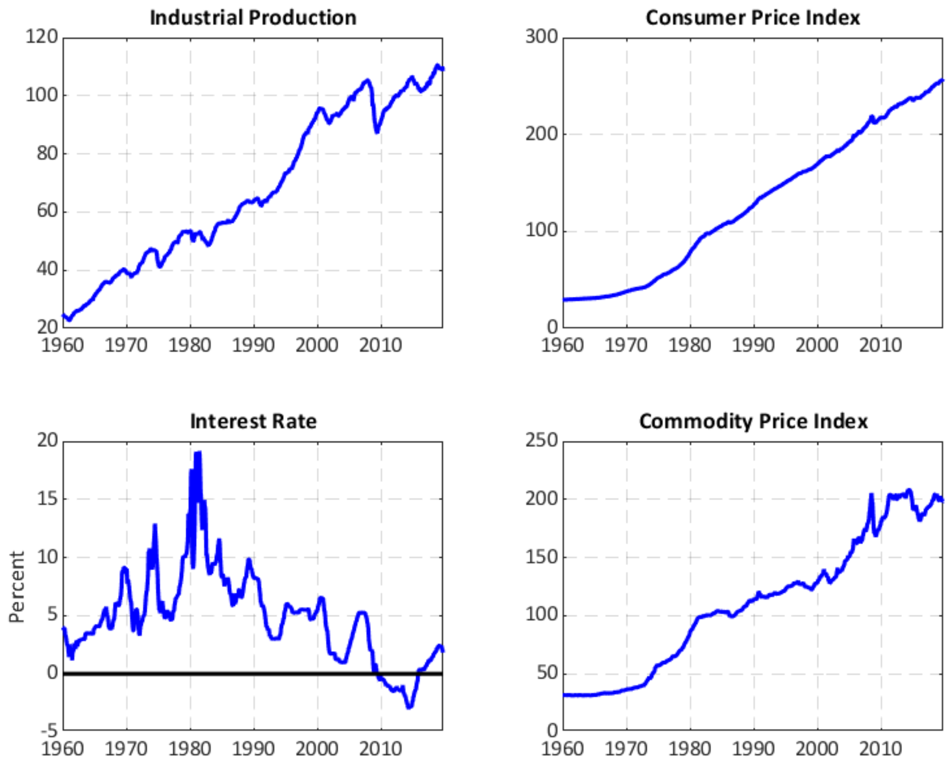
Take-home Exam: Solution

Advanced Macroeconomics: Business Cycles

Winter 2019-20

Part 1

Question 1 The FRED codes for the selected variables are as follows: INDPRO, CPIAUCSL, FEDFUNDS, and PPIACO. The series FEDFUNDS should then be merged with the Shadow Federal Funds Rate, with the latter replacing the observations in the former for the period 2009:M1-2015:M11. The four resulting variables are reported in the figure. Students are expected to note that the Shadow Rate turns negative for most of the ZLB period (as indicated in the figure), reaching almost -3 percent at its trough in 2014. Students are expected to consult Wu and Xia (2016) to learn about the nature of the Shadow Rate. This rate reflects the unconventional monetary policy measures enacted by the Federal Reserve during the ZLB period. It is worth noting, for example, that the Shadow Rate reaches its trough in the summer and fall of 2014, which coincided with the end of the Quantitative Easing programs of the Federal Reserve.

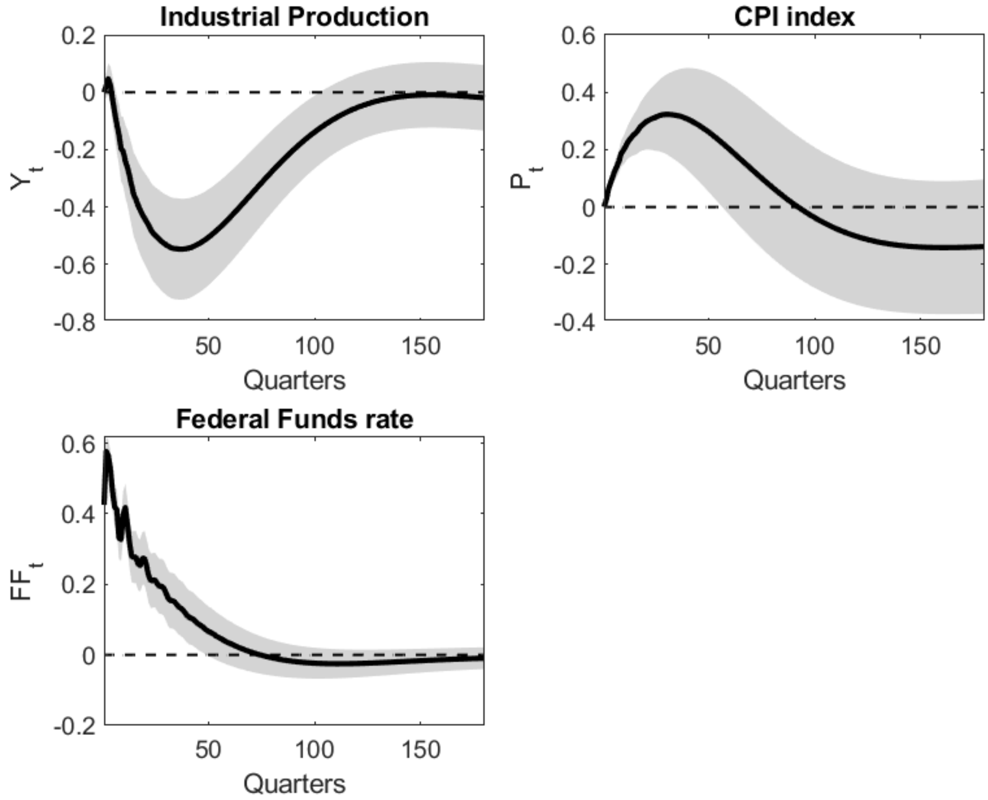


Question 2 Codes for the estimation of VAR models have been made available during the course. Standard transformations imply taking the natural logarithm of all variables except the nominal interest rate. A linear trend can be applied by setting the option 'tt = 2' in the codes distributed. The estimation itself (coefficient matrices etc.) need not be reported. For the results that follow, all log variables have been multiplied by 100.

Question 3 In order to apply a Cholesky decomposition to identify a monetary policy shock, it is crucial that the nominal rate is ordered last in the recursive ordering. This amounts to an implicit assumption that monetary policymakers can react to movements in the other variables in the VAR within-period, but not vice-versa. This is the identifying assumption proposed by Christiano *et al.* (1999). It is based on the short inside lag of the monetary policy process. It is possible for monetary policy decisionmakers to react quickly to incoming news about the economy. On the other hand, it is also well-known that monetary policy affects the economy (in this case, industrial production and prices) with a certain lag, making the assumption that these variables do not react within-period to a change in the policy rate realistic. In the present setup, data is monthly rather than quarterly. On one hand, it makes it even more realistic that industrial production and prices do not react to monetary policy changes within the same month. On the other hand, regular meetings of the Federal Open Market Committee (FOMC), which makes decisions about monetary policy in the US, are scheduled only every 6 weeks. This implies that in a given month in the data, the FOMC might not meet, and thus might not have the chance to change the interest rate (although occasionally, non-scheduled meetings might be held). This would tend to weaken the identifying assumption underlying our structural VAR model. As for the other two variables, the results presented below order industrial production before the price level, though this is not crucial.

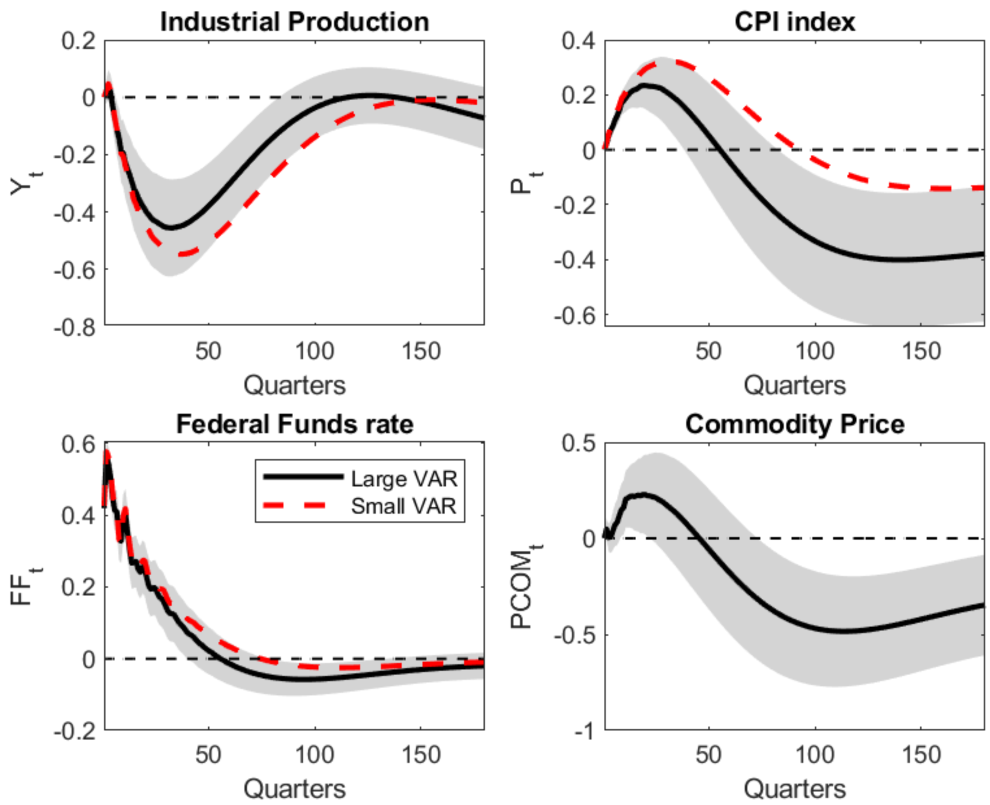
Question 4 The impulse-responses of the three variables, including the bootstrapped 68% confidence bands, are plotted below. It is seen that the Federal Funds rate increases by around 0.5 percent (or 50 basispoints), thus returning smoothly to its original level, which it reaches after around 60 months. The shock leads to a significant and persistent decline in industrial production, which lasts for around 10 years. On the other hand, the CPI index increases on impact and remains elevated for 7-8 years after the shock, after which it displays a small but insignificant decline. These results are in line with those seen during the course; at least qualitatively. This includes those reported by Christiano *et al.* (1999), which the students have been asked to reproduce during the course. The finding of an increase in prices, while counterintuitive, is also in line with most previous work. The extent to which this is to be expected can be discussed; however, given that the sample extends back to 1960, it may not be so surprising that the results do not change dramatically when another decade (or two) is added. The fact that results are in line with previous work may also indicate that unconventional policies were relatively successful in "mimicking" conventional policies, which is also what the path of the Shadow Federal Funds rate seems to indicate.

Question 5 The intuition why the addition of commodity prices may alleviate the price puzzle is as follows. Commodity price increases may often act as a harbinger of future inflationary pressures (much like, for example, increases in inflation expectations). Since commodity prices are in the information set of central bankers, but not of the econometrician if they are left out of the VAR, this may create an omitted variable bias. The observed increase in prices may then simply be a result of the increase in the commodity price index, and not a response to the increase in the Federal Funds



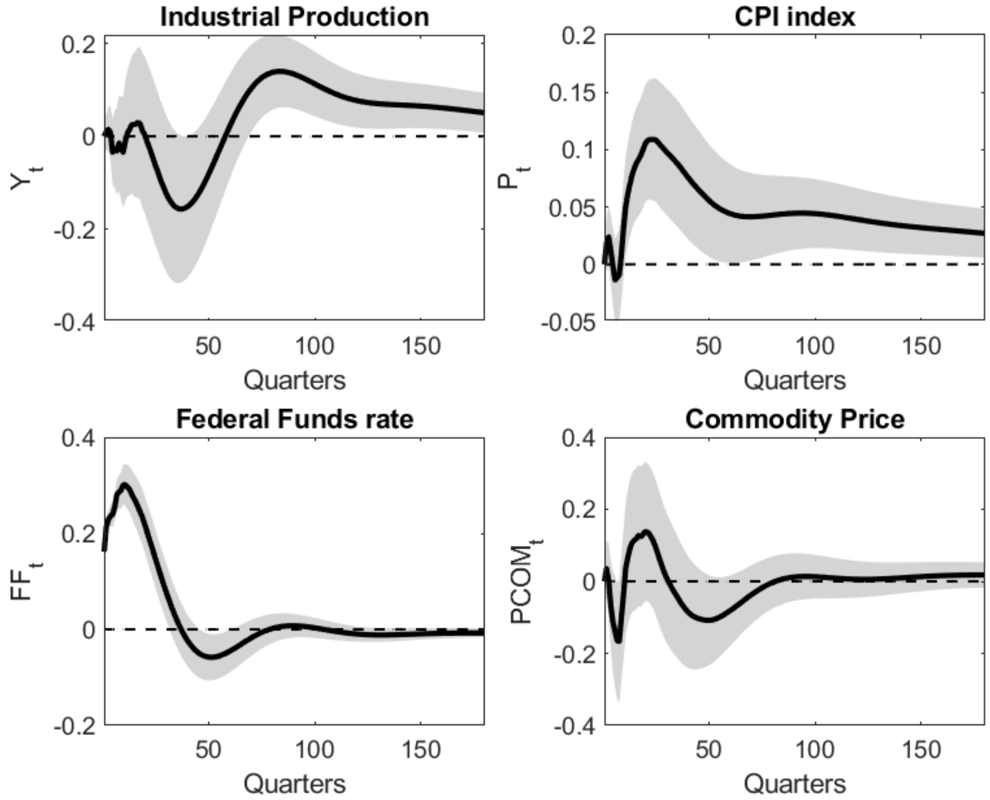
rate. Hence, commodity prices should be included in the VAR to avoid this problem. The figure below plots the impulse responses from the model with commodity prices. For comparison, the responses from the previous question are also included in dashed red lines ("Small VAR"). As seen, the increase in the Federal Funds rate is very similar, while the drop in industrial production is slightly smaller. Most importantly, the increase in prices is now much smaller, and is followed by a quicker, larger, and statistically significant drop in prices (from around 5 years after the shock). In other words, including commodity prices also seems to "work" when applied to this longer sample. Here, commodity prices have been ordered after industrial production and CPI in the VAR, but before the interest rate. This follows, e.g., Coibion (2012), but the results are largely unchanged if commodity prices are placed elsewhere in the VAR.

Question 6 Identifying monetary policy shocks using the recursiveness assumption implies that agents learn about a monetary policy shock when it shows up in the data for the nominal interest rate. In other words, they only learn about it after the central bank has changed the policy rate. In 2019, this assumption appears not particularly realistic: The communication and actions of central banks are followed closely by financial markets and commercial banks, who try to predict future policy rate changes, which have often been implicitly (or explicitly) anticipated by central bank governors or officials in speeches, monetary policy reports, etc. As a result, changes in policy rates by modern central banks are often foreseen before they are imple-



mented, meaning that they cannot be thought of as actual "monetary policy shocks". This was not always the case, and students are expected to dig a bit into U.S. monetary history to answer this question. For example, up until 1994 the U.S. Federal Reserve did not announce policy changes in the target for the Federal Funds Rate (market participants had to "figure it out" themselves). More generally, central bank communication was much more sparse until the latter decades of the sample, and financial markets were less developed until the 1980's than since then. In other words, the assumption appears much more realistic for the first part of the sample than in recent decades. Regarding alternative identification strategies, the use of sign restrictions (briefly discussed in the course) does not really alleviate this issue, as it relies on the same data. However, students have seen during the course how narrative approaches may fix a completely similar problem regarding the identification of government spending shocks. These approaches rely on external measures of surprises in expected government spending, which can then be interpreted as actual shocks. Students are expected to suggest a similar approach for monetary policy: For example, to use additional data to separate between expected and unexpected changes in the nominal interest rate. Indeed, such an approach exists in the literature, following the work of Romer and Romer (2004), which students may draw upon, though this is not required.

Question 7 The results for the Great Moderation subsample are shown in the figure. As illustrated, the conclusions for the longer sample are not robust to this choice of subsam-



ple period. Most importantly, there is no longer a significant decline in industrial production, but instead a short and small drop followed by an equally small (though significant) increase on a 5-10 year horizon. Prices increase, and in this case display no sign of the reversal observed in the full sample. The increase in the interest rate itself is both smaller and less persistent. Regarding the robustness of this result, adding a quadratic trend makes the initial drop in industrial production larger (and significant), and brings about a reversal in prices, thus bringing the results closer in line with the full sample, though they are still rather different (e.g., industrial production still increases eventually). Removing both trends does not make a large difference. Changing the starting date of the subsample by up to two years in either direction does not lead to major changes in the results (although if one starts the subsample in 1979:M8, the month in which Paul Volcker took office, the results look more like the ones for the full sample). In sum, the evidence regarding the effects of a monetary policy supply shock is substantially weaker when the 1960's and 1970's (and early 1980's) are excluded from the sample.

Question 8 The identified sequence of monetary policy shocks is reported in the figure. This series can be computed by using the relationship between the estimated residuals ε_t from the reduced-form VAR model and the structural shocks ξ_t:

$$\varepsilon_t = \mathbf{B}_0^{-1}\xi_t,$$

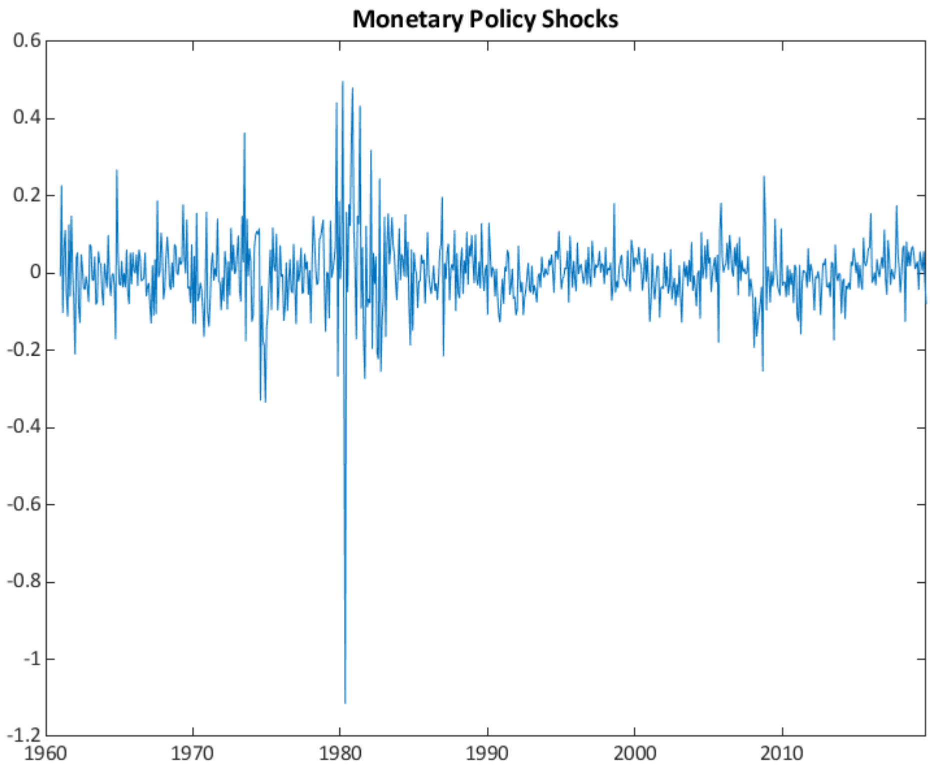
where $\mathbf{B}_0$ is a lower triangular matrix so that $\Sigma_\varepsilon = \mathbf{B}_0^{-1}\left(\mathbf{B}_0^{-1}\right)'$, where Σ_ε is the covariance matrix of the residuals. Upon imposing a Cholesky decomposition the matrix $\mathbf{B}_0^{-1}$ can be recovered, so that the desired matrix ξ_t can be computed from the relationship above. The monetary policy shocks are the shocks to the 4th equation (if the policy rate is ordered last). It is clearly seen that the largest monetary policy shocks occur around 1980. Moreover, the shocks before that period are generally larger than after that period. For example, the standard deviation of the shock series is 0.06 for the period starting in 1984:M1, while it is 0.13 for the period up until that date (and 0.09 until 1979:M8, when Paul Volcker was appointed). This is helpful in understanding why the identification of monetary policy shocks is weaker since 1984: there is simply not a lot of variation, i.e., only relatively small monetary policy shocks have occurred during this period, making it much harder to identify their effects. (It also makes clear why the observations around 1980 are important for identification, cf. the previous question). In their discussion, students are expected to make this point, which is also discussed by Ramey (2016). With monetary policy in the US becoming more rule-based in recent decades, exogenous policy surprises have become more rare events. This means that researchers may have to change the methods used to measure the macroeconomic effects of monetary policy. This is exactly the message of the paper by Nakamura and Steinsson (2018), who use high-frequency data to make the point that the information content in monetary policy announcements are crucial to understand the effects of those announcements. Students are welcome to draw on other sources in their discussion. The bottom line is to arrive at the conclusion that monetary policy shocks have become smaller and more rare during and after the Great Moderation, and therefore more difficult to analyze using existing methods such as VAR models, which may help explain the results of the previous question.

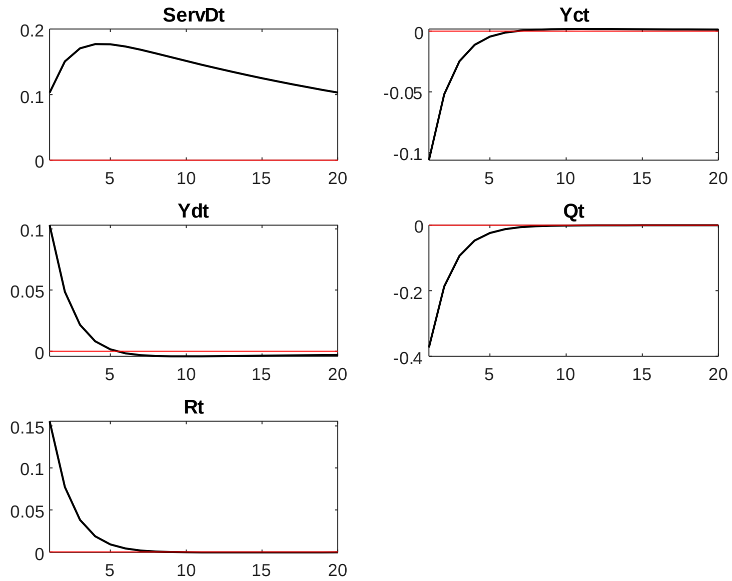
Part 2

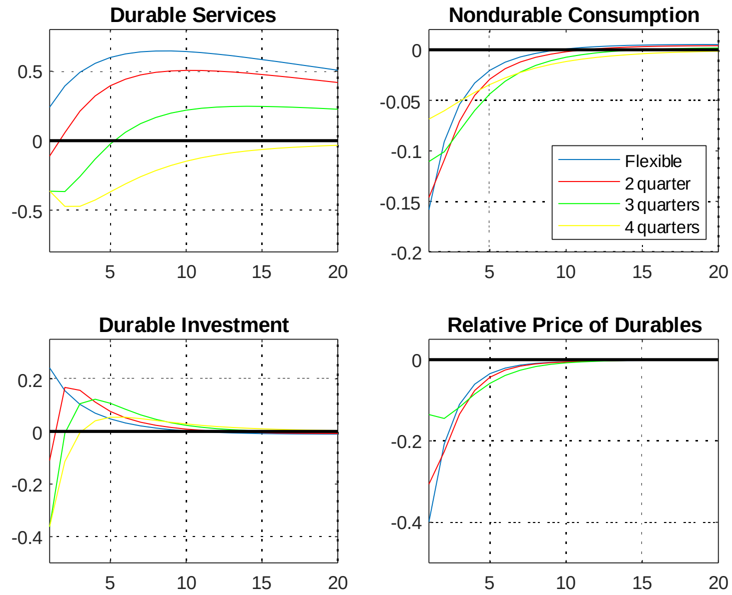
Question 1 See Monacelli (2009).

Question 2 The co-movement puzzle can be observed from the figure. In response to a monetary tightening, consumption of non-durables (Yct) declines, whereas durable investment (Ydt) and durable services (ServDt) both increase. The key explanation is the drop in the relative price of durables, which makes durable consumption more attractive: in response to a monetary tightening, firms would like to reduce their prices. This is possible in the durables sector, where prices are flexible. In contrast, since non-durable prices are sticky, their prices remain "too high", diverting the demand away from that sector. The value of the Rotemberg parameter used to generate price stickiness of four quarters in the non-durable sector is $\vartheta_c = 58.2524$.

Question 3 The correct Rotemberg parameters are the following: $\vartheta_d = \{0, 9.9010, 29.4118, 58.2524\}$ to obtain a duration of $n = \{1, 2, 3, 4\}$ quarters. The figure plots the responses of four key variables for this different set of parameter values. Non-durable consumption always declines, as does the relative price of durables (except when durables


Monetary Policy Shocks
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
1960
1970
1980
1990
2000
2010


ServDt
Yct
Ydt
Qt
Rt



prices are as sticky as non-durables, in which case the relative price is constant). Durable services and investment may increase or decline, depending on the assumed degree of price stickiness.

Question 4 Positive comovement between durable services and non-durable consumption obtains when durable goods prices display a sufficient degree of stickiness in this model. When durables prices are as sticky as non-durable prices ($\vartheta_d = 58.2524$), we observe that both variables display a clear and rather persistent decline. Some mild degree of comovement can already be observed at $\vartheta_c = 9.9010$, while for intermediate values of ϑ_d corresponding to an average price duration of 3 quarters, we observe a clear positive comovement. Notice also from the figure that the answer is the same whether students look at durable services or durable investment.

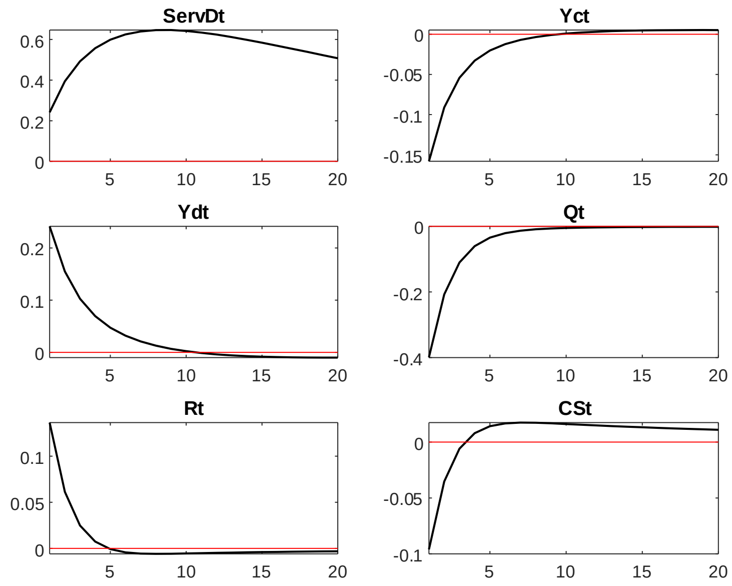
Question 5 It is useful to start from the savers' Euler equation for housing, which reads:

$$\widetilde{U}_{c,t} Q_t = j_t \widetilde{U}_{d,t} + \gamma \left(1 - \delta\right) E_t \left(\widetilde{U}_{c,t+1} Q_{t+1}\right).$$

Observe that this expression is similar to eq. (13) p. 246 in the paper, except that unlike the borrowers, the savers do not face a collateral constraint, so that the last term in eq. (13) drops out. The expression above can be solved forward to yield:

$$\widetilde{U}_{c,t} Q_t = \sum_{i=0}^{\infty} \gamma^i j_{t+i} \widetilde{U}_{d,t+i} \equiv \Upsilon_t \tag{1}$$

Now consider the case where there are no land demand shocks; e.g., $j_t = j$, $\forall\ t$. Since durable goods depreciate very slowly, they are similar to what Barsky *et al.* (2007) call an "idealized durable". This means that the intertemporal elasticity of substitution in the demand for durables is close to infinity. Any short-term

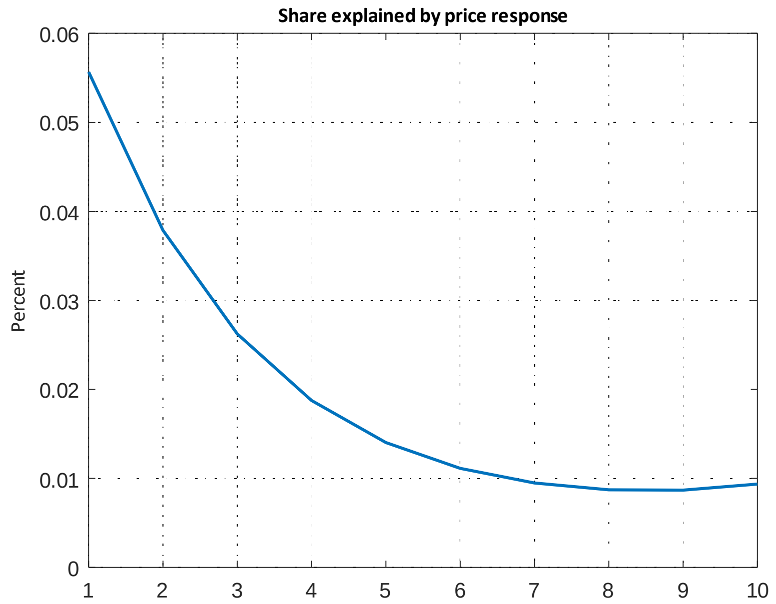


movements in durable services affect the right-hand side of (1) relatively little, as γ is close to one. Hence, we can make the approximation:

$$\begin{aligned} \widetilde{U}_{c,t} Q_t &= \Upsilon_t \approx \Upsilon \Leftrightarrow \\ Q_t &= \frac{\Upsilon}{\widetilde{U}_{c,t}} \end{aligned}$$

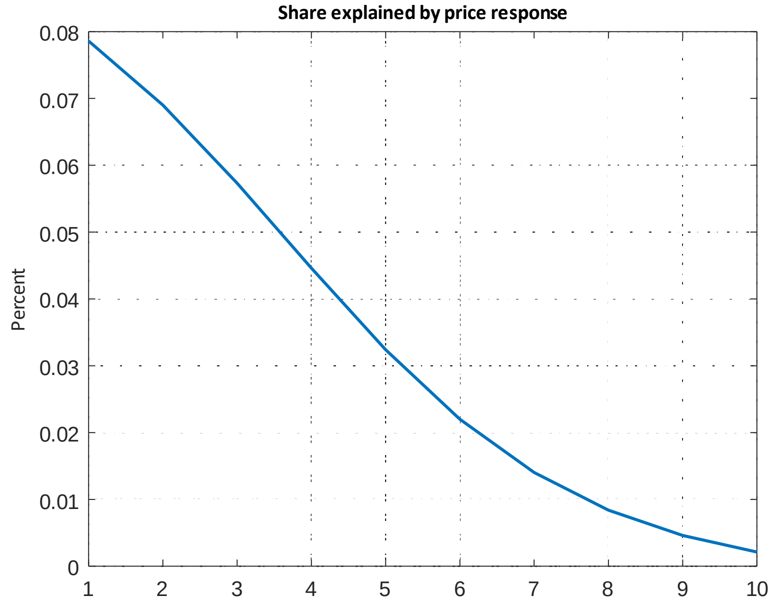
This condition shows that movements in housing prices (in absence of land-demand shocks) are inversely proportional to movements in the savers' marginal utility of non-durable consumption, and thus directly proportional to movements in savers' non-durable consumption. This can be appreciated from the impulse-response functions in the figure, which is obtained from the model with credit frictions (Qt is the price of durables and CSt is savers' consumption). The reason why the introduction of credit frictions do not change this result is that even when there are credit frictions, the savers' Euler equation is still an equlibrium condition of the model, so that the reasoning above carries through.

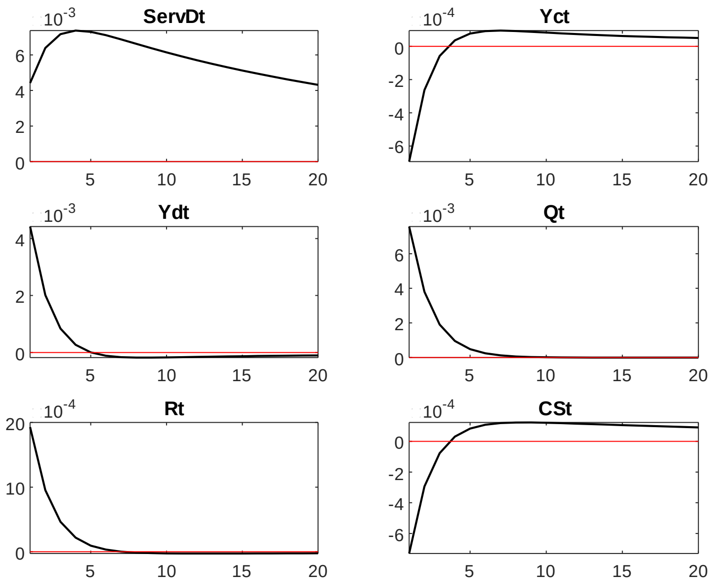
Question 6 The share of the response explained by the price of durables can be computed as the response of the price divided by the sum of the responses of the price and the quantity of durables held by impatient households. The figure reports this share for the first 10 quarters after the shock. As the figure illustrates, the share explained by the price response is quite small. In other words, the vast majority of the decline in borrowing capacity generated by the model in response to a monetary tightening comes from a change in the quantity of durables held. In other words, borrowers can borrow less not because the house price drops, but mainly because they sell off their stock of durables. This is in contrast to what we would expect to observe in the real world, not least since the stock of durables is rather slow-moving. This is an unrealistic feature of the transmission mechanism of the model.



Question 7 The figure shows the share of movements explained by the house price after a housing preference shock. While the share is somewhat higher than in the case of monetary policy shocks, it is still quite small (always less than 10 percent). It thus seems that the unrealistic feature described above is also present after this type of shock.

Question 8 The figure shows that the positive comovement is no longer observable. In fact, the two variables are now negatively correlated. Again, the explanation can be found from the arguments outlined in the response to Question 5. Recall that the approximation $\Upsilon_t \approx \Upsilon$ was warranted only in the absence of housing preference shocks. When these shocks are present, the approximation thus breaks down. Instead we have that $\widetilde{U}_{c,t}Q_t = \Upsilon_t$, and a housing preference shock entails an increase in Υ_t. It is entirely possible to observe that both $\widetilde{U}_{c,t}$ and Q_t increase, so that the price of durables and savers' non-durable consumption move in opposite directions. Intuitively, savers decide to accommodate their stronger taste for durables by reducing their non-durable consumption and by bidding up the price of durables.


Share explained by price response
Percent
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1
2
3
4
5
6
7
8
9
10


ServDt
Yct
Ydt
Qt
Rt
CSt

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