Appendix to paper:

"Identifying the Interdependence between U.S. Monetary Policy and the Stock Market",

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Appendix:

In this appendix we study the robustness of our finding that there is strong simultaneous interaction between the stock market and monetary policy, by using plausible alternative models. In the first section we study the robustness properties with respect to alternative monthly specifications of the model. We then estimate the same model using quarterly data, allowing us to substitute industrial production with GDP. We also expand the dimension of the model by including consumption and investment.

Robustness to alternative monthly specifications

In checking for the robustness of our findings, it is important to establish whether the strong interdependence found is driven by a few extreme events of strong and simultaneous response between stock prices and monetary policy. In the period examined, there were a few times when the stock market fell severely without the fundamentals changing significantly, and monetary policy was implemented to counteract the negative effects of the fall. The stock market crashes in October 1987 and following the September 11, 2001 terrorist attacks are both examples. Furthermore, it is important to establish whether our results change after Alan Greenspan took office in 1987. Regarding model specification, is the choice of lag length in the VAR model important for our results? Further, will the results prevail if the variables in the VAR are specified differently (i.e. taking first differences of the variables or de-trending the variables etc.) and finally, are the results robust to an alternative ordering of the variables?

To investigate the robustness of our results along these dimensions, the upper panel of Figure A1 reports the impulse responses of a normalized monetary policy shock (that increases the interest rate with 100 basis points) on stock prices when the baseline VAR is re-estimated using: (*i*) two dummies for the suggested stock price collapses (*Dummy*), (*ii*) a more recent time period, i.e. the Greenspan period 1987M1 to 2002M12 (*1987*), (*iii*) 6 instead of 4 lags (*6 lags*), (*iv*) a specification where we take first differences of all variables but the

interest rate (*First differences*), (*v*) a linear trend to de-trend both output and inflation (*Linear trend*), and, finally, (*vi*) an alternative order of the first four variables in the VAR. That is, we order output below the real stock price, i.e. we allow for the immediate impact of the stock price shock on output, but restrict real stock prices from responding on impact to output shocks (*Order*). The lower panel of Figure A1 reports the effect of a normalized stock price shock (that increases stock prices by one percent) on the federal funds rate to the same robustness tests.[1]

Starting with the top panel, we see that across the models, there is a substantial and immediate reduction in stock prices due to the monetary policy shock. The baseline model has about the average response across the models. In particular, removing the first part of the sample, re-estimating with a dummy for major events or using first differences, all reduce the impact; whereas alternative de-trending or using more lags increases the impact. All models suggest that real stock prices return to the steady state at approximately the same speed. Finally, note that the impulse responses using an alternative order remain indistinguishable from the baseline, as the effect of the monetary policy shock on stock prices remains identical. The results allow for a generalizing of Christiano et al. (1999; Proposition 4.1) to also include a variable that is identified using a (zero) long-run restriction.[2]

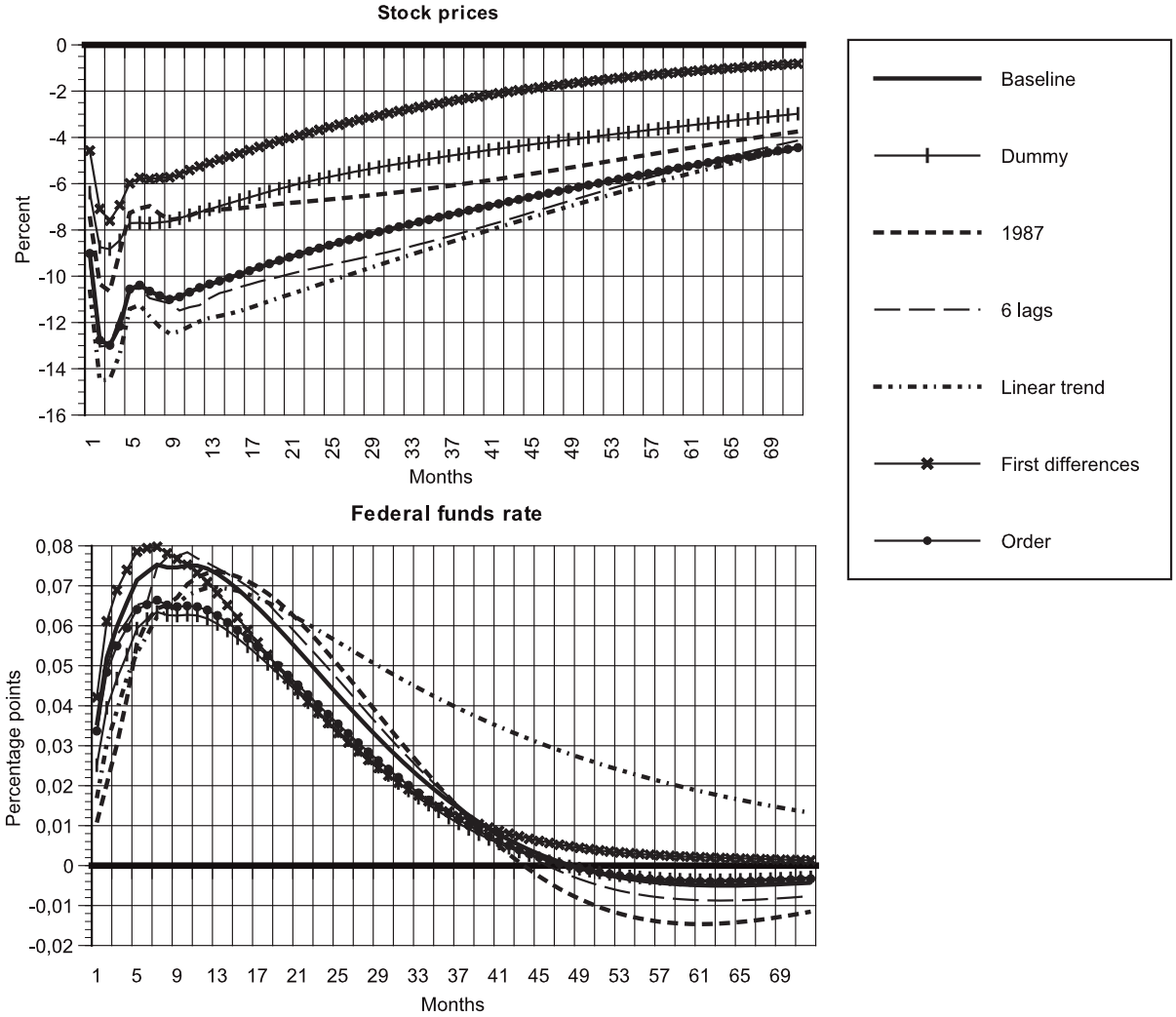
Turning to the response of a stock price shock, the lower panel emphasizes that there is a robust picture with respect to how the federal funds rate reacts to the stock price shock. The baseline model has about the average response across the models. Again, removing the

[1] Several other model specifications were also tested. For instance, specifying all variables in levels or adding a trend to the VAR increased the impact somewhat. However, these responses are not reported as we believe this to yield an improper representation of data. We also tested robustness to substituting some of the variables with plausible alternatives in the VAR. We found that this did not change the results significantly. The greatest difference was found when we included oil prices instead of a commodity price index in the VAR, which magnified all the results. All results can be obtained on request to the authors.

[2] Christiano et al. (1999; Proposition 4.1) states that using a Cholesky decomposition with the monetary policy variable (the interest rate) ordered last, the responses to the monetary policy shock will be invariant to the ordering of the variables above the interest rate. The real bite here is the assumption that the variables in the VAR do not respond contemporaneously to a monetary policy shock.

first part of the sample, re-estimating with a dummy for a major event or using first differences

Figure A1. Impulse responses under alternative monthly model specifications to a monetary policy shock (upper panel) and a stock price shock (lower panel).

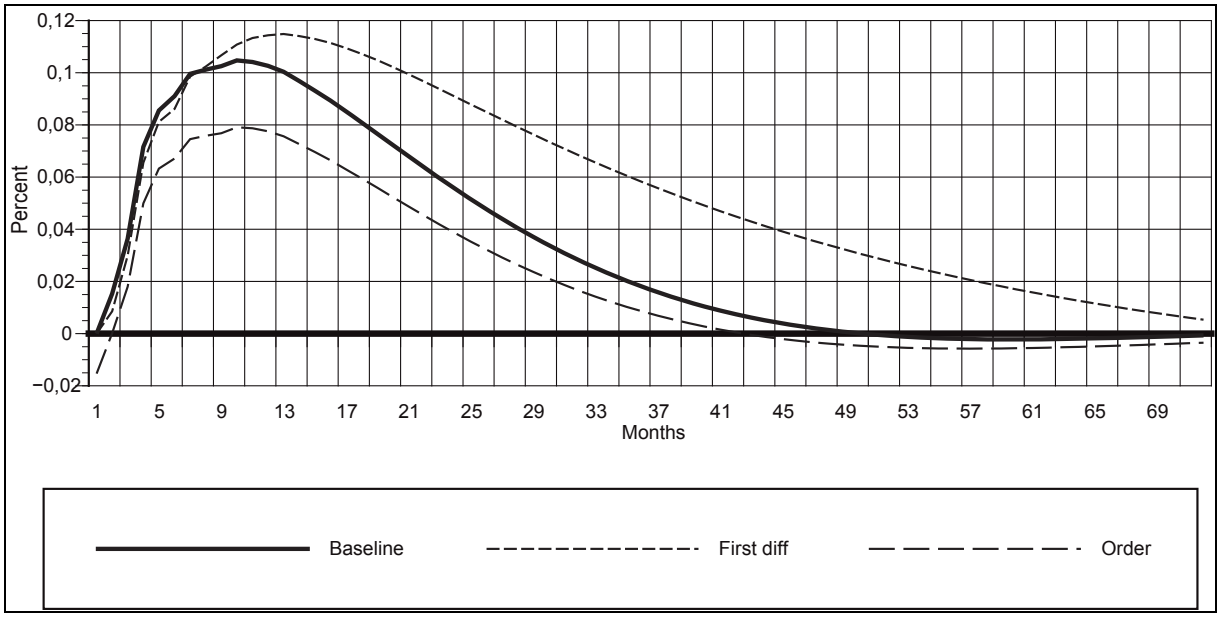


Note: The upper panel shows the impulse response of real stock prices to a normalized monetary policy shock that increases the nominal interest rate on impact by one percentage point. The lower panel shows the impulse response of the federal funds rate to a normalized stock price shock that increases stock prices by one percent. See the main text for an explanation of the different monthly specifications.

reduces the immediate response somewhat; whereas using more lags and alternative de-trending increases the response. Using an alternative order of the variables reduces the impact somewhat. Hence, we are confident in reporting that all models suggest that the interaction is quantitatively important. There may be some evidence that the impact effect of both shocks

has decreased somewhat over time, although these results depend on the specific VAR model specified.

Figure A2. Industrial production: Effect of a stock price shock using an alternative ordering or first differences



Note: The effect of a stock price shock comparing the baseline model with models using an alternative order (industrial production is ordered *after* real stock price) and using first differences.

Before turning to the quarterly model, Figure A2 reports robustness of the effect of a stock price shock on industrial production, using two alternative specifications; using (*i*) first differences (*First diff.*) or using (*ii*) the alternative order (*Order*) discussed above (where the real stock price is ordered above output). The two robustness tests are chosen to cast more light on the interpretation of the stock price shock. In particular, when output is measured in first differences, we allow for a potential long-run impact of shocks. However, as can be seen, the dynamic effects of the shock on output are similar, although somewhat more persistent.

The alternative order is chosen to allow the stock price shock to have an immediate effect on production (i.e., Jaimovich and Rebelo, 2006). This was ruled out by our original identification scheme. However, as discussed in the paper, it can be argued that it is not unlikely that consumer prices, consumption and investment decisions are subject to implementation lags of a similar length to the model's monthly frequency. A possible way to

test for implementation lags in output is to allow for the immediate impact of the stock price shock on output, but as a requirement for identification, to restrict real stock prices from responding on impact to output shocks. However, Figure A.2 emphasizes that the impact effect is close to zero, as in the baseline model. This gives some support to our assumption about implementation lags in output. However, we acknowledge that this is only an imperfect test since we might have imposed an implausible assumption when restricting real stock prices from responding on impact to shocks in output.

Robustness to alternative quarterly specifications

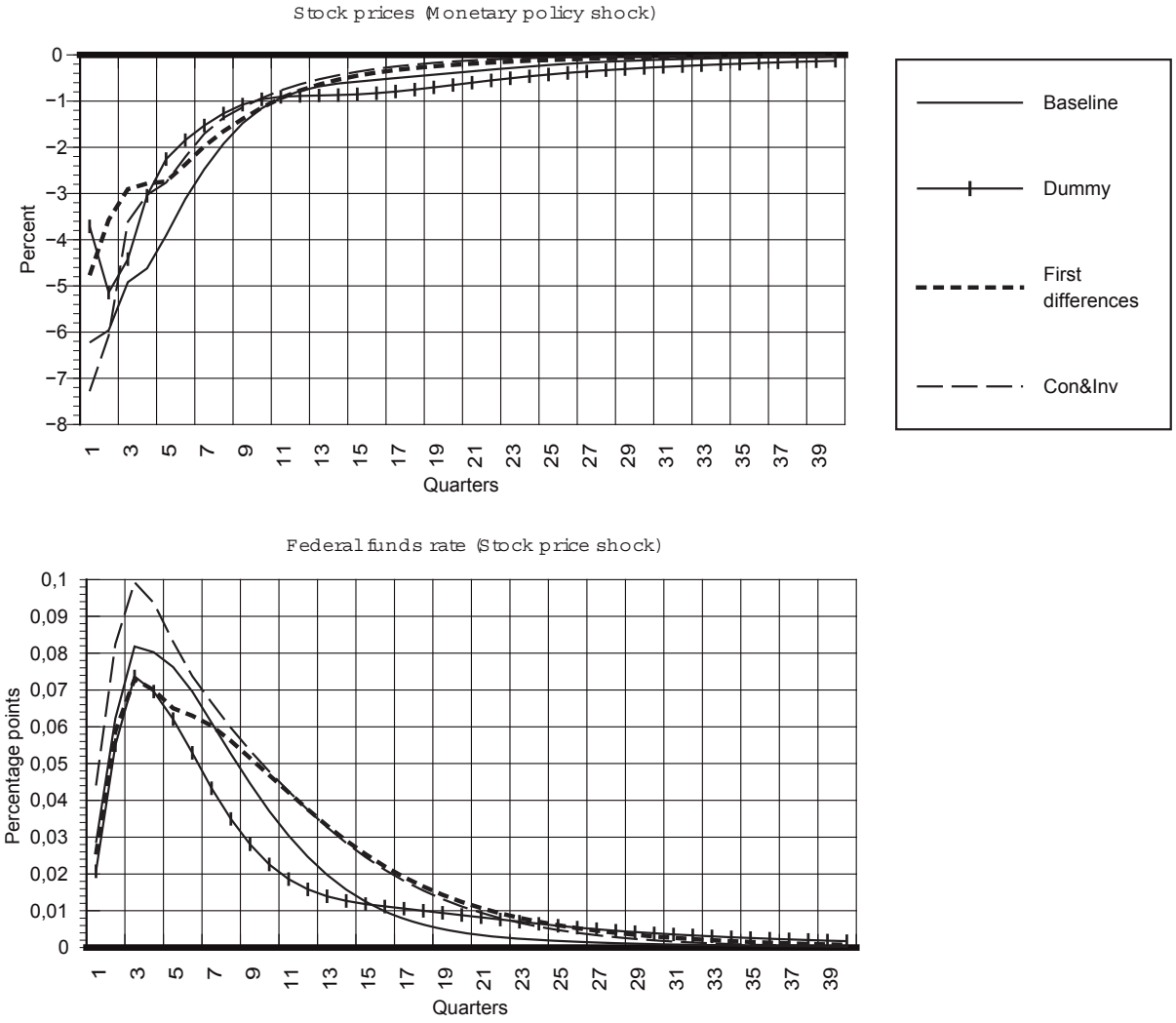
Although we believe that the interaction between monetary policy and asset markets is best modeled at high frequency, a quarterly specification allows us to use other macroeconomic series that are arguably more important for monetary policy and aggregate stock prices. Our results are, however, confirmed in a robust manner also at this frequency. We consider several specifications of the quarterly model. First, as the baseline model, we estimate the quarterly model from 1983 with GDP replacing industrial production (*Baseline*).[3] In a second specification we augment the VAR using the same dummies as above, albeit at a quarterly frequency, i.e. 1987Q4 and 2001Q3 (*Dummy*), then we augment the baseline model, transforming the variables to first differences (*First differences*) and, finally, in the last specification we augment the VAR by replacing GDP with consumption and investment (*Con&Inv*).[4]

The upper panel of Figure A3 shows the impulse responses of a normalized monetary policy shock (that increases the interest rate with one percentage point initially) on real stock prices for these model specifications, whereas in the lower panel of the same figure, we graph the responses in the federal funds rate of a normalized stock price shock (which increases real

[3] In all specifications, GDP replaces industrial production, whereas the other variables remain the same, but are aggregated up to a quarterly frequency. The variables are transformed the same way as in the monthly model (i.e. GDP is linearly de-trended), and we use two lags (2 quarters) in the VAR.
[4] When the VAR is augmented with consumption and investment, all variables but the interest rates are first differenced.

stock prices initially with one percent) for the same model specifications. Finally, in figure A4 we graph the response in consumption and investment to the stock price shock.

Figure A3. Impulse responses under alternative quarterly model specifications to a monetary policy shock (upper panel) and a stock price shock (lower panel).

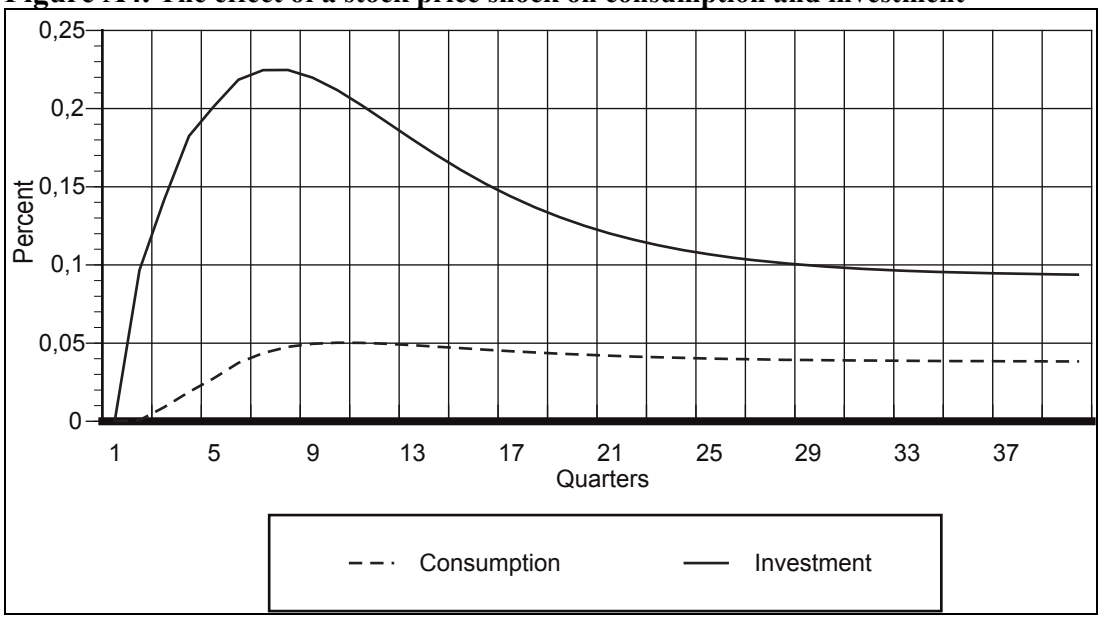


Note: The upper panel shows the impulse response of real stock prices to a normalized monetary policy shock that increases the nominal interest rate on impact by one percentage point. The lower panel shows the impulse response of the federal funds rate to a normalized stock price shock that increases stock prices by one percent. See the main text for an explanation of the different quarterly specifications.

The upper panel of Figure A3 emphasizes again that there is a substantial and immediate fall in stock prices due to the monetary policy shock. A monetary policy shock that increases the interest rate with 100 basis points, reduces the stock price with 6-7 percent. As in the monthly models, the baseline model displays an average response across the models. Using first

differences reduces the impact the most, whereas when we augment the model with consumption and investment (instead of GDP) the impact effect increases. Further, the lower panel emphasizes that a stock price shock that increases the real stock price by one percent increases the Fed rate with three basis points and increases to eight basis points within a year. Also here, the baseline model displays an average response across the models.

Figure A4. The effect of a stock price shock on consumption and investment



Note: Impulse response of consumption and investment from a normalized stock price shock (that increases stock prices with one percent initially) in the quarterly model (Con&Inv).

Finally, Figure A4 shows that a positive stock price shock increases both consumption and investment in the short run. This confirms the results found in the monthly model: a rise in real stock prices increases consumption through a wealth effect and investment through a Tobin Q effect, thus affecting aggregate demand. Under either the news or the sunspot interpretation, the shock may contain vital information to the central bank for reasons outlined in Section 2. However, Figure A4 also emphasizes that there may be some more persistent effects from stock price shocks than in the benchmark model, although low point estimates and wide standard error bands (not reported) suggest that the effects of the shock eventually die out.