co-movement patterns of expenditure categories and the tightening in credit conditions are consistent with the two other identification schemes. Overall, we note that the patterns documented in this section are robust: a tightening in monetary policy leads to a decline in output of the investment and consumption producing sectors, a rise in the excess bond premium and a drop in bank equity. The decline of investment is more pronounced than the one of consumption. In the next section, we turn to a structural model that can qualitatively generate such dynamics.

[13]The results with bank equity in lieu of the excess bond premium are robust to using other identification strategies.

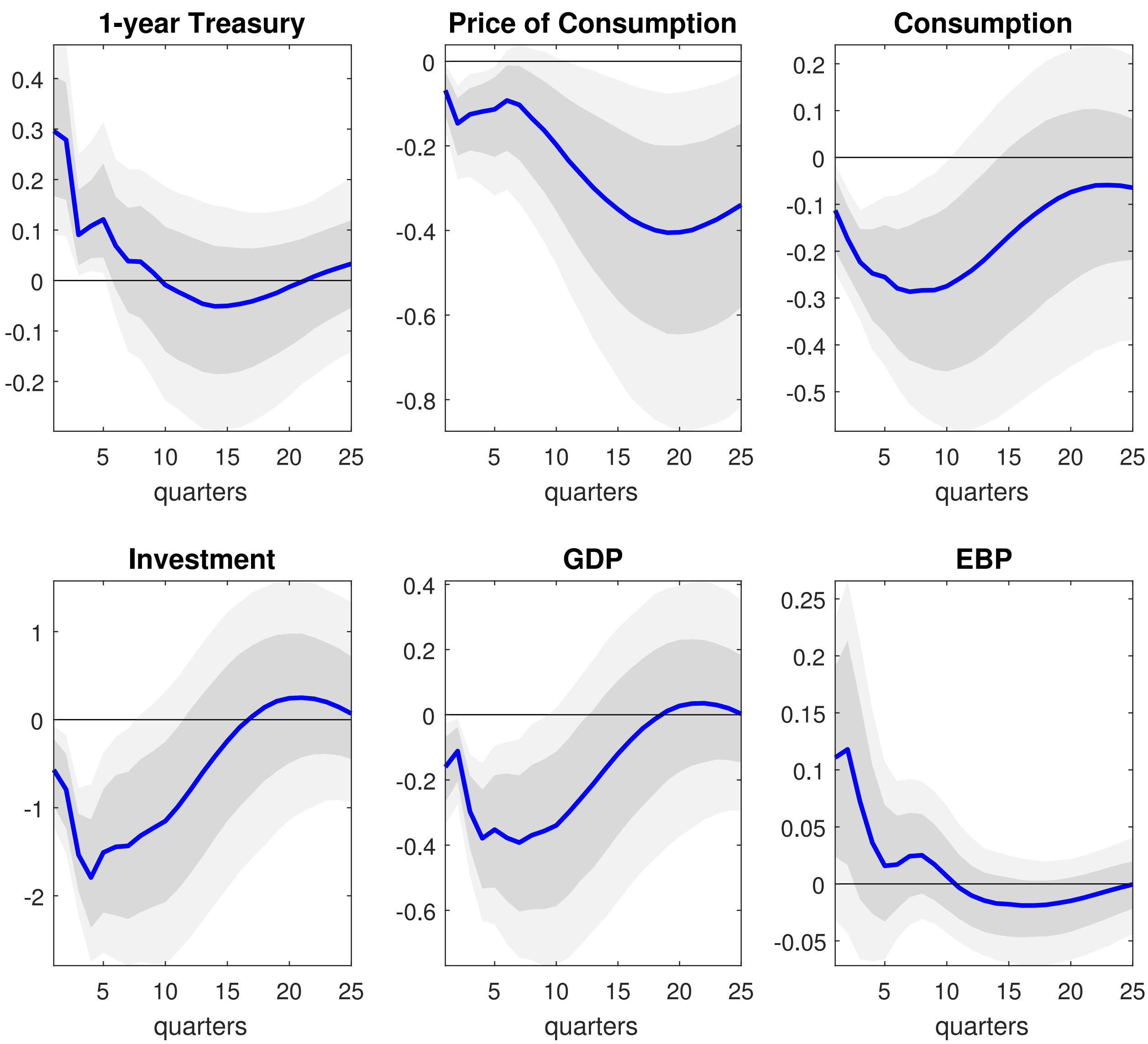

Figure 4: Impulse responses to an unexpected monetary tightening: identification using sign restrictions

Notes: This figure illustrats the (quarterly) empirical impulse responses to a (one standard deviation) monetary policy shock identified under sign restrictions. The median (quarterly) response is shown in solid blue, with the dark and light grey areas denoting the 68% and 90% confidence bands respectively. With the exception of the 1-year Treasury (Bill) rates and the Excess Bond Premium (EBP), responses are expressed in percentage deviations. Rates and premiums are expressed in percentage points.

3 A Two-Sector Model with Financial Frictions

3.1 Model Overview

The baseline model we adopt is akin to Görtz and Tsoukalas (2017) which nests for example the widely used models by Justiniano et al. (2010) and Huffman and Wynne (1999). Our baseline model can be interpreted as a two-sector version of the former, or a version with nominal rigidities of the latter framework. Our baseline model differs from these models in that it includes supply-side frictions in financial intermediation as in Gertler and Karadi (2011). In the following, we provide only a brief overview about the model as it consists of components that are by now relatively standard in the literature. A detailed exposition of the model is provided in Appendix C.[14]

The model comprises of two production sectors, one for investment goods and the other one for consumption goods. In each sector, a continuum of sector-specific firms use capital and labor to produce intermediate sectoral output goods. The firms are subject to sector-specific pricing contracts (as in Calvo (1983)) when re-setting prices. The sectors are connected in a way that firms from both sectors use the output goods of the investment sector to build and maintain their respective capital stocks. As it is standard in many multi-sector models, capital is assumed to be sector-specific, but labor is assumed to be fully mobile.[15]

In addition to nominal price rigidities, the model features a standard set of real rigidities — investment adjustment costs, habit formation and variable capacity utilization — that the literature introduced to help matching the hump shaped responses in the data. Households consume non-durable goods, supply labor for production and save in the form of interest-bearing deposits. Sector-specific financial intermediaries collect deposits from households and use these, together with their own equity, to finance firms' acquisition of capital. This financial channel in the model is subject to leverage constraints as in Gertler and Karadi (2011) and Gertler and Kiyotaki (2010). Financial intermediaries are limited from infinitely borrowing households' funds by a moral hazard/costly enforcement problem. This moral hazard problem introduces an endogenous leverage constraint, so that these frictions in financial markets limit the banks' ability to acquire assets. Finally, there is a monetary authority that sets the nominal interest rate following a Taylor rule.

We rely on the estimates in Görtz and Tsoukalas (2017) — who estimate the quarterly model using Bayesian techniques — to assign parameter values. Their estimates are also

[14] The model can also be interpreted as a version of the framework in DiCecio (2009) enriched with frictions in financial markets.

[15] Limited capital mobility is known to be able to correct many counterfactual predictions of one sector models with respect to both aggregate quantities and asset returns (see e.g. Huffman and Wynne (1999) and Papanikolaou (2011).

broadly in line with those in Justiniano et al. (2010) and Khan and Tsoukalas (2012). Details of the model's calibration are provided in Appendix C.2. Our only deviation from the parameter estimates is that we assume prices in the investment sector to be fully flexible. We do so to stay close to the micro-econometric evidence, which suggests that durable prices are flexible (see e.g. Bils and Klenow 2004 and Klenow and Kryvtsov 2008), and to retain comparability with previous studies on the co-movement puzzle who conformed to this assumption (see e.g. Monacelli (2009), Carlstrom and Fuerst (2010) and Katayama and Kim (2013)). We show in the next section that our results are robust to deviating from the assumption of fully flexible prices in the investment sector and also hold using the estimates in Görtz and Tsoukalas (2017) for all parameters.

3.2 Sectoral Co-movement and the Response of Credit Spreads

In this section, we use the structural model to investigate whether the theoretical impulse responses are in line with their empirical counterpart as documented in Section 2: a contraction in the production of both consumption and investment goods, and a rise in credit spreads.

Figures 5 and 6 show the baseline model's responses to a one standard deviation contractionary monetary policy shock (solid lines). The rise in the policy rate triggers a decline in total output, as well as in investment and consumption. Consistent with the empirical evidence, the drop in investment sector production is larger than the one in the consumption goods producing sector. The contraction in sectoral outputs comes along with a fall in hours worked and a reduction in the real wage and real marginal cost. The resulting decline in inflation is in line with the empirical evidence, which also holds for the observed hike in credit spreads and the decline in bank equity. Overall, we find our baseline model with frictions in financial markets is able to match well the empirical responses documented in Section 2.

Figures 5 and 6 also include responses of a restricted model which abstracts from financial frictions (dash-dotted lines).[16] It is well known that this type of standard New Keynesian model fails to replicate the co-movement of sectoral outputs in response to a monetary contraction (see e.g. Barsky et al. (2007)). Our exercise confirms this finding. The model variant without financial frictions displays a decline in consumption and aggregate output, but it falls short of delivering co-movement as investment goods production increases. It is evident from Figure 5 that the counterfactual positive response in investment is even more pronounced in the absence of investment adjustment costs. In a model variant without financial frictions and without investment adjustment costs (dashed lines), we observe a

[16] The parametrization for this model is shown in Appendix C.2 and is consistent with estimates in Görtz and Tsoukalas (2017) for this model variant.

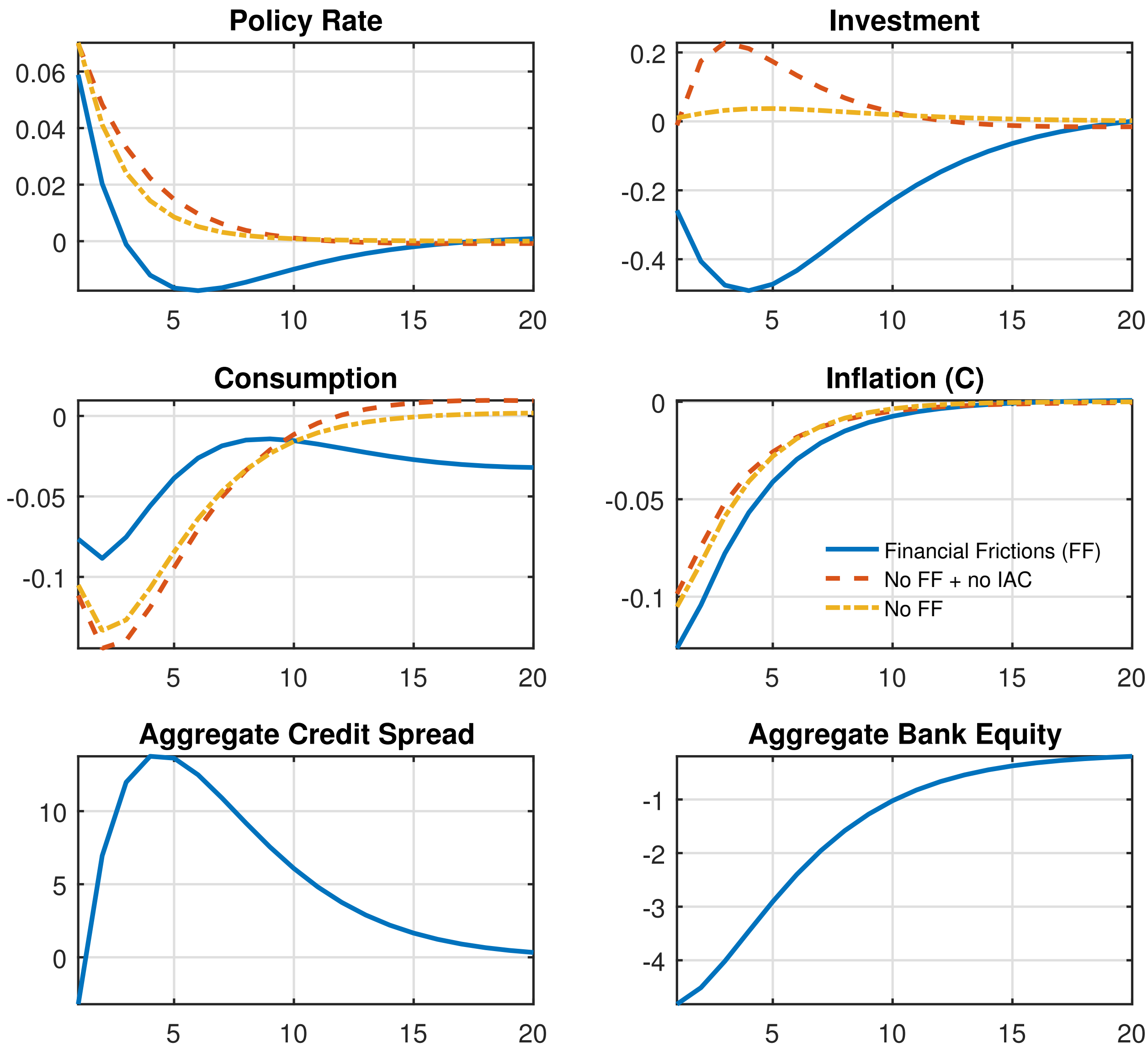

Figure 5: Impulse responses to a monetary contraction.

Notes: This figure shows the impulse responses to a (one standard deviation) monetary policy shock in the baseline model - featuring financial frictions - (solid blue lines) and in the frictionless model (dash-dotted red lines). Responses are expressed in percentage deviations from steady state values. Aggregate credit spreads and aggregate bank equity are computed as a weighted average between the corresponding sectoral variables. In the legend IAC denotes investment adjustment costs.

substantial expansion in the accumulation of physical capital.

Why does the standard New Keynesian two-sector model fail to deliver the co-movement of consumption and investment? In the model version without financial frictions (dash-dotted lines), a rise in the policy rate comes along with a decline in inflation. The latter implies, via the New-Keynesian Phillips curve, a drop in goods produced in the consumption sector. The reason is that firms which cannot adjust their prices have to reduce output to keep pace

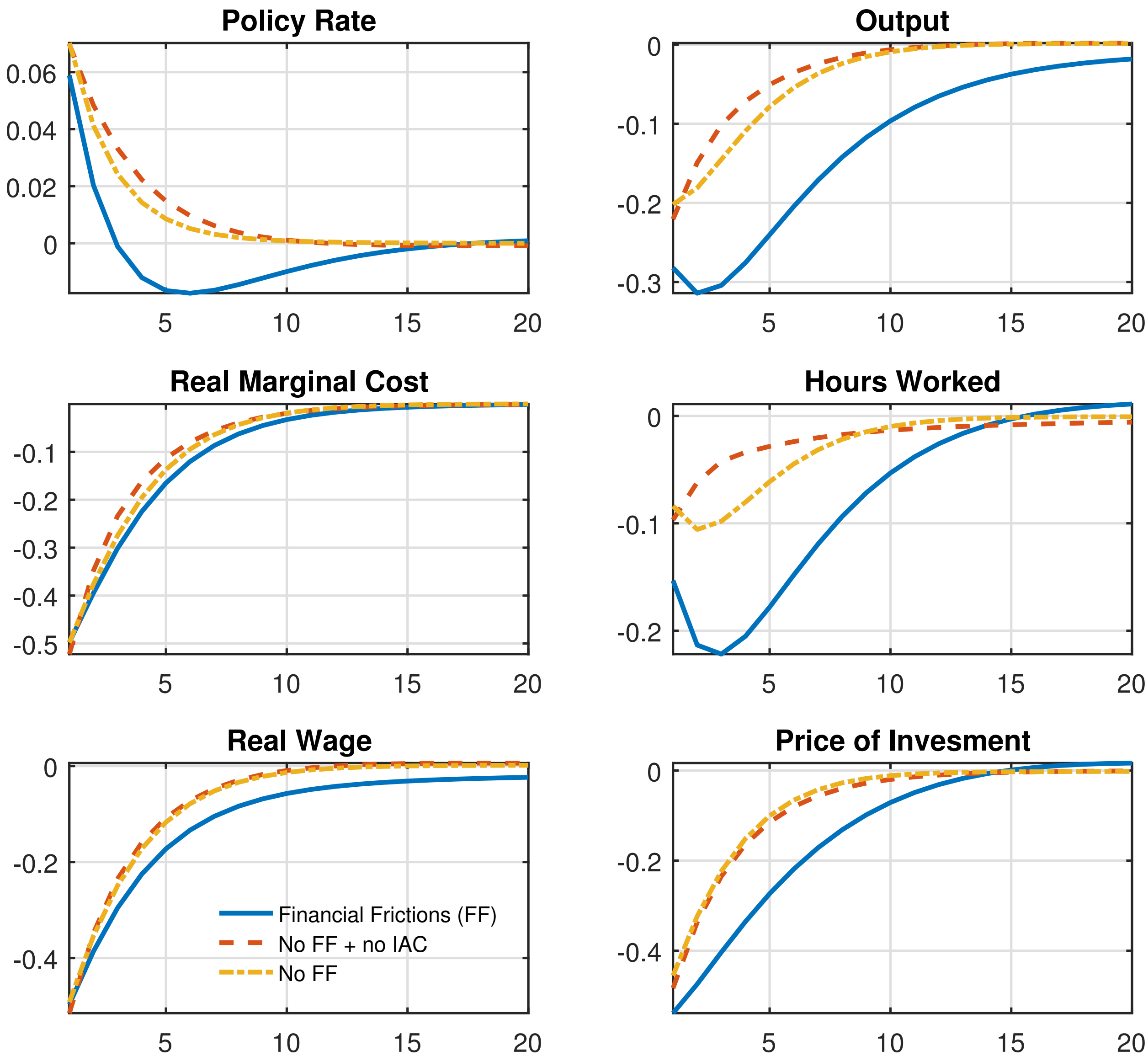

Figure 6: Impulse responses to a monetary contraction.

Notes: This figure shows the impulse responses to a (one standard deviation) monetary policy shock in the baseline model - featuring financial frictions - (solid blue lines) and in the frictionless model (dash-dotted red lines). Responses are expressed in percentage deviations from steady state values. Aggregate credit spreads and aggregate bank equity are computed as a weighted average between the corresponding sectoral variables. In the legend IAC denotes investment adjustment costs.

with the decline in the price level.[17] This comes along with a reduction in input demands in the consumption sector (i.e. capital and labor), which in turn puts downward pressure on the real wage and sectoral rental rates, and hence translates into a lower sectoral real marginal cost. Due to the assumption of perfect labor mobility, the real wage is common

[17] See Rupert and Sustek (2019) who show that the monetary policy transmission mechanism in New-Keynesian models does not, as conventionally assumed, operate through the real interest rate channel.

across sectors. So the drop in the real wage also implies lower production costs for the investment sector at the margin. This is reflected in a decline in the real price of investment, which is a function of sectoral marginal cost and sectoral factor shares. The lower price for investment goods stimulates the accumulation of capital and drives up the production of investment goods.

Having understood the shock transmission in the model without financial frictions, what are the mechanisms that allow for co-movement of investment and consumption in the baseline model? The transmission mechanism outlined for the model without financial frictions is also present in our baseline model. However, in addition to the already discussed reduction in demand for consumption goods and the decline in factor prices, the baseline model exhibits an additional channel that dampens the accumulation of investment goods due to an endogenous weakening in bank's financial position. The additional dynamic responses of the baseline model provided in Figure 7 can help to illustrate this channel. The contractionary monetary policy shock leads to a drop in the price of capital (Tobin's marginal Q). Financial intermediaries collateralize against the physical capital stock so that a lower price of capital results in a fall in the value of their capital claims, and subsequently in a deterioration of their equity capital. The substantial decline in bank's net worth shown in Figure 7 is consistent with the empirical evidence on the severe contraction of bank equity reported in Section 2.2. This is important as the dynamics of bank's equity capital are behind a sharp contraction in credit supply. Since banks are leverage constrained, the decline in bank equity exacerbates the amount of lending to the real economy, and hence results in reduced funding of investment projects. The latter, in a second round effect, dampens the price of capital further and harms lending even further. So the tightening of credit conditions in the baseline model is the channel, in comparison to the frictionless model, that limits the financing of investment projects and thereby induces a contraction in investment. Alongside the reduction in consumption, the fall in investment is consistent with the empirical evidence on co-movement of sectoral outputs.

To rebuild balance sheets, financial intermediaries increase the spread between the interest rate charged on loans and the interest rate paid on deposits — the latter is equal to the policy rate in the model. This rise in sectoral credit spreads shown in Figure 7 is consistent with the empirical responses in aggregate spreads discussed in Section 2. When financial intermediation is frictionless, there is no wedge between loan and deposit rates. Our model without financial frictions, like the other existing frameworks suggested in the literature to resolve the co-movement puzzle, falls short in jointly matching the dynamics of real and financial variables in response to a monetary policy shock, thereby neglecting an important channel for the transmission of the monetary policy shock. With respect to

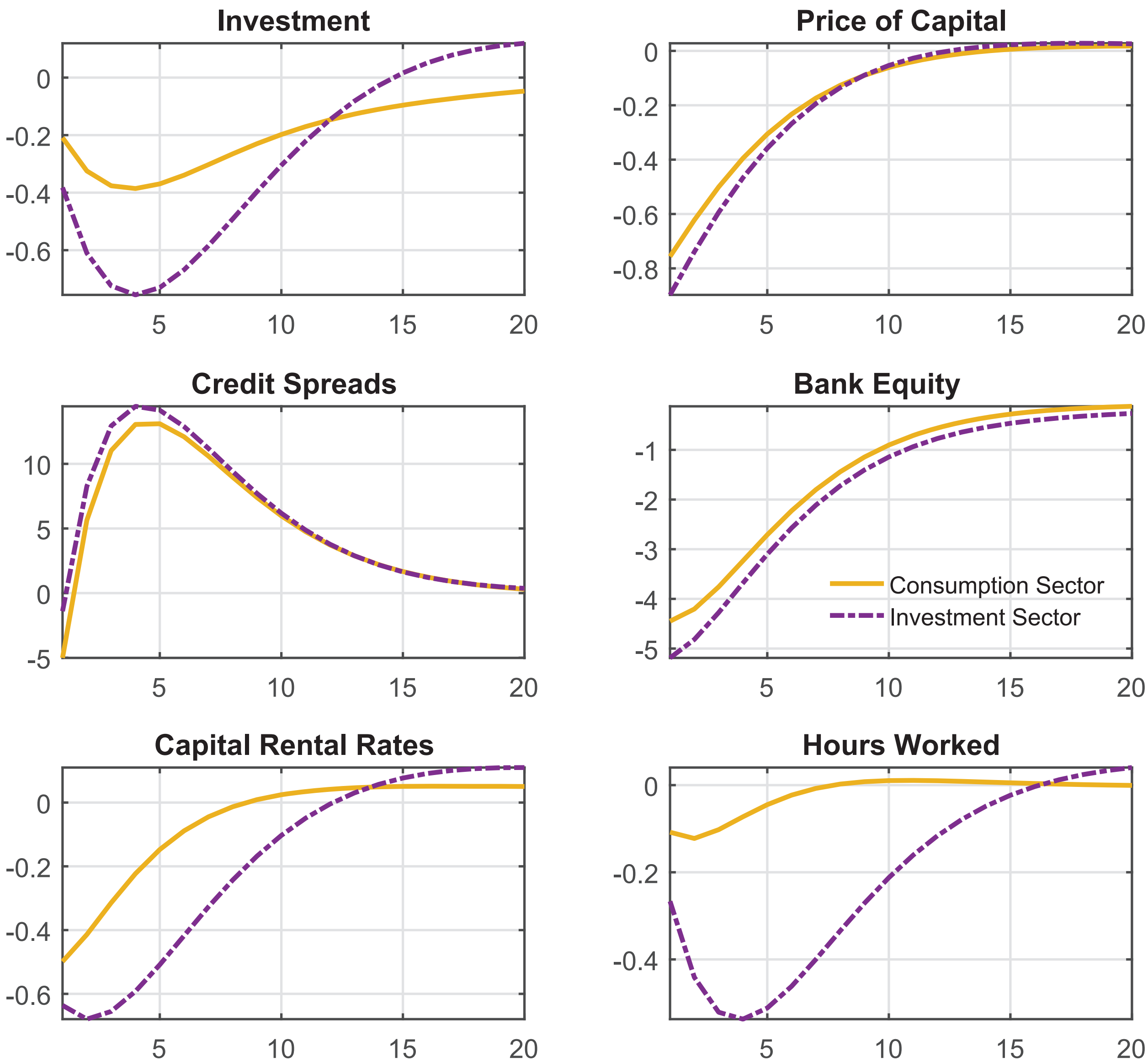

Figure 7: Impulse responses to a monetary contraction — sectoral variables of the baseline model

Notes: This figure shows the impulse responses to a (one standard deviation) monetary policy shock to variables in the consumption sector (solid yellow lines) and in the investment sector (dash-dotted purple lines). Responses of sectoral credit are expressed in basis points. Responses of all remaining variables are expressed in percentage deviations from steady state values.

facilitating co-movement of sectoral expenditure categories, and in light of the empirical evidence on the importance of credit conditions for macroeconomic outcomes, we view the transmission channel operating via frictions in financial markets as one that should not be ignored.

Next, we briefly discuss the inclusion of additional channels suggested in the literature and

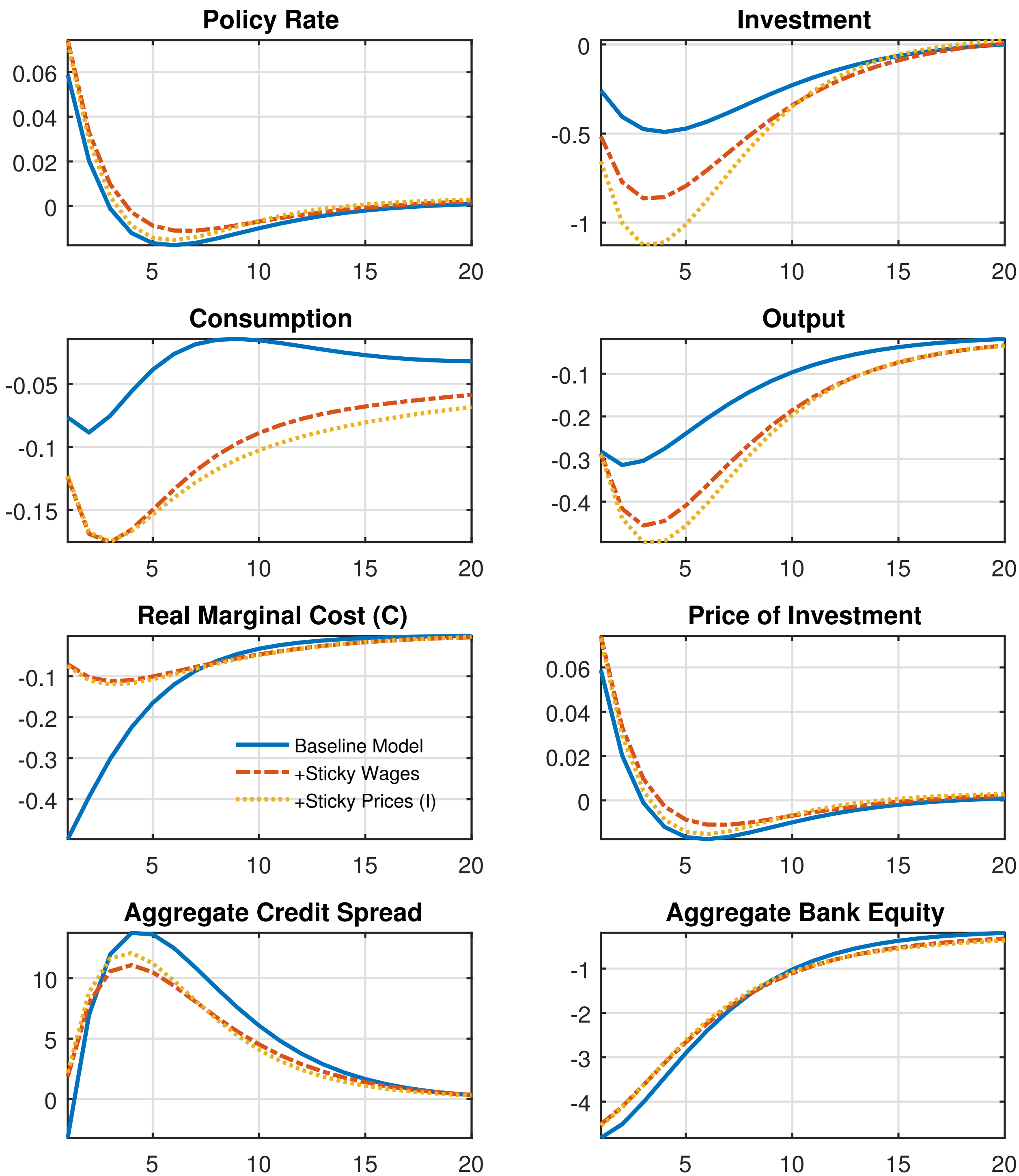

Figure 8: Impulse responses to a monetary contraction — model variants with additional nominal rigidities.

Notes: This figure shows the aggregate impulse responses to a (one standard deviation) monetary policy innovation in the baseline model (solid blue lines), the frictional model with nominal wage rigidities (dash-dotted red lines) and the frictional model with nominal rigidities in the investment sector (dotted yellow lines). Apart from the credit spread, responses are expressed in percentage deviations from steady state values.

provide evidence for the robustness of our findings derived from the structural model. The financial channel we highlight above, suffices on its own to generate the empirically observed patterns in real quantities and credit spreads. But even though mechanisms put forward in the literature to solve the co-movement puzzle cannot account for the movements in spreads (or in other financial variables), they can potentially complement the credit channel in generating co-movement in consumption and investment. Carlstrom and Fuerst (2010) and DiCecio (2009) suggest nominal wage rigidities as a potential solution to the co-movement puzzle. Figure 8 shows responses from the baseline model enriched with nominal wage rigidities (dashed lines). To conduct this first experiment, we take the parameters for the Calvo wage stickiness parameter ($\xi_w = 0.6599$) and wage indexation ($\iota_w = 0.1306$) as estimated in Görtz and Tsoukalas (2017). The responses of the baseline model (solid lines) are shown for comparison. The model predictions are qualitatively very similar when nominal wage stickiness is considered. As one would expect, this additional mechanism helps with the co-movement and triggers an even stronger contraction in consumption and investment and, as a result, in output. In addition, the response of credit spreads is robust in that they continue to rise in the wake of a monetary innovation.

We scrutinize the analysis above along a second dimension. In calibrating our baseline model, we have assumed full flexibility of prices in the investment goods producing sector. Even though microeconomic evidence suggests rather flexible prices in this sector, for expositional purposes we relax this assumption. In particular, we set the price Calvo probability to $\xi_{p,i} = 0.7058$, price indexation in the investment sector to $\iota_{p_I} = 0.3033$ and retain $\xi_w = 0.6599$ and $\iota_w = 0.1306$ as in the first exercise, so that the model is calibrated exactly at the estimates of Görtz and Tsoukalas (2017). Figure 8 (dotted lines) shows that our results on co-movement and the countercyclicality of spreads are still present when introducing price stickiness in the investment sector. These additional nominal frictions result in greater sectoral and aggregate output amplification.

Overall, the two exercises show that adding further nominal rigidities to the baseline model does not qualitatively affect the results. It has been argued in the literature that particularly nominal wage rigidities help with the sectoral co-movement and hence trigger, in combination with the financial channel, an even stronger decline in sectoral production. If anything, accounting for nominal wage rigidities further strengthens the results insofar as the response of the excess bond premium becomes neatly positive. However, wage rigidities on their own, without frictions in financial markets, can neither account for the countercyclical movements in credit spreads nor generate amplification in the responses of investment.

4 Conclusion

We show that an unexpected contractionary monetary policy shock, identified using structural vector autoregressions, triggers a decline in investment and consumption, but also leads to a tightening in credit conditions through a rise in the excess bond premium and a contraction in bank equity. The transmission of monetary policy shocks operating through financial markets turns out to be important. The standard New Keynesian two-sector model cannot generate comovement across durable and non-durable production after a monetary shock, being at odds with the empirical evidence. We show that one way to resolve this, so called, co-movement puzzle, is to introduce frictions in financial intermediation á-la Gertler and Karadi (2011) in an otherwise standard two-sector model. As a distinguishing feature from other mechanisms suggested in the literature to resolve the co-movement puzzle, the financial channel we highlight, does not only allow the model to resemble the empirical movements of real expenditure categories, but also the documented patterns in bank equity and the excess bond premium.

References

Barsky, R. B., C. L. House, and M. S. Kimball (2007): "Sticky-Price Models and Durable Goods," *American Economic Review*, 97, 984–998.

Bils, M. and P. J. Klenow (2004): "Some Evidence on the Importance of Sticky Prices," *Journal of Political Economy*, 112, 947–985.

Bouakez, H., E. Cardia, and F. J. Ruge-Murcia (2011): "Durable goods, intersectoral linkages and monetary policy," *Journal of Economic Dynamics and Control*, 35, 730–745.

Bu, C., J. Rogers, and W. Wu (2021): "A Unified Measure of Fed Monetary Policy Shocks," *Journal of Monetary Economics*, forthcoming.

Caldara, D. and E. Herbst (2019): "Monetary Policy, Real Activity, and Credit Spreads: Evidence from Bayesian Proxy SVARs," *American Economic Journal: Macroeconomics*, 11, 157–192.

Calvo, G. A. (1983): "Staggered prices in a utility-maximizing framework," *Journal of Monetary Economics*, 12, 383–398.

Canova, F. and F. Ferroni (2020): "A hitchhiker guide to empirical macro models," CEPR Discussion Papers 15446, C.E.P.R. Discussion Papers.

Canova, F. and G. D. Nicolo (2002): "Monetary disturbances matter for business fluctuations in the G-7," *Journal of Monetary Economics*, 49, 1131–1159.

Carlstrom, C. T. and T. S. Fuerst (2010): "Nominal Rigidities, Residential Investment, And Adjustment Costs," *Macroeconomic Dynamics*, 14, 136–148.

Cesa-Bianchi, A. and A. Sokol (2017): "Financial Shocks, Credit Spreads, and the International Credit Channel," *Bank of England Working Paper*.

Christiano, L. J., M. Eichenbaum, and C. L. Evans (2005): "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy," *Journal of Political Economy*, 113, 1–45.

Christiano, L. J., R. Motto, and M. Rostagno (2014): "Risk Shocks," *American Economic Review*, 104, 27–65.

Dey, J. and Y.-C. Tsai (2017): "Explaining the durable goods co-movement puzzle: A Bayesian approach," *Journal of Macroeconomics*, 52, 75–99.

Di Pace, F. (2008): "Revisiting the Comovement Puzzle: the Input-Output Structure as an Alternative Solution," Birkbeck Working Papers in Economics and Finance No. 0807, Birkbeck, Department of Economics, Mathematics & Statistics.

Di Pace, F. and M. Hertweck (2019): "Labor Market Frictions, Monetary Policy, and Durable Goods," *Review of Economic Dynamics*, 32, 274–304.

DiCecio, R. (2009): "Sticky wages and sectoral labor comovement," *Journal of Economic Dynamics and Control*, 33, 538–553.

Erceg, C. and A. Levin (2006): "Optimal monetary policy with durable consumption goods," *Journal of Monetary Economics*, 53, 1341–1359.

Erceg, C. J., D. W. Henderson, and A. T. Levin (2000): "Optimal monetary policy with staggered wage and price contracts," *Journal of Monetary Economics*, 46, 281–313.

Faust, J. (1998): "The robustness of identified VAR conclusions about money," International Finance Discussion Papers 610, Board of Governors of the Federal Reserve System (U.S.).

Gertler, M. and P. Karadi (2011): "A model of unconventional monetary policy," *Journal of Monetary Economics*, 58, 17–34.

——— (2015): "Monetary Policy Surprises, Credit Costs, and Economic Activity," *American Economic Journal: Macroeconomics*, 7, 44–76.

Gertler, M. and N. Kiyotaki (2010): "Financial Intermediation and Credit Policy in Business Cycle Analysis," in *Handbook of Monetary Economics*, ed. by B. M. Friedman and M. Woodford, Elsevier, vol. 3 of *Handbook of Monetary Economics*, chap. 11, 547–599.

Gertler, M., N. Kiyotaki, and A. Prestipino (2016a): "Anticipated Banking Panics," *American Economic Review*, 106, 554–559.

——— (2016b): "Wholesale Banking and Bank Runs in Macroeconomic Modeling of Financial Crises," in *Handbook of Macroeconomics*, ed. by J. B. Taylor and H. Uhlig, Elsevier, vol. 2 of *Handbook of Macroeconomics*.

——— (2020): "Credit Booms, Financial Crises, and Macroprudential Policy," *Review of Economic Dynamics*, forthcoming.

Gertler, M., N. Kiyotaki, and A. Queralto (2012): "Financial crises, bank risk exposure and government financial policy," *Journal of Monetary Economics*, 59, 17–34.

Gilchrist, S. and E. Zakrajsek (2012): "Credit Spreads and Business Cycle Fluctuations," *American Economic Review*, 102, 1692–1720.

Görtz, C., J. Tsoukalas, and F. Zanetti (2021): "News Shocks under Financial Frictions," *American Economic Journal: Macroeconomics*, forthcoming.

Görtz, C. and J. D. Tsoukalas (2017): "News and Financial Intermediation in Aggregate Fluctuations," *The Review of Economics and Statistics*, 99, 514–530.

Hamilton, J. D. (2018): "Why You Should Never Use the Hodrick-Prescott Filter," *The Review of Economics and Statistics*, 100, 831–843.

Huffman, G. W. and M. A. Wynne (1999): "The role of intratemporal adjustment costs in a multisector economy," *Journal of Monetary Economics*, 43, 317–350.

Iacoviello, M. and S. Neri (2010): "Housing Market Spillovers: Evidence from an Estimated DSGE Model," *American Economic Journal: Macroeconomics*, 2, 125–164.

Justiniano, A., G. Primiceri, and A. Tambalotti (2011): "Investment Shocks and the Relative Price of Investment," *Review of Economic Dynamics*, 14, 101–121.

Justiniano, A., G. E. Primiceri, and A. Tambalotti (2010): "Investment shocks and business cycles," *Journal of Monetary Economics*, 57, 132–145.

Katayama, M. and K. H. Kim (2013): "The delayed effects of monetary shocks in a two-sector New Keynesian model," *Journal of Macroeconomics*, 38, 243–259.

Khan, H. and J. Tsoukalas (2012): "The Quantitative Importance of News Shocks in Estimated DSGE Models," *Journal of Money, Credit and Banking*, 44, 1535–1561.

Kiyotaki, N. and J. Moore (1997): "Credit Cycles," *Journal of Political Economy*, 105, 211–48.

Klenow, P. J. and O. Kryvtsov (2008): "State-Dependent or Time-Dependent Pricing: Does It Matter for Recent U.S. Inflation?" *The Quarterly Journal of Economics*, 123, 863–904.

Mertens, K. and M. O. Ravn (2013): "The Dynamic Effects of Personal and Corporate Income Tax Changes in the United States," *American Economic Review*, 103, 1212–47.

Miranda-Agrippino, S. and G. Ricco (2017): "The Transmission of Monetary Policy Shocks," Economic Research Papers 269310, University of Warwick - Department of Economics.

Monacelli, T. (2009): "New Keynesian models, durable goods, and collateral constraints," *Journal of Monetary Economics*, 56, 242–254.

Papanikolaou, D. (2011): "Investment Shocks and Asset Prices," *Journal of Political Economy*, 119, 639–685.

Petrella, I., R. Rossi, and E. Santoro (2019): "Monetary Policy with Sectoral Trade-Offs," *Scandinavian Journal of Economics*, 121, 55–88.

Ramey, V. and M. D. Shapiro (2001): "Displaced Capital: A study of Aerospace Plant Closings," *Journal of Political Economy*, 109, 959–992.

Rupert, P. and R. Sustek (2019): "On the mechanics of New-Keynesian models," *Journal of Monetary Economics*, 102, 53–69.

Sterk, V. (2010): "Credit frictions and the comovement between durable and non-durable consumption," *Journal of Monetary Economics*, 57, 217–225.

Stock, J. H. and M. W. Watson (2012): "Disentangling the Channels of the 2007-2009 Recession," NBER Working Papers 18094, National Bureau of Economic Research, Inc.

——— (2018): "Identification and Estimation of Dynamic Causal Effects in Macroeconomics Using External Instruments," *Economic Journal*, 128, 917–948.

Sudo, N. (2012): "Sectoral Co-Movement, Monetary-Policy Shock, and Input-Output Structure," *Journal of Money, Credit and Banking*, 44, 1225–1244.

Uhlig, H. (2005): "What are the effects of monetary policy on output? Results from an agnostic identification procedure," *Journal of Monetary Economics*, 52, 381–419.

Appendix (for online publication)

A Data Sources and Observable Construction

Table 2 provides an overview of all monthly and quarterly time series used in Section 2. We construct durable investment and non-durable consumption of industrial production using formulas advised by the US Federal Reserve. Details are available at the Federal Reserve Board website $https://www.federalreserve.gov/releases/G17/20200814/ipdisk/rel\_imp.htm$. The excess bond premium is taken from Gilchrist and Zakrajsek (2012). All time series are seasonally adjusted (where applicable). Table 3 summarizes all transformations to the data prior to their use as observables in the VAR.

The monthly market value of commercial bank's equity is constructed using monthly data from the Center for Research in Security Prices (CRSP). From the raw data we retain companies with the following SIC codes to cover the commercial banking sector: 6021 (National Commercial Banks), 6022 (State Commercial Banks), 6029 (Commercial Banks, not elsewhere classified), 6081 (Branches and Agencies of Foreign Banks), 6153 (Short-Term Business Credit Institutions, except Agricultural), 6159 (Miscellaneous Business Credit Institutions) and 6111 (Federal and Federally-Sponsored Credit Agencies). The market value is calculated as the product of Price (PRC) and Shares Outstanding (SHROUT) and subsequently aggregated for each month. The final series for total equity is generated by taking the log after dividing by the consumption deflator.

Table 2: Definitions and sources of raw data.

Series	Definition	Source	Mnemonic
	Monthly Series		
CPI	consumer price index for all urban consumers: all Items in U.S. city average	FRED	CPIAUCSL
IP	industrial production Index: Total Index	FRED	INDPRO
$GVIP$	industrial production: final products (gross value)	FRB	GVIP.T50002.S
$GVIP^{nd}$	industrial production: non-durable consumption (gross value)	FRB	GVIP.T51200.S
$GVIP^{d}$	industrial production: durable consumer goods (gross value)	FRB	GVIP.T51100.S
$GVIP^{g}$	industrial production: defense and space equipment (gross value)	FRB	GVIP.T52300.S
RIW	final product (RIW)	FRB	RIW.B50002.S
RIW^{nd}	durable consumer goods (RIW)	FRB	RIW.B51100.S
RIW^{g}	defense and space equipment (RIW)	FRB	RIW.B52300.S
P^{B}	price of commercial banks	CRSP	PRC
S^{B}	shares outstanding of commercial banks	CRSP	SHROUT
	Quarterly Series		
NY_t	nominal GDP	BEA	Table 1.1.5, Line 1
NC_t^d	nominal durable goods	BEA	Table 1.1.5, Line 4
NC_t^{nd}	nominal non-durable goods	BEA	Table 1.1.5, Line 5
NC_t^s	nominal services	BEA	Table 1.1.5, Line 6
NI_t	nominal investment	BEA	Table 1.1.5, Line 12
P_t^y	price deflator, GDP	BEA	Table 1.1.9, Line 1
P_t^d	price deflator, durable goods	BEA	Table 1.1.9, Line 4
P_t^n	price deflator, non-durable goods	BEA	Table 1.1.9, Line 5
P_t^s	price deflator, services	BEA	Table 1.1.9, Line 6
P_t^i	price deflator, investment	BEA	Table 1.1.9, Line 12
POP_t	civilian population 16+	FRED	CLP16OV
	Monthly and Quarterly Series		
$GS1$	1-year treasury constant maturity rate	FRED	GS1

Table 3: Observable variables used in the SVARs.

Variable	Symbol	Transformation
	Monthly Data	
industrial production (IP)	ip_t	$\ln(IP_t) \times 100$
(IP) non-durable consumption (gross value)	$gvip_t^{nd}$	$\ln\left(IP_t^{nd}\right) \times 100$
(IP) investment (gross value)	$gvip_t^{i}$	$\ln\left(IP_t^{i}\right) \times 100$
CPI	cpi_t	$\ln\left(CPI_t\right) \times 100$
Excess Bond Premium	ebp_t	EBP_t
1-year Treasury Bonds rate	r_t	$((1 + GS1_t/100)^{1/12} - 1) \times 100$
Market value of commercial bank's equity	n_t	$\ln(\sum(P^B \times S^B)/CPI_t)$
	Quarterly Data	
per capita consumption	c_t	$\ln\left(C_t/Pop_t\right) \times 100$
per capita investment	i_t	$\ln\left(I_t/Pop_t\right) \times 100$
per capita gross domestic product	gdp_t	$\ln\left(GDP_t/Pop_t\right) \times 100$
consumption deflator	p_t^c	$\ln\left(P_t^c\right)$
Excess Bond Premium	ebp_t	EBP_t
1-year Treasury Bonds rate	r_t	$(1 + GS1_t/100)^{1/4} - 1$
Market value of commercial bank's equity	n_t	$\ln(\sum(P^B \times S^B)/(Pop_t \times P_t^c))$

Notes: C_t and I_t denote the chain-linked real consumption and investment aggregates and P_t^c the resulting consumption implicit price deflator.

B Additional Empirical Evidence

This section provides additional evidence on the robustness of our empirical results. In particular, we show that the results corresponding to Figure 1 are robust to using an alternative measure for the policy rate and to extending the sample.

Figure 9 shows responses to an unexpected monetary policy shock identified using the SVAR-IV identification on our monthly sample from $1973M1$ to $2009M12$. Instead of the 1-year treasury bill, we use the Federal Funds Rate as a measure for the policy rate. The responses correspond qualitatively, and to a large extent also quantitatively, to the ones shown in Figure 1. The monetary tightening triggers a rise in the policy rate and a decline in inflation. Industrial production and its investment and non-durable consumption components decline in response to the shock and we observe a rise in the excess bond premium.

In Section 2, we restrict our sample to end in $2009M12$ when the policy rate hits the zero lower bound. This conservative cut-off for our sample is consistent with choices on sample endpoints made in existing studies, see e.g. Caldara and Herbst (2019). It ensures that we do not capture the presence of the zero lower bound or the effects of unconventional monetary policy in our baseline estimates. Nonetheless, we scrutinize the robustness of our findings also over a longer sample that ends in $2019M12$. Figure 10 shows responses to an unexpected monetary policy shock identified using the SVAR-IV identification over the sample $1973M1$ to $2019M12$. An unexpected monetary tightening triggers a decline in industrial production, IP investment and IP non-durable consumption. The increase in the Federal Funds Rate comes along with a decline in CPI and a tightening in credit conditions indicated by the rise in the excess bond premium. As such, these results correspond closely to the ones shown in Section 2 on the shorter baseline sample.

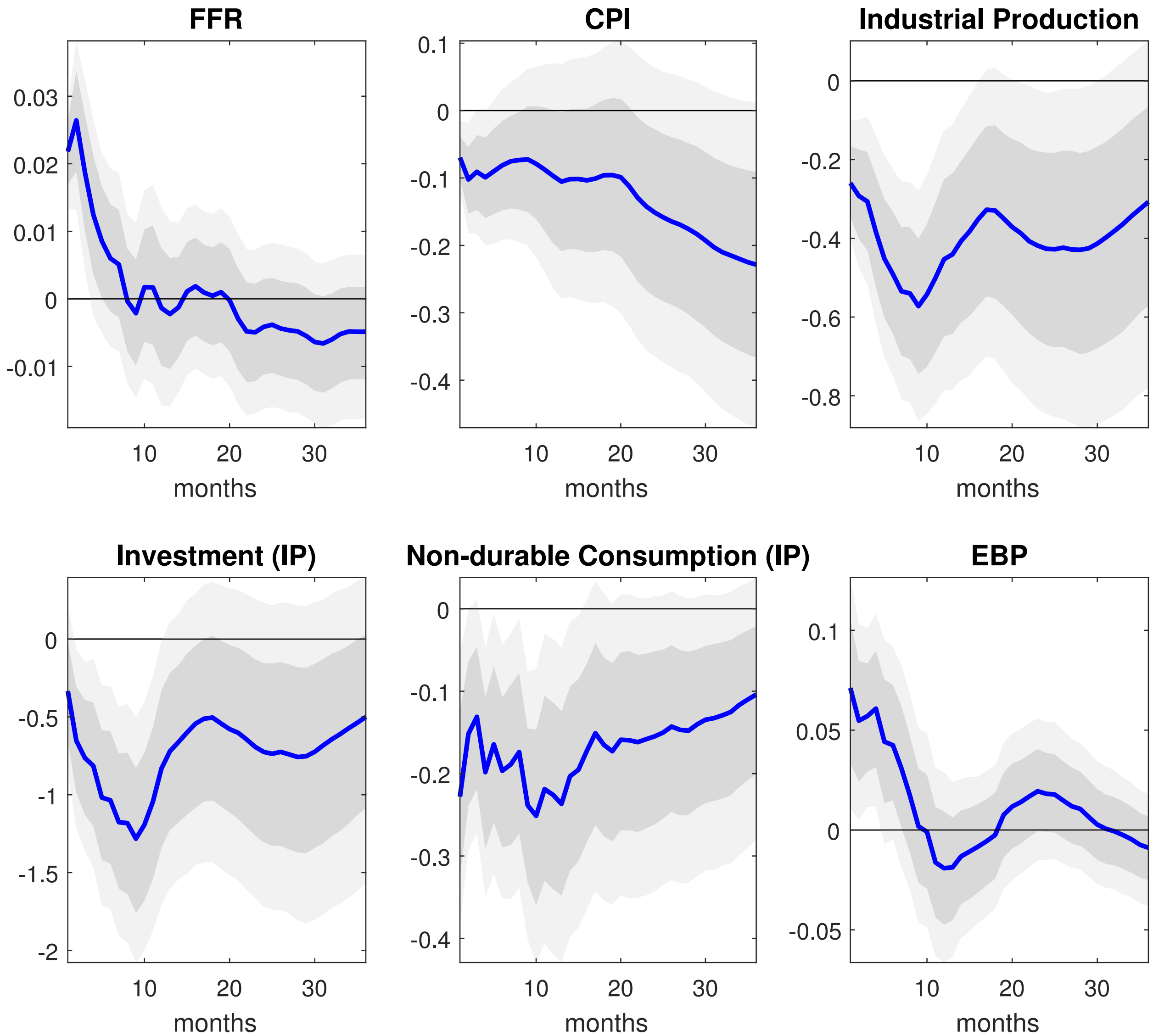

Figure 9: Impulse responses to an unexpected monetary tightening.

Notes: This figure shows the (monthly) empirical impulse responses to a (one standard deviation) monetary policy shock. Sample: $1973M1$ to $2009M12$. The median monthly response is shown in solid blue, with the dark and light grey areas denoting the 68% and 90% confidence bands respectively. With the exception of the FFR and the Excess Bond Premium (EBP), responses are expressed in percentage deviations. Rates and premiums are expressed in percentage points.

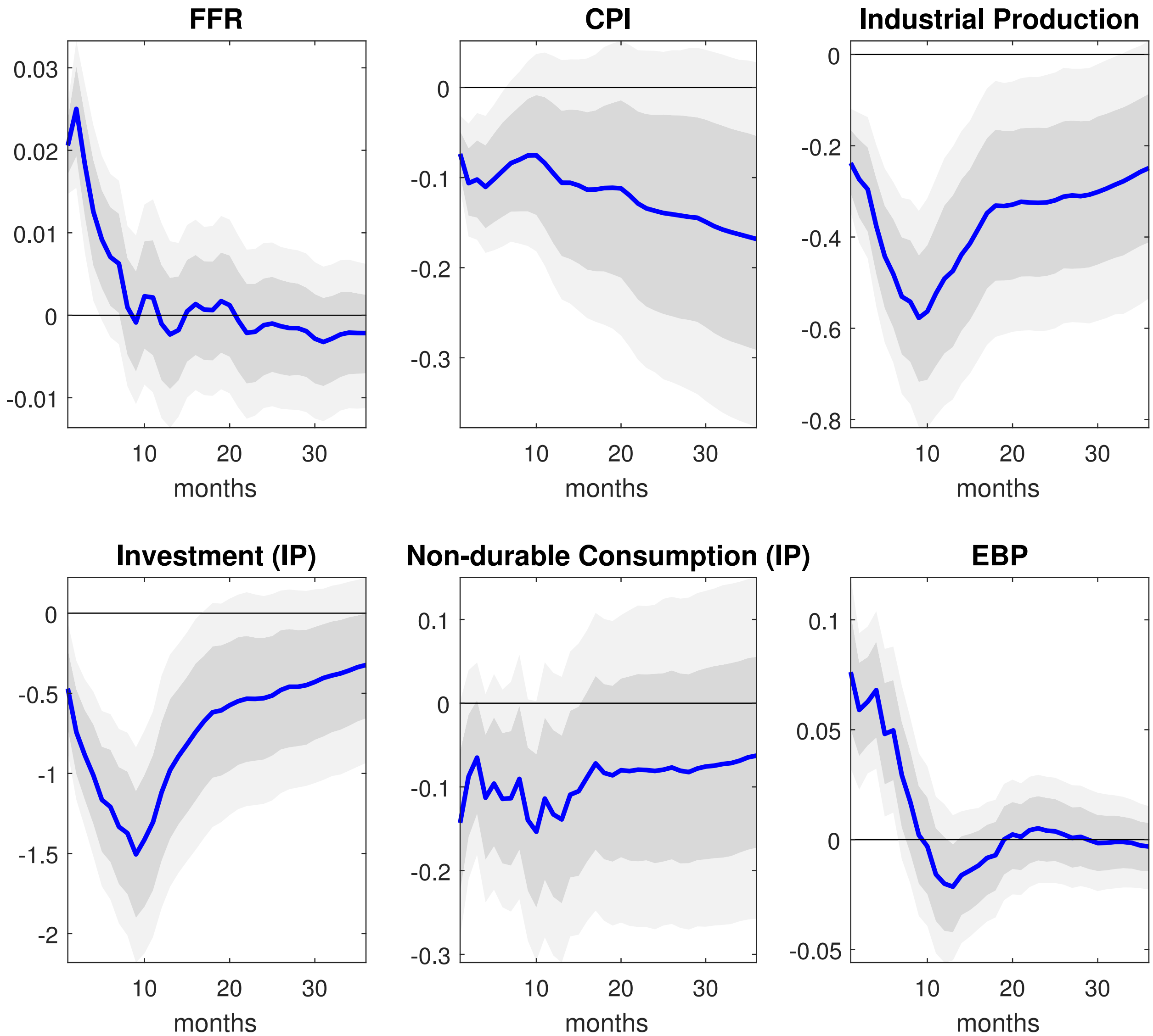

Figure 10: Impulse responses to an unexpected monetary tightening.

Notes: This figure shows the (monthly) empirical impulse responses to a (one standard deviation) monetary policy shock. Sample: $1973M1$ to $2019M12$. The median monthly response is shown in solid blue, with the dark and light grey areas denoting the 68% and 90% confidence bands respectively. With the exception of the FFR and the Excess Bond Premium (EBP), responses are expressed in percentage deviations. Rates and premiums are expressed in percentage points.

C The Structural Model

This section presents the the details of the two-sector model and provides an overview about parameter estimates used to calibrate the model.

C.1 Details of the Two-Sector Model

C.1.1 Intermediate and final goods production

Intermediate goods in the consumption sector are produced by a monopolist according to the production function,

$$C_t(i) = max\Big\{A_t(L_{C,t}(i))^{1-a_c}(K_{C,t}(i))^{a_c} - A_t V_t^{\frac{a_c}{1-a_i}} F_C; 0\Big\}.$$

Intermediate goods in the investment sector are produced by a monopolist according to the production function,

$$I_t(i) = max\Big\{V_t(L_{I,t}(i))^{1-a_i}(K_{I,t}(i))^{a_i} - V_t^{\frac{1}{1-a_i}} F_I; 0\Big\},$$

where $K_{x,t}(i)$ and $L_{x,t}(i)$ denote the amount of capital services and labor services rented by firm i in sector $x = C, I$ and $a_c, a_i \in (0, 1)$ denote capital shares in production.[18] The variables A_t and V_t denote the (non-stationary) level of TFP in the consumption and investment sector respectively, and $z_t = ln\Big(\frac{A_t}{A_{t-1}}\Big)$ and $v_t = ln\Big(\frac{V_t}{V_{t-1}}\Big)$ denote corresponding (stationary) stochastic growth rates of TFP.[19]

The intermediate goods producers set prices according to Calvo (1983) contracts. In each period t, a randomly selected fraction of intermediate firms, $(1-\xi_{p,x})$, in sector $x = C, I$ reoptimize their prices. The complementary fraction, $\xi_{p,x}$, set prices according to the indexation rules, $P_{C,t}(i) = P_{C,t-1}(i)\pi_{C,t-1}^{\iota_{p_C}}\pi_C^{1-\iota_{p_C}}$, $P_{I,t}(i) = P_{I,t-1}(i)\pi_{I,t-1}^{\iota_{p_I}}\pi_I^{1-\iota_{p_I}}\left[\Big(\frac{A_t}{A_{t-1}}\Big)^{-1}\Big(\frac{V_t}{V_{t-1}}\Big)^{\frac{1-a_c}{1-a_i}}\right]^{\iota_{p_I}}$ where $\pi_{C,t} \equiv \frac{P_{C,t}}{P_{C,t-1}}$ and $\pi_{I,t} \equiv \frac{P_{I,t}}{P_{I,t-1}}\Big(\frac{A_t}{A_{t-1}}\Big)^{-1}\Big(\frac{V_t}{V_{t-1}}\Big)^{\frac{1-a_c}{1-a_i}}$ is gross inflation in the two sectors, π_C, π_I denote steady state values and ι_{p_C}, ι_{p_I} denote indexation parameters. The factor that appears in the investment sector expression adjusts for investment specific progress.

Final goods, C_t and I_t, in the consumption and investment sector respectively, are produced by perfectly competitive firms combining a continuum—$C_t(i)$ and $I_t(i)$—of interme-

[18]Fixed costs of production, $F_C, F_I > 0$, ensure that profits are zero along a non-stochastic balanced growth path and allow us to dispense with the entry and exit of intermediate good producers (Christiano, Eichenbaum, and Evans (2005)). The fixed costs are assumed to grow at the same rate as output in the consumption and investment sector to ensure that they do not become asymptotically negligible.

[19]For ease of exposition, these latter processes, along with all other exogenous processes introduced in various parts of the model will be described in Section C.1.7.

diate goods, according to the technology,

$$C_t = \left[\int_0^1 (C_t(i))^{\frac{1}{1+\lambda_{p,t}^C}} di \right]^{1+\lambda_{p,t}^C}, \qquad I_t = \left[\int_0^1 (I_t(i))^{\frac{1}{1+\lambda_{p,t}^I}} di \right]^{1+\lambda_{p,t}^I},$$

The elasticities $\lambda_{p,t}^C$ and $\lambda_{p,t}^I$ are the exogenous stochastic process of (sectoral) price markup over marginal cost. As is standard in New Keynesian models, prices of final goods are CES aggregates of intermediate good prices.

C.1.2 Households

Following Gertler and Karadi (2011), households consist of two member types, workers (relative size $1-f$) and bankers (relative size f). Workers supply (specialized) labor, indexed by j, and earn wages while bankers manage a financial intermediary. The household thus effectively owns the intermediaries managed by its bankers, however the household does not own the deposits held by the financial intermediaries. Within a household there is perfect consumption insurance. While over time the overall proportion of bankers and workers remains constant, household members switch between the two occupations to avoid that over time bankers can fund all investments from their own capital. In particular, bankers become workers in the next period with probability $(1-\theta_B)$ and in this case transfer their retained earnings to their household. Workers who become new bankers are provided with start up funds by the household. The household maximizes,

$$E_0 \sum_{t=0}^{\infty} \beta^t b_t \left[\ln(C_t - hC_{t-1}) - \varphi \frac{(L_{C,t}(j) + L_{I,t}(j))^{1+\nu}}{1+\nu} \right], \quad \beta \in (0,1), \quad \varphi > 0, \quad \nu > 0,$$

where E_0 is the conditional expectation operator, β is the discount factor and h is the degree of (external) habit formation. The inverse Frisch labor supply elasticity is denoted by ν, while φ is a free parameter which allows to calibrate total labor supply in the steady state.[20] The variable b_t is a inter-temporal preference shock. The household's flow budget constraint (in consumption units) is,

$$C_t + \frac{B_t}{P_{C,t}} \leq \frac{W_t(j)}{P_{C,t}}(L_{C,t}(j) + L_{I,t}(j)) + R_{t-1}\frac{B_{t-1}}{P_{C,t}} - \frac{T_t}{P_{C,t}} + \frac{\Psi_t(j)}{P_{C,t}} + \frac{\Pi_t}{P_{C,t}},$$

where B_t is holdings of risk free bank deposits, Ψ_t is the net cash flow from household's portfolio of state contingent securities, T_t is lump-sum taxes, R_t the (gross) nominal interest rate paid on deposits and Π_t is the net profit accruing to households from ownership of

[20] Consumption is not indexed by (j) because the existence of state contingent securities ensures that in equilibrium, consumption and asset holdings are the same for all households.

all firms. Notice above, the wage rate, W_t, is identical across sectors due to perfect labor mobility.

C.1.3 Household's wage setting

Each household $j \in [0,1]$ supplies specialized labor, $L_t(j)$, monopolistically as in Erceg, Henderson, and Levin (2000). A large number of competitive "employment agencies" aggregate this specialized labor into a homogenous labor input which is sold to intermediate goods producers in the two sectors. Aggregation is given as,

$$L_t = \left[\int_0^1 L_t(j)^{\frac{1}{1+\lambda_{w,t}}} dj \right]^{1+\lambda_{w,t}}.$$

The desired markup of wages over the household's marginal rate of substitution (or wage mark-up), $\lambda_{w,t}$, follows an exogenous stochastic process.

Profit maximization by the perfectly competitive employment agencies implies the labor demand function,

$$L_t(j) = \left(\frac{W_t(j)}{W_t} \right)^{-\frac{1+\lambda_{w,t}}{\lambda_{w,t}}} L_t, \tag{1}$$

where $W_t(j)$ is the wage received from employment agencies by the supplier of labor of type j, while the wage paid by intermediate firms for the homogenous labor input is,

$$W_t = \left[\int_0^1 W_t(j)^{\frac{1}{\lambda_{w,t}}} dj \right]^{\lambda_{w,t}}.$$

Following Erceg et al. (2000), in each period, a fraction ξ_w of the households cannot freely adjust its wage but follows the indexation rule,

$$W_{t+1}(j) = W_t(j) \left(\pi_{c,t} e^{z_t + \frac{a_c}{1-a_i} v_t} \right)^{\iota_w} \left(\pi_c e^{g_a + \frac{a_c}{1-a_i} g_v} \right)^{1-\iota_w}.$$

where, g_a, g_v denote the steady state growth rates of the z_t, v_t process respectively. The remaining fraction of households, $(1-\xi_w)$, chooses an optimal wage, $W_t(j)$.[21]

C.1.4 Capital goods production

Physical capital production. Capital is sector-specific. Our assumption is motivated by evidence in Ramey and Shapiro (2001) who report significant costs of reallocating capital across sectors. Capital producers in sector $x = C, I$, use a fraction of investment goods from final goods producers and undepreciated capital from capital services producers to produce new capital goods, subject to investment adjustment costs (IAC) as proposed by Christiano et al. (2005). Solving their optimization problem yields a standard capital accumulation

[21] All households that can reoptimize will choose the same wage.

equation,

$$\bar{K}_{x,t} = (1-\delta_x)\xi^K_{x,t}\bar{K}_{x,t-1} + \left(1 - S\left(\frac{I_{x,t}}{I_{x,t-1}}\right)\right) I_{x,t}, \qquad x = C, I, \tag{2}$$

where δ_x denotes the sectoral depreciation rate, $S\left(\frac{I_{x,t}}{I_{x,t-1}}\right)$ denotes IAC, where $S(\cdot)$ satisfies the following: $S(1) = S'(1) = 0$, $S''(1) = \kappa > 0$, and $\xi^K_{x,t}$ is explained below.

Capital services producers. These agents purchase – using funds from intermediaries – physical capital from capital producers and transform it to capital services by choosing the utilization rate. They rent capital services—in perfectly competitive markets – to intermediate goods producers earning a rental rate equal to $R^K_{x,t}/P_{C,t}$ per unit of capital. They sell the un-depreciated portion of capital at the end of period $t+1$ at price $Q_{x,t+1}$ back to capital producers.[22] The utilization rate, $u_{x,t}$, transforms physical capital into capital services according to

$$K_{x,t} = u_{x,t}\xi^K_{x,t}\bar{K}_{x,t-1}, \qquad x = C, I,$$

and incurs a cost denoted by $a_x(u_{x,t})$ per unit of capital. This function has the properties that in the steady state $u = 1$, $a_x(1) = 0$ and $\chi_x \equiv \frac{a''_x(1)}{a'_x(1)}$, denotes the cost elasticity.

In the transformation above, we allow for a capital quality shock (as in Gertler and Karadi (2011)), $\xi^K_{x,t}$. Capital services producers solve,

$$\underset{u_{x,t+1}}{max}\left[\frac{R^K_{x,t+1}}{P_{C,t+1}} u_{x,t+1}\xi^K_{x,t+1}\bar{K}_{x,t} - a_x(u_{x,t+1})\xi^K_{x,t+1}\bar{K}_{x,t}A_{t+1}V_{t+1}^{\frac{a_C-1}{1-a_i}}\right] \quad x = C, I.$$

Total receipts of capital services producers in period $t+1$ are equal to,

$$R^B_{x,t+1}Q_{x,t}\bar{K}_{x,t},$$

with

$$R^B_{x,t+1} = \frac{\frac{R^K_{x,t+1}}{P_{x,t+1}}\xi^K_{x,t+1}u_{x,t+1} + Q_{x,t+1}\xi^K_{x,t+1}(1-\delta_x) - a_x(u_{x,t+1})\xi^K_{x,t+1}A_{t+1}V_{t+1}^{\frac{a_C-1}{1-a_i}}}{Q_{x,t}}, \tag{3}$$

where $R^B_{x,t+1}$ is the real rate of return on capital. Since these agents finance their purchase of capital at the end of each period with funds from financial intermediaries (to be described below), $R^B_{x,t+1}$ is the stochastic return earned by the latter.

C.1.5 Financial sector

Financial intermediaries use deposits from households and their own equity to finance the acquisitions of physical capital by capital services producers. The financial sector in the model is a special case of Gertler and Kiyotaki (2010) where banks lend in specific islands

[22]The price of capital, equivalent to Tobin's marginal Q, is $Q_{x,t} = \frac{\Phi_{x,t}}{\Lambda_t}$, where Λ_t, $\Phi_{x,t}$, are the lagrange multipliers on the households' budget constraint, and capital accumulation constraint respectively.

(sectors)—they cannot switch between them. Alternatively, we can interpret the financial sector as a single intermediary with two branches, each specializing in providing financing to one sector only, where the probability of lending specialization is equal across sectors and independent across time. Due to sector specific technologies, each branch earns a sector specific return and maximizes equity from financing the specific sector.[23] Since we follow closely Gertler and Karadi (2011), we only briefly describe the essential mechanics. These can be described with three key equations. The balance sheet identity, the demand for assets that links equity with the value of assets (physical capital), and finally, the evolution of equity.

The **balance sheet** (in nominal terms) of a branch that lends in sector $x = C, I$, is,

$$Q_{x,t}P_{C,t}S_{x,t} = N_{x,t}P_{C,t} + B_{x,t},$$

where $S_{x,t}$ denotes the quantity of financial claims on capital services producers held by the intermediary and $Q_{x,t}$ denotes the price per unit of claim. The variable $N_{x,t}$ denotes equity at the end of period t, $B_{x,t}$ are household deposits and $P_{C,t}$ is the consumption sector price level.

Financial intermediaries are limited from infinitely borrowing household funds by a moral hazard/costly enforcement problem, where bankers can steal funds and transfer them to households. Intermediaries maximize expected terminal wealth, i.e. the discounted sum of future equity. The moral hazard problem introduces an endogenous **leverage constraint**, limiting the bank's ability to acquire assets. This is formalized in the equation that determines the demand for assets,

$$Q_{x,t}S_{x,t} = \varrho_{x,t}N_{x,t}. \tag{4}$$

In the equation above, the value of assets which the intermediary can acquire depends on equity, $N_{x,t}$, scaled by the leverage ratio, $\varrho_{x,t}$.[24] With $\varrho_{x,t} > 1$, the leverage constraint magnifies changes in equity on the demand for assets. Higher demand for capital goods for example, which raises the price of capital, increases equity (through the balance sheet identity) which in turn brings about further changes in the demand for assets by intermediaries pushing the price of capital further. This amplification turns out to be the key reason for the important role of news shocks we recover from the estimated model.

[23]The specific segmentation adopted can be justified for example by the fact that within an intermediary there are divisions specializing in consumer or corporate finance.

[24]The leverage ratio (bank's intermediated assets to equity) is a function of the marginal gains of expanding assets (holding equity constant), expanding equity (holding assets constant), and the gain from diverting assets.

Finally, the evolution of equity is described by the following **law of motion for equity**,

$$N_{x,t+1} = \big(\theta_B[(R^B_{x,t+1}\pi_{C,t} - R_t)\varrho_{x,t} + R_t]\frac{N_{x,t}}{\pi_{C,t+1}} + \varpi Q_{x,t+1}S_{x,t+1}\big),$$

where θ_B is the survival rate of bankers, ϖ denotes the fraction of assets given to new bankers. It is useful to define the expected (nominal) excess return (or risk premium) on assets earned by banks as

$$R^S_{x,t} = R^B_{x,t+1}\pi_{C,t+1} - R_t, \qquad x = C, I. \tag{5}$$

The presence of the financial intermediation constraint in equation (4), implies a non-negative excess return (equivalently wedge between the expected return on capital and the risk free interest rate), which varies over time with intermediaries equity.

Financing capital acquisitions by capital services producers. Capital services producers issue $S_{x,t}$ claims equal to units of physical capital acquired, $\bar{K}_{x,t}$, priced at $Q_{x,t}$. Then, by arbitrage the following constraint holds,

$$Q_{x,t}\bar{K}_{x,t} = Q_{x,t}S_{x,t},$$

where the left-hand side stands for the value of physical capital acquired and the right-hand side denotes the value of claims against this capital.[25] Using the assumptions in Gertler and Karadi (2011) we can interpret these claims as one period state-contingent bonds which allows interpreting the excess return defined in equation (5) as a corporate bond spread.

C.1.6 Monetary policy and market clearing

The nominal interest rate R_t, set by the monetary authority follows a feedback rule,

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_R}\left[\left(\frac{\pi_{c,t}}{\pi_c}\right)^{\phi_\pi}\left(\frac{Y_t}{Y_{t-1}}\right)^{\phi_{\Delta Y}}\right]^{1-\rho_R}\eta_{mp,t}, \quad \rho_R \in (0,1), \phi_\pi > 0, \phi_{\Delta Y} > 0,$$

where R is the steady state (gross) nominal interest rate and (Y_t/Y_{t-1}) is the gross growth rate in real GDP. The interest rate responds to deviations of consumption goods (gross) inflation from its target level, and real GDP growth and is subject to a monetary policy shock $\eta_{mp,t}$. GDP (in consumption units) is defined as,

$$Y_t = C_t + \frac{P_{I,t}}{P_{C,t}}I_t + G_t,$$

where G_t denotes government spending (in consumption units) assumed to evolve exogenously according to $G_t = \left(1 - \frac{1}{g_t}\right)Y_t$, and g_t is a government spending shock. The sectoral resource constraints are as follows.

[25]We assume—in line with Gertler and Karadi (2011)—there are no frictions in the process of intermediation between non-financial firms and banks.

The resource constraint in the consumption sector is,

$$C_t + (a(u_{C,t})\xi^K_{C,t}\bar{K}_{C,t-1} + a(u_{I,t})\xi^K_{I,t}\bar{K}_{I,t-1})\frac{A_t V_t^{\frac{a_c}{1-a_i}}}{V_t^{\frac{1}{1-a_i}}} = A_t L_{c,t}^{1-a_c} K_{c,t}^{a_c} - A_t V_t^{\frac{a_c}{1-a_i}} F_C.$$

The resource constraint in the investment sector is,

$$I_{I,t} + I_{C,t} = V_t L_{I,t}^{1-a_i} K_{I,t}^{a_i} - V_t^{\frac{1}{1-a_i}} F_I.$$

Hours worked are aggregated as,

$$L_t = L_{I,t} + L_{C,t}.$$

Bank equity is aggregated as,

$$N_t = N_{I,t} + N_{C,t}.$$

C.1.7 Shocks and Estimation

We briefly describe the shocks in the model. The baseline model includes the following shocks: $z_t, v_t, \lambda^I_{p,t}, \lambda^C_{p,t}, b_t, \lambda_{w,t},\ \xi^K_{I,t}, \xi^K_{C,t}, \eta_{mp,t}, g_t$. They are, growth rate of TFP in the C-sector, growth rate of TFP in the I-sector, price mark-up in the I-sector, price mark-up in the C-sector, preference, wage mark-up, capital quality in the I-sector, capital quality in the C-sector, monetary policy, and government spending shock, respectively. The log deviations of each shock from its steady state are modeled as a first order autoregressive (AR(1)) process. The only exception is the monetary policy shock, $\eta_{mp,t}$, where the first order autoregressive parameter is set to zero.

For further details about the shock processes used in the Bayesian estimation, see Görtz and Tsoukalas (2017). We refrain from a further discussion here as our work solely focusses on the monetary policy shock.

C.2 Parameter Estimates

We calibrate the model using the posterior mean estimates of Görtz and Tsoukalas (2017). The only deviation in our baseline calibration is that we assume nominal wages and the nominal price of investment goods to be flexible. We relax this assumption in a robustness exercise in Section 3 which conforms exactly to their estimates. The calibration of the baseline model is summarized in Table 4. This table also summarizes the calibration of the model without financial frictions, which is also based on the estimates of Görtz and Tsoukalas (2017). Parameter values that are common across the two models are calibrated in their estimation procedure.

Table 4: Calibration

Description	**Parameter**	**Value**	
		Baseline	**No-FF**
Depreciation rate in sector $x = C, I$	δ_x	0.025	0.025
Capital share in sector $x = C, I$	α_x	0.3	0.3
Steady state inflation rate in sector C	π_c	0.6722	0.642
Steady state government spending to GDP ratio	$\frac{g}{y}$	0.19	0.19
Discount factor	β	0.9974	0.9974
Inverse of the Frisch elasticity	ν	0.8718	0.6691
Habit persistence	h	0.6275	0.6231
Steady state price mark-ups in sector $x = C, I$	λ_p^x	0.15	0.15
Investment adjustment cost	κ	2.2890	2.2389
Capacity utilisation (C)	$a''(1)$	4.6983	4.4477
Capacity utilisation (I)	$a''(1)$	4.9975	4.8295
Calvo price stickiness in sector C	$\xi_{p,c}$	0.7785	0.7842
Calvo price indexation in sector C	ι_{p_C}	0.0726	0.0690
Calvo price stickiness in sector I	$\xi_{p,i}$	0	0
Calvo price indexation in sector I	ι_{p_I}	0	0
Calvo wage stickiness	ξ_w	0	0
Calvo wage indexation	ι_w	0	0
Taylor rule inertia	ρ_r	0.8434	0.8423
Taylor rule responsiveness to inflation	ρ_ϕ	1.5864	1.5459
Taylor rule responsiveness output gap	$\phi_{\Delta y}$	0.6822	0.6805
Fraction of surviving bankers	θ_b	0.94	$---$
Steady state leverage ratios	ϱ_x	5.47	$---$
Sectoral steady state spreads	$R_x^B \pi_c - R$	2/400	$---$