Sectoral TFP News Shocks

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Abstract

We document a strong similarity in the macroeconomic effects of consumption-specific and investment specific TFP news shocks. This co-linearity suggests a diffusion channel of technological innovations from the investment to the consumption sector that forecast future changes in aggregate TFP. This finding connects two views of the literature on news shocks: aggregate TFP news and investment specific news.

Keywords: News shocks, Business cycles, VAR, Sectoral TFP.

JEL Classification: E2, E3.

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1 Introduction

Shocks to future aggregate TFP have been proposed by Beaudry and Portier (2006) as important sources of U.S. business cycles. This contrasts with a different view articulated by Ben Zeev and Khan (2015) which suggests a shift of focus from aggregate to investment-specific news shocks.[1] However, aggregate TFP is by construction a weighted average of investment specific and consumption specific TFP and hence shocks to the latter cannot be dismissed *a-priori* as an influential source of business cycle fluctuations.[2]

This paper provides new evidence on the macroeconomic effects of consumption- and investment-specific TFP news shocks that can synthesize both views. We document that VAR-identified news shocks to aggregate, investment-, and consumption-specific TFP exhibit qualitatively and quantitatively very similar dynamics on prices, quantities and asset prices. Specifically, each of these shocks, independently identified, is associated with a broad based increase in economic activity, the stock market and consumer confidence, as well as a decline in the relative price of investment (RPI), inflation and a credit spread indicator.

The timing of the responses to the sectoral shocks provides further insights into their propagation. We find that the statistically significant response of consumption-specific TFP occurs with a considerable delay (and is smaller in magnitude) compared to the statistically significant response of investment-specific TFP. Such a delayed pattern is also evident in the responses of the RPI. Specifically, while the RPI declines immediately following the investment-specific TFP news shock, it declines statistically significant in response to a consumption-specific news shock with a delay. Importantly, the timing of this decline coincides with the statistically significant increase in consumption-specific TFP. These timing patterns suggest diffusion of technologies from innovations that take place in equipment producing industries (investment sector) to faster TFP growth in equipment using industries (consumption sector).

[1] For further work highlighting the importance of aggregate and investment specific TFP news shocks see the review by Beaudry and Portier (2014) and the references therein.

[2] The weights in the construction of aggregate TFP are the sectoral shares of value added which are (on average) 0.23/0.77 for the investment/consumption series. More detailed information on the weights is provided in Section 3.

Basu et al. (2013) provide new evidence on sector specific TFP shocks. They document that unanticipated consumption and investment specific shocks can have different macroeconomic effects. To the best of our knowledge, the only other studies concerned with sectoral TFP news shocks are Nam and Wang (2014) and Vukotic (2016). Nam and Wang (2014) demonstrate that the decomposition of aggregate TFP into its sectoral components matters for the interpretation of the effects of news shocks. Vukotic (2016) documents responses to TFP news shocks in the durables and non-durables industries in the US manufacturing sector, suggesting that an aggregate TFP news shock reveals information about future TFP of the durable manufacturing sector. Both studies broadly support the notion that future growth shocks that emanate in the durables sector are quite important for understanding aggregate TFP news shocks. These studies differ however in the identified economic effects of news shocks; while Nam and Wang (2014) find that investment specific news (which nests the durables sector) are key contributors to economic fluctuations, Vukotic (2016), provides evidence against this finding. Our study provides new valuable evidence on the propagation of news shocks by focussing on the diffusion of technology from the investment to the consumption sector and aggregate TFP.

The remainder of the paper is organized as follows. Sections 2 and 3 discuss data and econometric methodology. Section 4 reports results and section 5 concludes.

2 Data and estimation

We estimate the VAR using quarterly U.S. data for the period 1983:Q1–2017:Q1. We focus on the post Great Moderation era (mid-1980s onwards), informed by a wide body of evidence that points to important structural changes (including nature of shocks) in the economy, and evidence that suggests a proliferation of technological innovations in the 1980s and 1990s (see e.g. Basu et al. (2003)). We identify (i), an aggregate, (ii), a consumption specific (iii), an investment specific TFP news shock, one at a time, from the VAR model, adopting the Max Share identification method proposed by Francis et al. (2014). Our analysis will apply the method seeking for a news shock that maximizes its contribution to the forecast error variance (FEV) of the aggregate or a sector specific TFP measure at a specific horizon (forty quarters) and does not move the respective TFP measure on impact.[3] The aggregate, consumption, and investment specific utilization-adjusted TFP are provided by Fernald (2014) and serve as observable measures for technology.[4] We estimate two different seven-variable VAR specifications for our analysis. Each specification will be used to separately identify each of the three news shocks explained above. Specification I uses one indicator of utilization adjusted TFP (either the aggregate or one of the two sectoral series), real per capita GDP, real per capita consumption (services and non-durables), per capita hours worked, BAA corporate bond spread, inflation and the Michigan consumer confidence indicator (E5Y). Specification II uses one indicator of utilization adjusted TFP (either the aggregate or one of the two sectoral series), real per capita GDP, real per capita investment (fixed private investment and consumer durables), per capita hours worked, relative price of investment (ratio of investment to consumption deflator), S&P 500 index and the E5Y. To estimate the VAR model we use three lags and a Minnesota prior. Consistent with the treatment in the empirical VAR literature (see e.g. Beaudry and Portier (2014)) time series in the VAR are used in levels.[5]

3 Properties of aggregate and sectoral TFP measures

The growth rate of aggregate TFP is an expenditure share-weighted average of the growth rates of TFP in equipment and consumer durables (the investment goods producing sector) and TFP in non-equipment business output (the consumption goods producing sector), where weights are the sectors' shares in value added (see Fernald (2014)). Table 1 reports statistics on aggregate and sectoral TFP growth measures. Not surprisingly, investment sec-

[3]We provide additional details and show robustness of our results using alternative identification methodologies in an online appendix available on the authors' websites, section B.1.

[4]In contrast to the related study by Nam and Wang (2014), we use a shorter sample, but importantly also the latest 2017 vintage for utilization-adjusted TFP which contains — unlike previous vintages — significant corrections on utilization from industry data following Basu et al. (2013).

[5]The VAR approach and the time series used are standard in the literature. Further details on time series construction and VAR estimation can be found in the online appendix, sections A and C. This appendix also shows that our results are robust to alternative maximization horizons of the variance in the news shock identification (section B.2) and alternative lag specifications in the VAR (section B.3).

tor TFP growth is both higher on average and more volatile compared to consumption sector TFP growth. The weak correlation (0.31) between the sectoral TFP growth rates points to a weak co-movement between the two series and therefore suggests that changes in aggregate TFP cannot be interpreted as a single homogeneous technological indicator (see also Basu et al. (2013) for corroborating evidence). Moreover, since the weight on investment sector TFP (0.23) is relatively small, by construction, moments of the aggregate TFP growth rate are largely determined by the properties of the consumption sector series. This dominance is also reflected in the correlation statistics: the aggregate TFP growth rate co-moves more closely with the growth rate of consumption-specific TFP (0.88) than the growth rate of investment-specific TFP (0.73), further suggesting that movements in the growth rate of aggregate TFP should be influenced significantly by the growth rate in consumption-specific TFP.

Table 1: Statistics on utilization-adjusted TFP data. Sample is 1983Q1-2017Q1.

	moments		correlations of growth rates	
	mean	stdev	I-sector TFP	C-sector TFP
Investment sector TFP growth rate	2.93	5.85	1	0.31
Consumption sector TFP growth rate	0.26	2.55	0.31	1
Aggregate TFP growth rate	0.91	2.72	0.73	0.88
I-sector TFP weight in aggregate	0.23	0.01		

4 Findings

Figure 1 displays impulse responses (IRFs) from specification I to an aggregate, investment-specific and consumption-specific TFP news shock. Quite strikingly, the dynamics induced by the aggregate or sectoral TFP news shocks are extremely similar to each other. Aggregate and sectoral TFP rises in a delayed fashion, and it becomes significantly different from zero after several years.[6] Each of the independently identified TFP news shocks creates a boom today: output, consumption, and hours increase significantly on impact, and they display hump-shaped dynamics. The BAA corporate bond spread declines significantly, suggesting that corporate bond markets anticipate movements in future TFP, consistent with the findings by Görtz et al. (2016) who highlight the importance of frictions in financial markets for the propagation of TFP news shocks. Moreover, confidence indicator (E5Y) increases in anticipation of the future rise in TFP, and inflation exhibits a short lived decline.

Figure 2 displays IRFs for VAR specification II confirming the striking similarity discussed above. Variables that are common in specifications I and II exhibit IRFs that are qualitatively and quantitatively similar. The response of investment is consistent with the overall broad-based rise in activity, and it rises significantly in response to good news about future TFP. The S&P 500 index also rises significantly in anticipation of the future rise in TFP, consistent with the evidence reported in Beaudry and Portier (2006). The RPI declines significantly in response to an aggregate or either sectoral TFP news shock. The investment specific news shock can be thought of as a supply of capital shifter and hence can theoretically generate a decline in the RPI. The surprising finding is that the consumption specific news shock, which can be thought as a capital demand shifter, is associated with a decline in the RPI. We provide an interpretation for this finding below.

Overall, these *a-priori* different sectoral shocks are qualitatively and quantitatively very similar to each other. Moreover, as evident from figures 1 and 2 the IRFs to the sectoral TFP news shocks are largely within the confidence bands of the IRF to the aggregate news shock. The only difference arises in the case of sectoral TFP, where the long-run response of the investment-specific TFP measure is larger compared to the long-run responses of either aggregate or consumption-specific TFP measures, a consequence of the significantly higher average TFP growth in the sample (see Table 1).[7]

[6] The initial drop in the median response of TFP, most notably in the consumption sector, may be rationalised by complementary investment that usually accompanies general purpose technologies and has a short run depressing effect on measured TFP. Evidence for this is provided in Basu et al. (2003).

[7] Appendix B.4 reports shares of FEV accounted for by sector specific and aggregate TFP news shocks derived from VAR specification II. We find that, beyond the first year, aggregate TFP news shocks account for over 20% and for most variables 40% of the FEV in all horizons, supporting their significance as a driving force of the business cycle.

Figures 3 and 4 display IRFs with confidence bands for the sectoral TFP news shocks discussed above. Two additional robust findings are worth highlighting: (i) in the short run, the expansion of investment-specific TFP is faster and larger in magnitude than the expansion of the consumption-specific TFP. For example, in Figure 4, investment-specific TFP rises significantly above zero after seven quarters whereas consumption-specific TFP rises significantly above zero after fourteen quarters. (ii) the decline of the RPI to the consumption-specific news shock becomes significant with a delay (see Figure 4), and this timing roughly coincides with the timing of the statistically significant increase in consumption-specific TFP. Since consumption-specific TFP largely determines the path of aggregate TFP, this pattern of long run co-movement between the RPI and consumption-specific TFP is consistent with the evidence of co-integration between aggregate TFP and the RPI reported in Schmitt-Grohe and Uribe (2011).[8]

Figure 5 confirms the strong co-linearity of sector-specific TFP news shocks. It displays scatter plots of sector-specific news (top panels) and unanticipated (bottom panels) shock time series for the two specifications of the VAR model.[9] The top panels suggest a very strong correlation between sector-specific news shocks across the different specifications of the VAR model (0.97 and 0.97).[10] By contrast, the bottom panels point to a weak correlation between sector-specific unanticipated TFP shocks across the different specifications of the VAR model (0.29 and 0.31), consistent with the weak correlation between the two sectoral TFP growth rates reported in Table 1.[11]

The strong collinearity between sector-specific TFP news shocks in combination with

[8] In the on-line Appendix B.5 we report results from VAR specification II that includes both sectoral TFP measures at the same time. These VAR specifications allow us to examine more closely how a news TFP shock in one sector impacts TFP in the other sector. The findings suggest that TFP in the consumption sector always lags behind the significant increase TFP in the investment sector and therefore support the finding of technological diffusion from the latter to the former.

[9] Our identification method identifies the unanticipated TFP shock as the reduced form innovation of the TFP equation in the VAR. The TFP news shock is then identified as the linear combination of all the other reduced form innovations except the TFP reduced form innovation.

[10] The correlation between the sectoral and aggregate news shocks is also very strong, ranging between 0.90 and 0.95.

[11] The weak correlation between sectoral unanticipated TFP shocks is consistent with the evidence in Basu et al. (2013) who argue for separate sector-specific technologies. We also tested for Granger causality to investigate whether there is evidence for a direction of causation between sector-specific TFP news shocks. We cannot reject the null of no Granger causality for all the different pairs of sectoral TFP news shocks identified from the VAR model.

the findings (i) and (ii) described above, favors an interpretation of technological spillovers, that is, innovations in new capital equipment produced by the investment sector that are adopted on a large scale basis by the consumption sector. This spillover is consistent with the delayed long-run decline in the RPI and the delayed increase in consumption sector TFP (in comparison to responses to the investment sector news shock). Basu et al. (2003) have documented, using detailed industry data, this type of spillover which typically characterizes general purpose technologies. They establish that innovations in information and communication technologies (ICT) in a set of equipment-producing industries, coincided with a decline in the price of ICT, and were associated with a strong TFP acceleration in industries that used ICT technologies in the 1990s. The majority of the ICT using industries were service-oriented, comprising a large fraction of the consumption sector.

5 Conclusion

We show that VAR identified sector specific TFP news shocks are highly collinear. We identify timing patterns in the sectoral TFP and RPI responses that are consistent with diffusion of innovations from the investment sector that materialize in higher TFP in the consumption sector and the aggregate economy. Our findings can therefore reconcile two views of the news shocks literature, namely, the importance of both aggregate and investment-specific TFP news shocks for U.S. business cycle fluctuations. In an important study, Basu et al. (2013) report that unanticipated consumption specific shocks have expansionary effects on economic activity consistent with our findings on consumption specific news shocks. However, they find that unanticipated investment specific shocks have depressing effects on economic activity, whereas we find that investment specific news shocks behave very much alike consumption specific news. A direct and close examination is beyond the scope of the paper but we note a key difference.[12] Our findings suggest that news TFP shocks predict a slow and widespread build up in TFP across both sectors in the future, a pattern which seems to be absent from the unanticipated technology shocks in Basu et al. (2013).

[12] It is important to stress that there are many parameters that differ between our study and theirs, namely, sample period, econometric methods, and frequency of sampling to allow a close comparison.

Our finding that news shocks may involve significant spillover across sectors indicates interesting directions for future research. Enriching theoretical models — which typically imply orthogonality across shocks — with a mechanism for technological diffusion and spillovers across sectors, may allow isolating the mechanisms through which expected innovations in one sector diffuse and enhance the expected productive efficiency of other sectors and the overall economy.

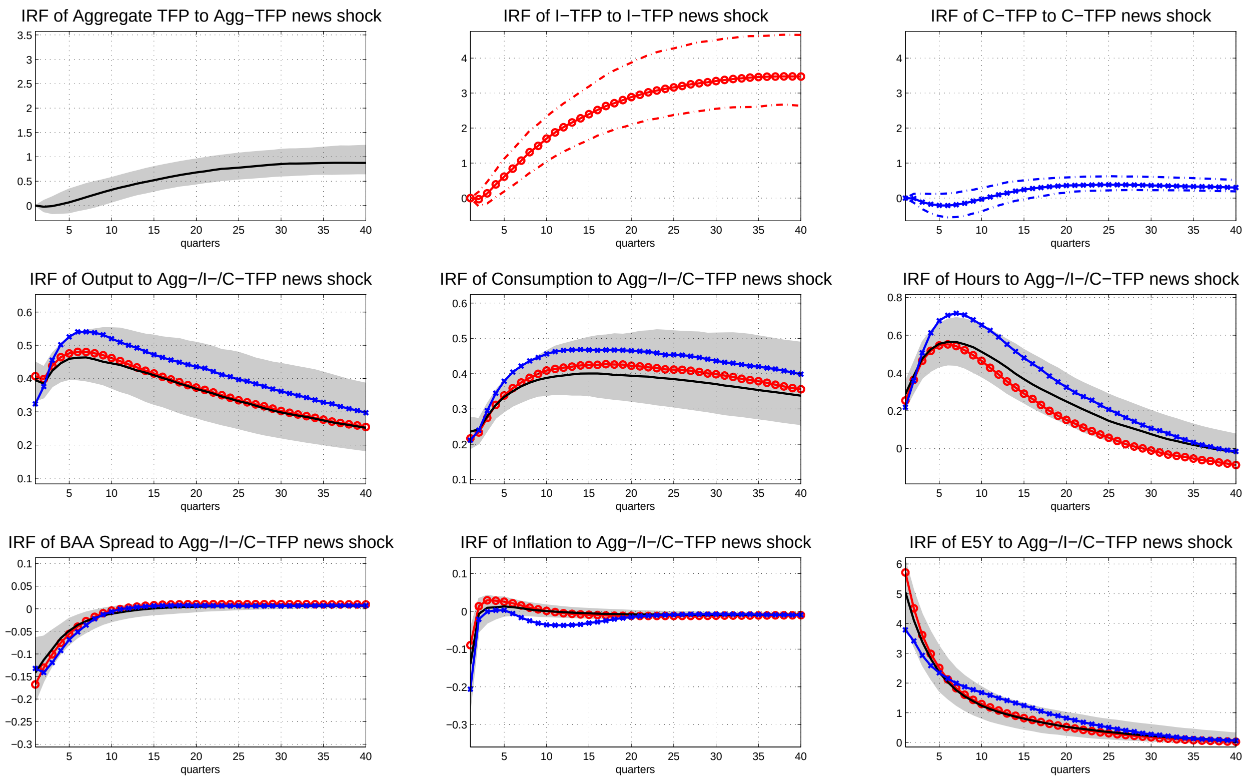

Figure 1: **Responses to aggregate and sector-specific TFP news shocks from 7-variable VAR, specification I.** Median responses to an aggregate (solid line), consumption- (blue line with crosses) and investment-specific (red line with circles) TFP news shock from a seven variable VAR. The shaded gray areas are the 16% and 84% posterior bands generated from the posterior distribution of VAR parameters corresponding to the specification with the aggregate TFP measure. The units of the vertical axes are percentage deviations.

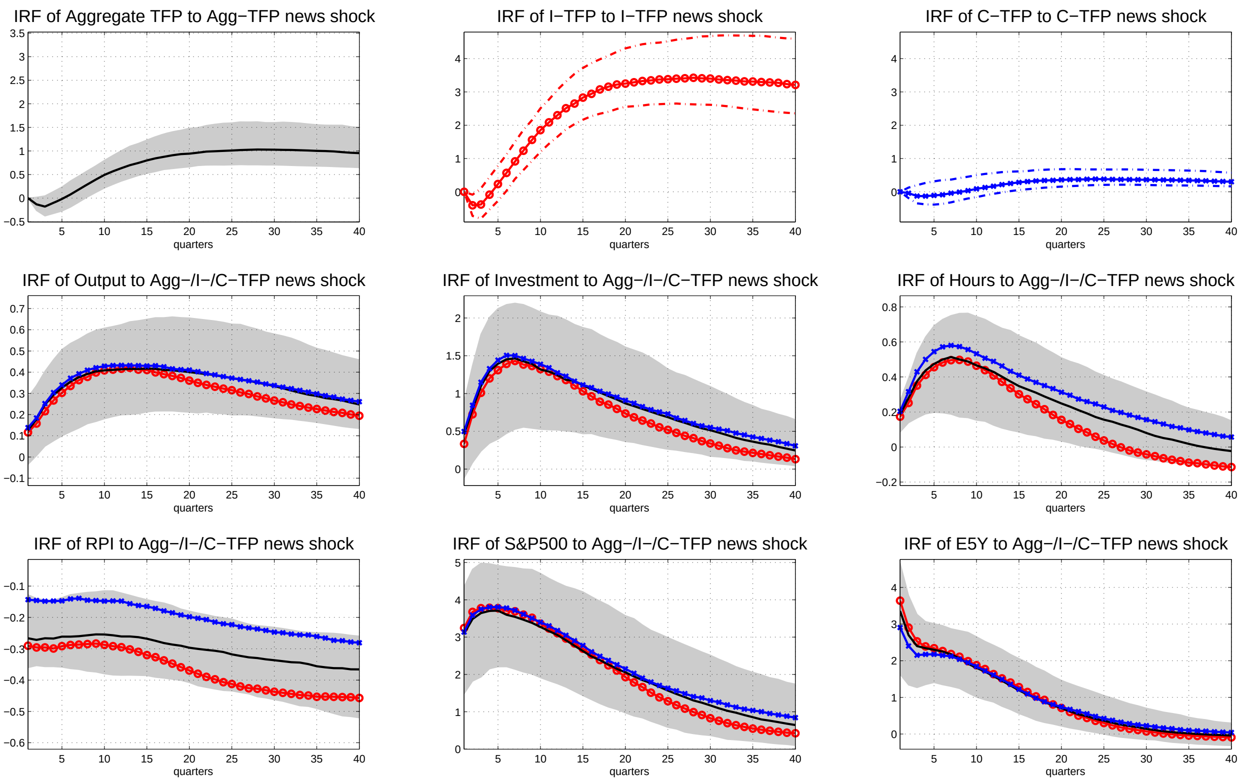

Figure 2: **Responses to aggregate and sector-specific TFP news shocks from 7-variable VAR, specification II.** Median responses to an aggregate (solid line), consumption- (blue line with crosses) and investment-specific (red line with circles) TFP news shock from a seven variable VAR. The shaded gray areas are the 16% and 84% posterior bands generated from the posterior distribution of VAR parameters corresponding to the specification with the aggregate TFP measure. The units of the vertical axes are percentage deviations.

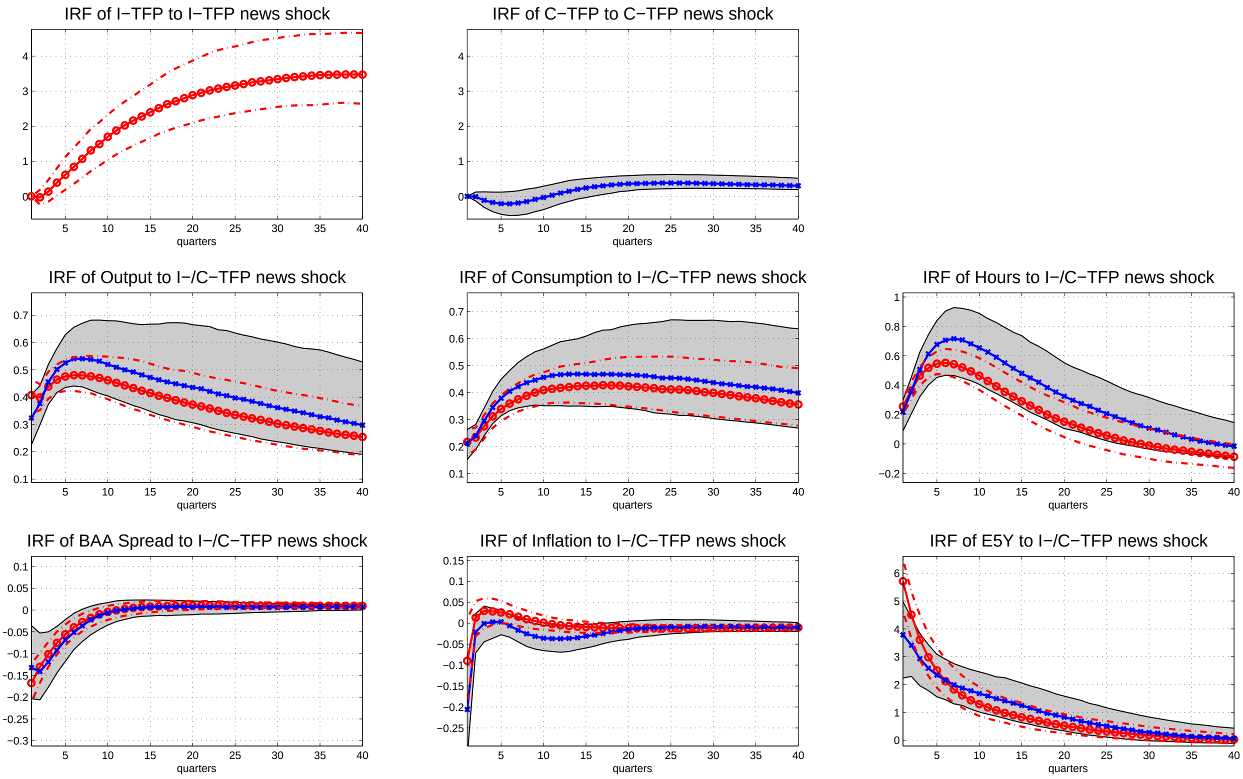

Figure 3: **Responses to sector-specific TFP news shocks from 7-variable VAR, specification I.** Median responses to a consumption- (blue line with crosses) and investment-specific (red line with circles) TFP news shock from a seven variable VAR. The shaded gray areas (red dash-dotted lines) are the 16% and 84% posterior bands generated from the posterior distribution of VAR parameters corresponding to the specification with the consumption sector (investment sector) TFP measure. The units of the vertical axes are percentage deviations.

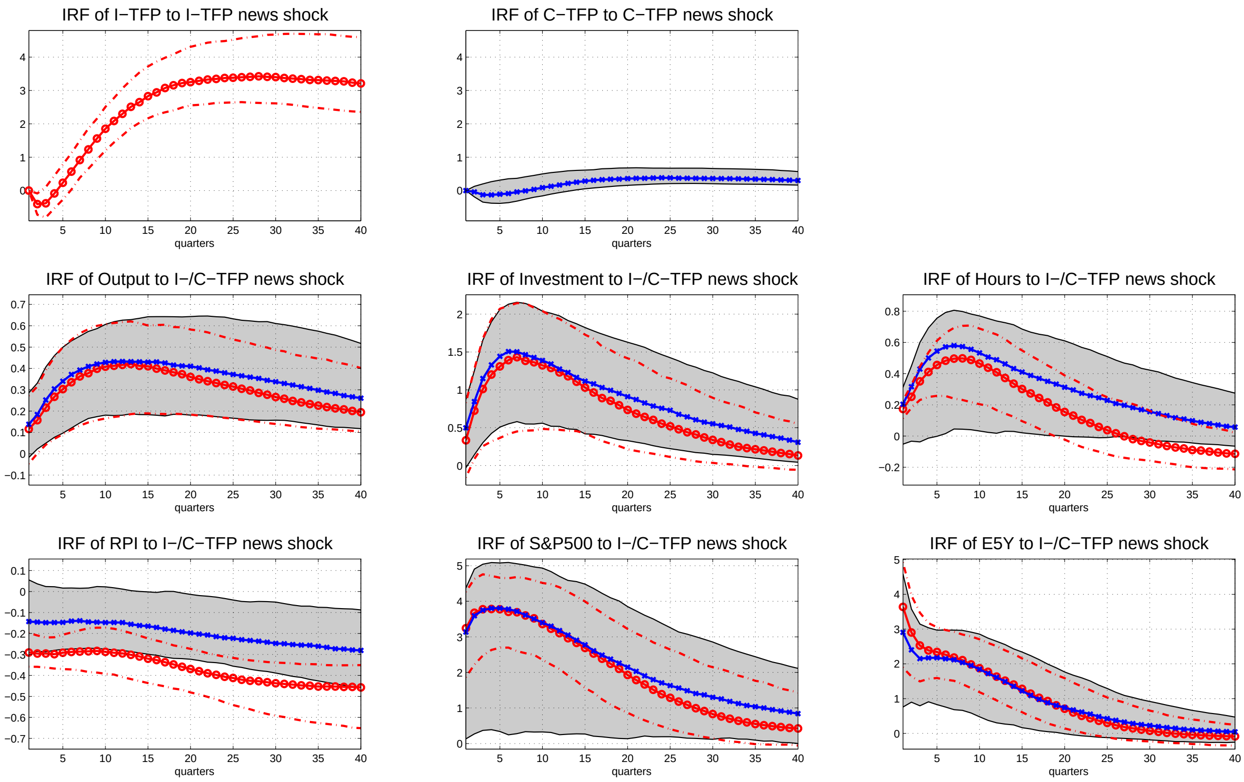

Figure 4: **Responses to sector-specific TFP news shocks from 7-variable VAR, specification II.** Median responses to a consumption- (blue line with crosses) and investment-specific (red line with circles) TFP news shock from a seven variable VAR. The shaded gray areas (red dash-dotted lines) are the 16% and 84% posterior bands generated from the posterior distribution of VAR parameters corresponding to the specification with the consumption sector (investment sector) TFP measure. The units of the vertical axes are percentage deviations.

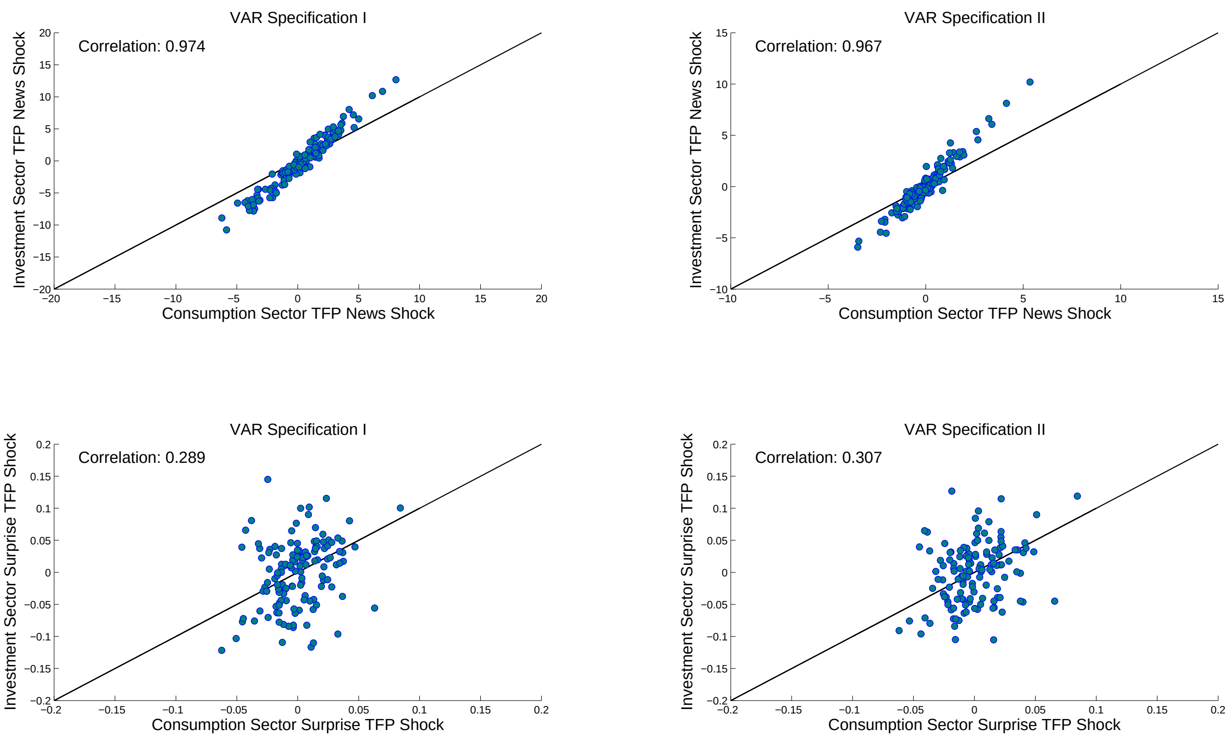

Figure 5: Scatter plots of the sectoral TFP news shocks from the VAR model (top panels) and sectoral TFP surprise shocks (bottom panels) for specifications I and II.

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Sectoral TFP News Shocks *

Appendix with supplementary material

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A The VAR model

This section provides an overview about the underlying VAR model and the Minnesota prior used for the VAR coefficients. Consider the following reduced form VAR(p) model,

$$y_t = A(L)u_t,$$

where y_t is an $n \times 1$ vector of variables of interest, $A(L) = I + A_1 L + A_2 L^2 + ... + A_p L^p$ is a lag polynomial, $A_1, A_2, ..., A_p$ are $n \times n$ matrices of coefficients and, finally, u_t is an error term with $n \times n$ covariance matrix Σ. Define a linear mapping between reduced form, u_t, and structural errors, ε_t,

$$u_t = B_0 \varepsilon_t,$$

We can then write the structural moving average representation as

$$y_t = C(L)\varepsilon_t,$$

where $C(L) = A(L)B_0$, $\varepsilon_t = B_0^{-1}u_t$, and the matrix B_0 satisfies $B_0 B_0^{'} = \Sigma$. The B_0 matrix may also be written as $B_0 = \tilde{B}_0 D$, where $\tilde{B}_0$ is any arbitrary orthogonalization of Σ and D is an orthonormal matrix ($DD' = I$).

The h step ahead forecast error is,

$$y_{t+h} - E_{t-1}y_{t+h} = \sum_{\tau=0}^{h} A_\tau \tilde{B}_0 D \varepsilon_{t+h-\tau}.$$

The share of the forecast error variance of variable i attributable to shock j at horizon h is then

$$V_{i,j}(h) = \frac{e_i^{'}\Big(\sum_{\tau=0}^{h} A_\tau \tilde{B}_0 D e_j e_j^{'} D' \tilde{B}_0^{'} A_\tau^{'}\Big)e_i}{e_i^{'}\Big(\sum_{\tau=0}^{h} A_\tau \Sigma A_\tau^{'}\Big)e_i} = \frac{\sum_{\tau=0}^{h} A_{i,\tau}\tilde{B}_0 \gamma\gamma' \tilde{B}_0^{'} A_{i,\tau}^{'}}{\sum_{\tau=0}^{h} A_{i,\tau}\Sigma A_{i,\tau}^{'}},$$

where e_i denotes selection vectors with one in the i-th position and zeros elsewhere. The e_j vectors pick out the j-th column of D, denoted by γ. $\tilde{B}_0\gamma$ is an $n \times 1$ vector corresponding to the j-th column of a possible orthogonalization and can be interpreted as an impulse response vector. In the following section, we discuss the estimation and identification methodology that yields an estimate for the TFP news shock from the VAR model.

We specify a Minnesota prior for the VAR coefficients, A, of the form

$$vec(A) \sim N\left(\underline{\beta}, \underline{V}\right),$$

where $\underline{\beta}$ is one for variables which are in log-levels, and zero for the corporate bond spread as well as inflation. The prior variance $\underline{V}$ is diagonal with elements,

$$\underline{V}_{i,jj} = \begin{cases} \frac{\underline{a}_1}{p^2} \text{ for coefficients on own lags} \\ \frac{\underline{a}_2 \sigma_{ii}}{p^2 \sigma_{jj}} \text{ for coefficients on lags of variable } j \neq i \\ \underline{a}_3 \sigma_{ii} \text{ for intercepts} \end{cases}$$

where, p denotes the number of lags. Here σ_{ii} is the residual variance from the unrestricted p-lag univariate autoregression for variable i. The degree of shrinkage depends on the hyperparameters $\underline{a}_1, \underline{a}_2, \underline{a}_3$. We set $\underline{a}_3 = 100$ and we select $\underline{a}_1, \underline{a}_2$ by searching on a grid and selecting the prior that maximizes the in-sample fit of the VAR, as measured by the Bayesian Information Criterion.[1]

B Robustness and Corroborative Results

B.1 Robustness to alternative identification approaches

In this section we show that our results are robust to alternative identification approaches used in the literature. These identification schemes have been proposed by Barsky and Sims (2011) and Forni et al. (2014) and are closely related to our baseline identification proposed by Francis et al. (2014) in that they all impose a zero impact restriction on TFP to identify the news shocks. The Barsky and Sims (2011) method identifies the news shock as the shock that maximizes the forecast error variance over a horizon from zero to forty quarters. Forni et al. (2014) identify the news shock as the shock that has maximum impact on TFP at the forty quarter horizon. We prefer the Max Share method of Francis et al. (2014), compared to the closely related Barsky and Sims (2011) method, since the latter seeks the shock that maximizes the FEV of TFP at long and short horizons, potentially confounding temporary and permanent future TFP shocks. In addition, revisions in utilization estimates in successive revisions of the TFP data can be a source of short run measurement error; the Max Share method by the nature of the maximization problem, is preferable compared to the Barsky and Sims (2011) method, which may not be robust to this source of measurement error. The advantage of the Max Share method over the Forni et al. (2014) method is that the former treats the maximization horizon as a parameter that the user can change.

[1] The grid of values we use is:
$\underline{a}_1$ = (1e-5,2e-5,3e-5,4e-5,5e-5,6e-5,7e-5,8e-5,9e-5, 1e-4,2e-4,3e-4,4e-4,5e-4,6e-4,7e-4,8e-4,9e-4, 0.001,0.002,0.003,0.004,0.005,0.006,0.007,0.008,0.009, 0.01,0.02,0.03,0.04,0.05,0.06,0.07,0.08,0.09, 0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9, 1,2,3,4,5,6,7,8,9,10),
$\underline{a}_2$ = (0.01,0.02,0.03,0.04,0.05,0.06,0.07,0.08,0.09, 0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9,1,2,3,4,5,6,7,8,910).
We take all possible pairs of $\underline{a}_1$ and $\underline{a}_2$ in the above grids, so we end up estimating 1540 models.

Figures 1, 2 and 3 display the median IRFs for VAR specification II. It is evident that these are virtually indistinguishable for either the aggregate or the two sectoral TFP news shocks.

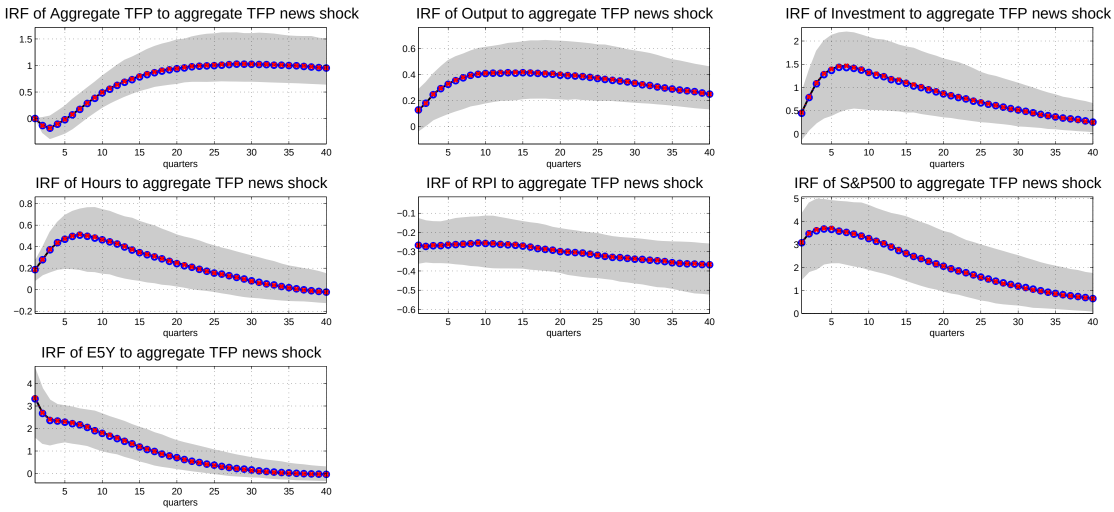

Figure 1: **Aggregate TFP news shock, specification II.** Median responses to a aggregate TFP news shock identified using the baseline scheme proposed by Francis et al. (2014) (black solid line), the Barsky and Sims (2011) methodology (red line with crosses) and the Forni et al. (2014) methodology (blue line with circles). The shaded gray areas are the 16% and 84% posterior bands generated from the posterior distribution of VAR parameters corresponding to the baseline identification. The units of the vertical axes are percentage deviations.

B.2 Robustness to horizon of variance maximization in shock identification

In the main body of the paper the Max Share methodology identifies the news shock as the shock that (i) does not move TFP on impact and (ii) maximizes the variance of TFP at a specific finite horizon. As a baseline specification in the paper we have set the horizon to 40 quarters which is the baseline specification used in several existing papers in the literature, e.g. Barsky and Sims (2011). Figures 4, 5 and 6 show that our results are also robust to varying this horizon to 30 or 50 quarters.

B.3 Robustness to the number of lags

We undertake robustness tests also with respect to the number of lags used in the VAR. Figures 7, 8 and 9 show that the baseline specification with three lags delivers very similar results to specifications with four or five lags.

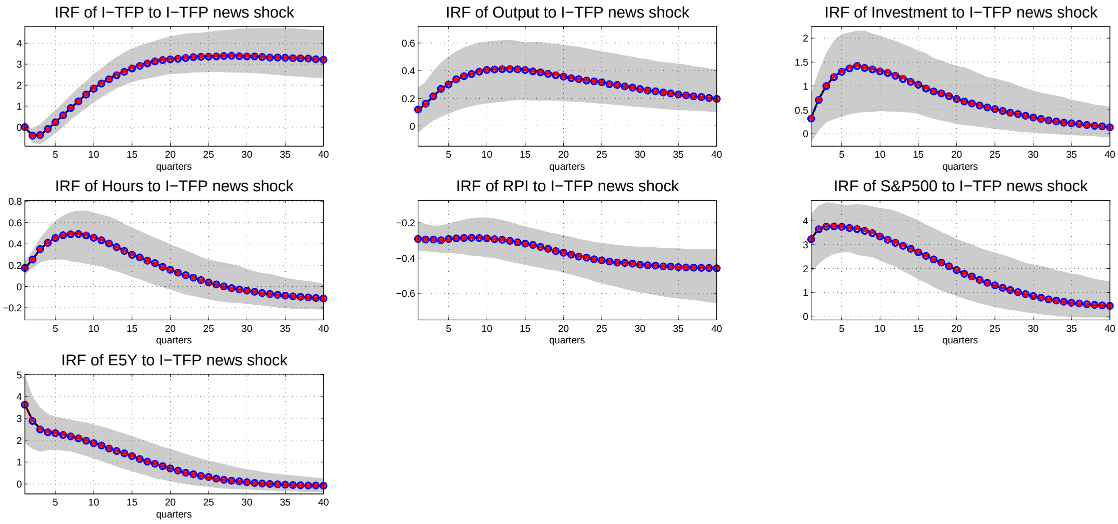

Figure 2: **Investment specific TFP news shock, specification II.** Median responses to a investment sector TFP news shock identified using the baseline scheme proposed by Francis et al. (2014) (black solid line), the Barsky and Sims (2011) methodology (red line with crosses) and the Forni et al. (2014) methodology (blue line with circles). The shaded gray areas are the 16% and 84% posterior bands generated from the posterior distribution of VAR parameters corresponding to the baseline identification. The units of the vertical axes are percentage deviations.

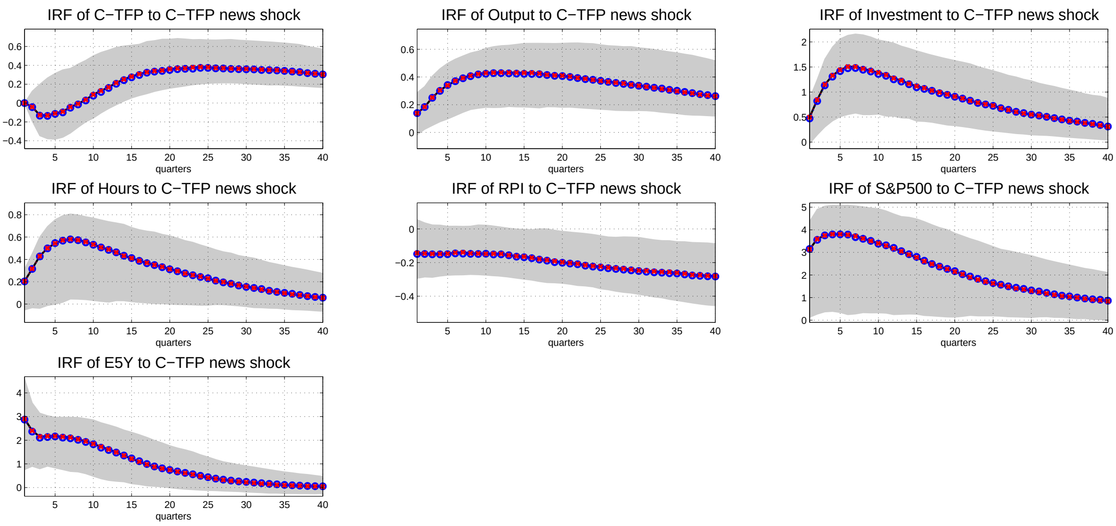

Figure 3: **Consumption specific TFP news shock, specification II.** Median responses to a consumption sector TFP news shock identified using the baseline scheme proposed by Francis et al. (2014) (black solid line), the Barsky and Sims (2011) methodology (red line with crosses) and the Forni et al. (2014) methodology (blue line with circles). The shaded gray areas are the 16% and 84% posterior bands generated from the posterior distribution of VAR parameters corresponding to the baseline identification. The units of the vertical axes are percentage deviations.

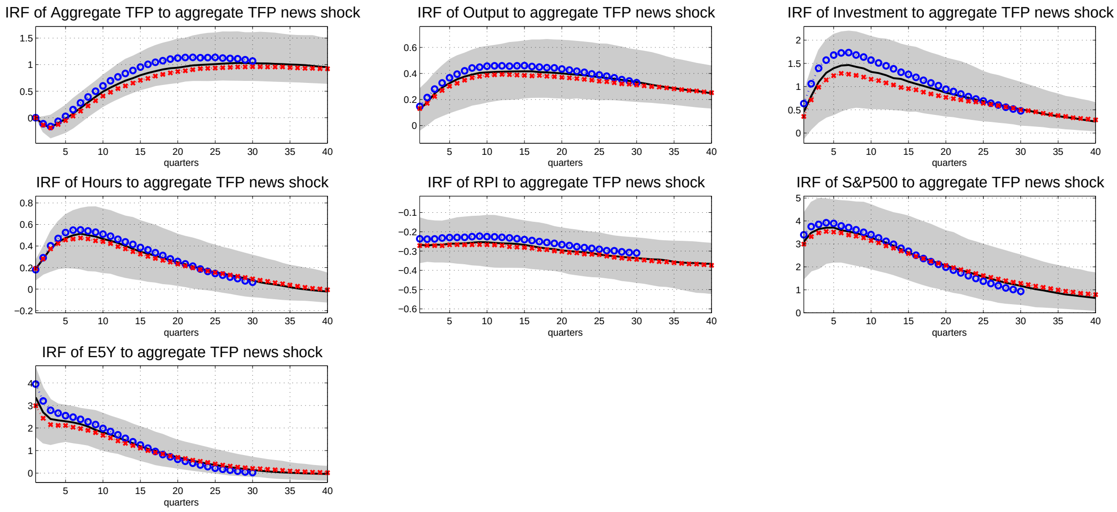

Figure 4: **Aggregate TFP news shock, specification II.** Median responses to a aggregate TFP news shock using a 40 quarter horizon (black solid line), 50 quarter horizon (red line with crosses) and 30 quarter horizon (blue line with circles). The shaded gray areas are the 16% and 84% posterior bands generated from the posterior distribution of VAR parameters corresponding to the baseline identification with three lags. The units of the vertical axes are percentage deviations.

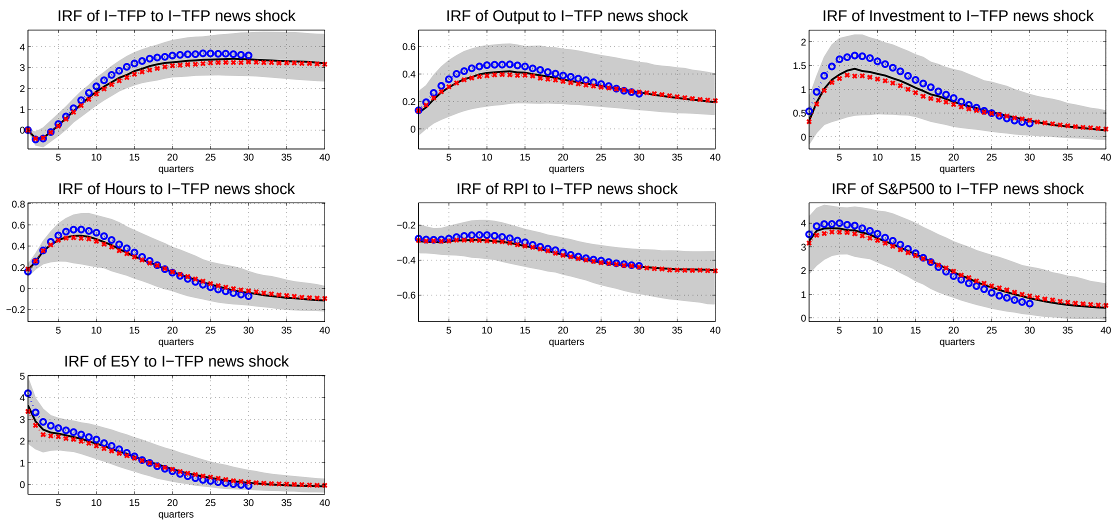

Figure 5: **Investment specific TFP news shock, specification II.** Median responses to a investment sector TFP news shock using a 40 quarter horizon (black solid line), 50 quarter horizon (red line with crosses) and 30 quarter horizon (blue line with circles). The shaded gray areas are the 16% and 84% posterior bands generated from the posterior distribution of VAR parameters corresponding to the baseline identification with three lags. The units of the vertical axes are percentage deviations.

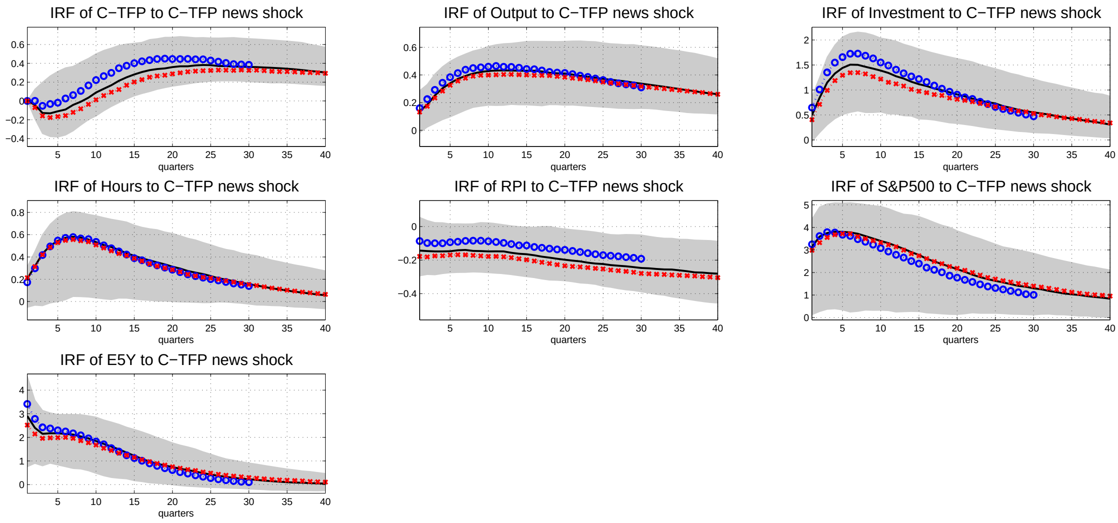

Figure 6: **Consumption specific TFP news shock, specification II.** Median responses to a consumption sector TFP news shock using a 40 quarter horizon (black solid line), 50 quarter horizon (red line with crosses) and 30 quarter horizon (blue line with circles). The shaded gray areas are the 16% and 84% posterior bands generated from the posterior distribution of VAR parameters corresponding to the baseline identification with three lags. The units of the vertical axes are percentage deviations.

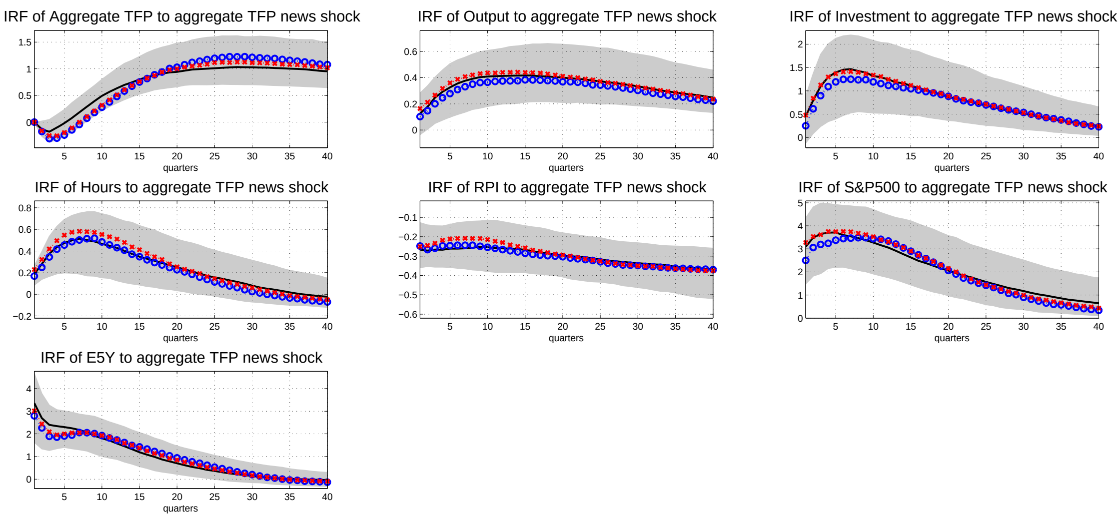

Figure 7: **Aggregate TFP news shock, specification II.** Median responses to a aggregate TFP news shock using three lag (black solid line), four lags (red line with crosses) and five lags (blue line with circles). The shaded gray areas are the 16% and 84% posterior bands generated from the posterior distribution of VAR parameters corresponding to the baseline identification with three lags. The units of the vertical axes are percentage deviations.

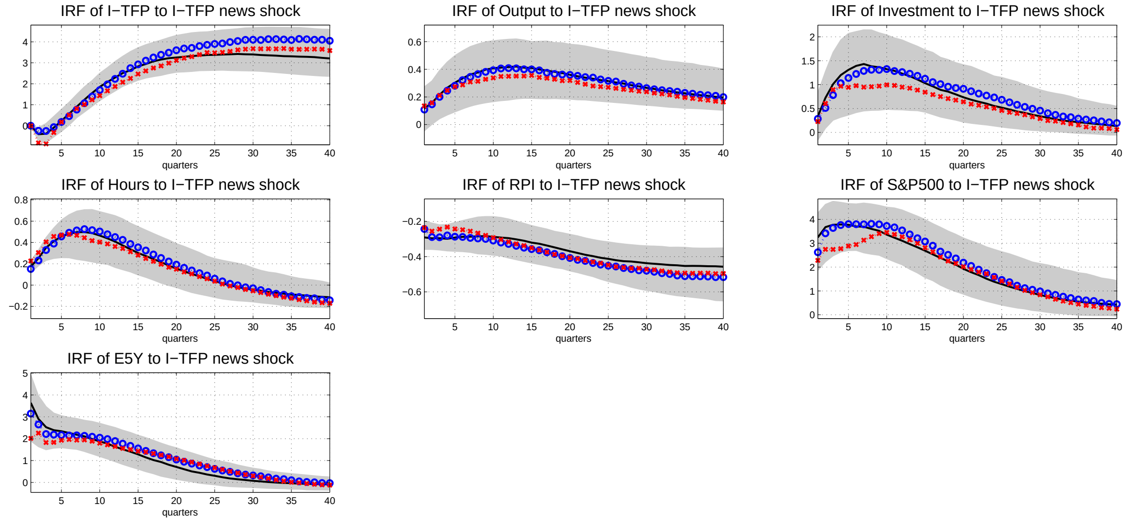

Figure 8: **Investment specific TFP news shock, specification II.** Median responses to a investment sector TFP news shock using three lag (black solid line), four lags (red line with crosses) and five lags (blue line with circles). The shaded gray areas are the 16% and 84% posterior bands generated from the posterior distribution of VAR parameters corresponding to the baseline identification with three lags. The units of the vertical axes are percentage deviations.

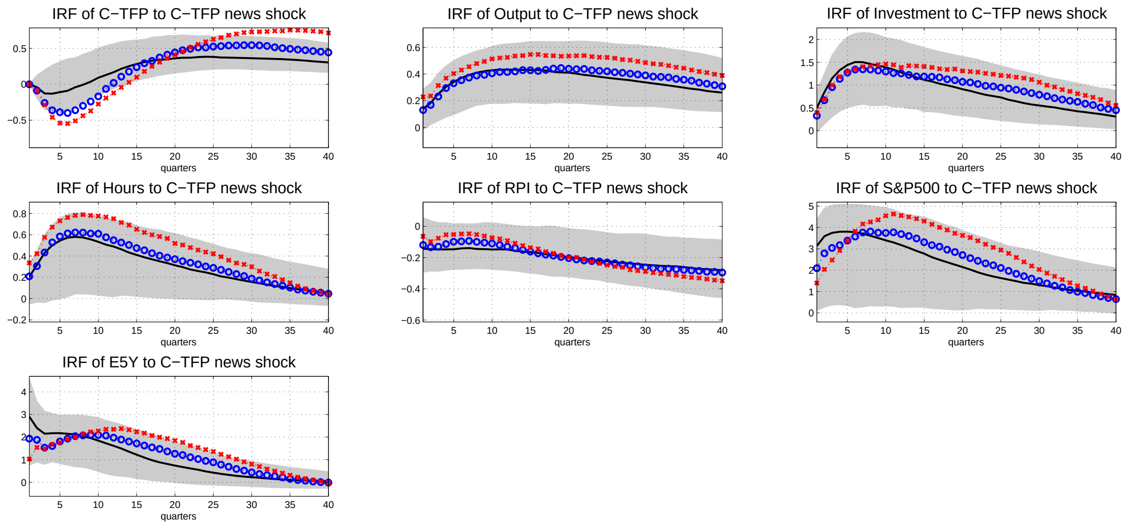

Figure 9: **Consumption specific TFP news shock, specification II.** Median responses to a consumption sector TFP news shock using three lag (black solid line), four lags (red line with crosses) and five lags (blue line with circles). The shaded gray areas are the 16% and 84% posterior bands generated from the posterior distribution of VAR parameters corresponding to the baseline identification with three lags. The units of the vertical axes are percentage deviations.

B.4 Forecast error variance decompositions

Figures 10, 11 and 12 show the forecast-error variance shares attributed to the variables in specification II in response to an aggregate-, investment sector- and consumption sector-TFP news shock. The aggregate TFP news shock as well as both of the two sectoral TFP news shocks explain a sizeable share of fluctuations in output and hours. This finding is consistent with findings in Görtz et al. (2016) who argue that TFP news shocks are important driving forces of business cycles.

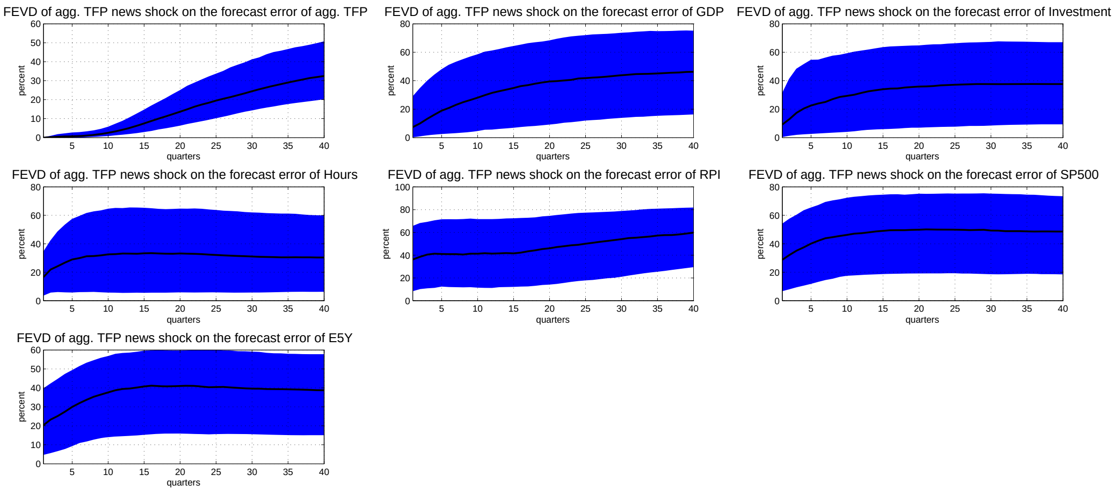

Figure 10: **Forecast error variance decomposition for the aggregate TFP news shock, specification II.** The median is shown by the solid line and the shaded gray areas are the 16% and 84% posterior bands generated from the posterior distribution of VAR parameters.

B.5 Extending the 7-variable VARs with sectoral TFP

As described in the main body of the paper, VAR specification II includes either a sectoral or aggregate TFP measure, one at a time. In this section, we extend this specification to an eight variable VAR by including both consumption and investment-specific TFP series. This allows us to evaluate how a TFP news shock in the one sector affects TFP in the other sector.

Figure 13 displays IRFs of the extended specification II to an investment-specific TFP news shock. It is notable that investment sector TFP increases significantly from about two years onwards while consumption sector TFP rises significantly with a considerable delay. Figure 14 displays responses to a consumption-specific TFP news shock when VAR specification II is extended to include both sectoral TFP measures. Similarly, this figure highlights that TFP in the investment sector rises before TFP in the consumption sector. It is interesting to note from this figure that

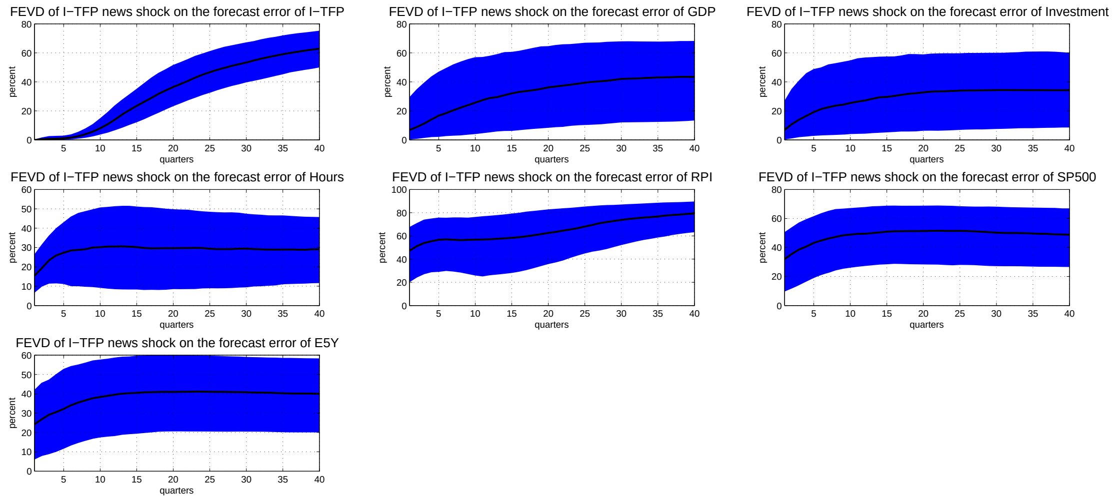

Figure 11: **Forecast error variance decomposition for the investment sector TFP news shock, specification II.** The median is shown by the solid line and the shaded gray areas are the 16% and 84% posterior bands generated from the posterior distribution of VAR parameters.

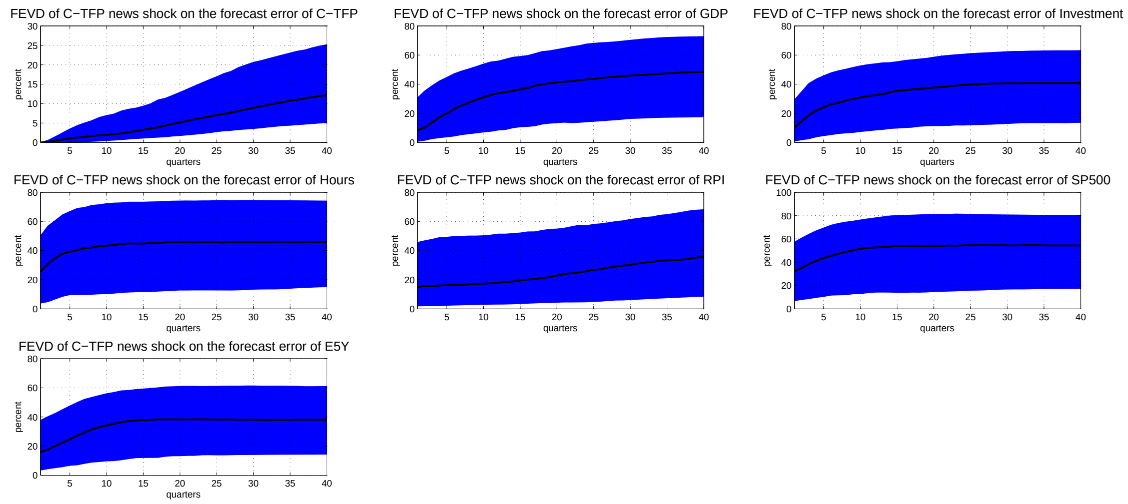

Figure 12: **Forecast error variance decomposition for the consumption sector TFP news shock, specification II.** The median is shown by the solid line and the shaded gray areas are the 16% and 84% posterior bands generated from the posterior distribution of VAR parameters.

the significant decline in the RPI occurs simultaneously with the significant increase of investment sector TFP. These observations further corroborate the results stated in the main body of paper on the diffusion of TFP news shocks from the investment to the consumption goods producing sector.

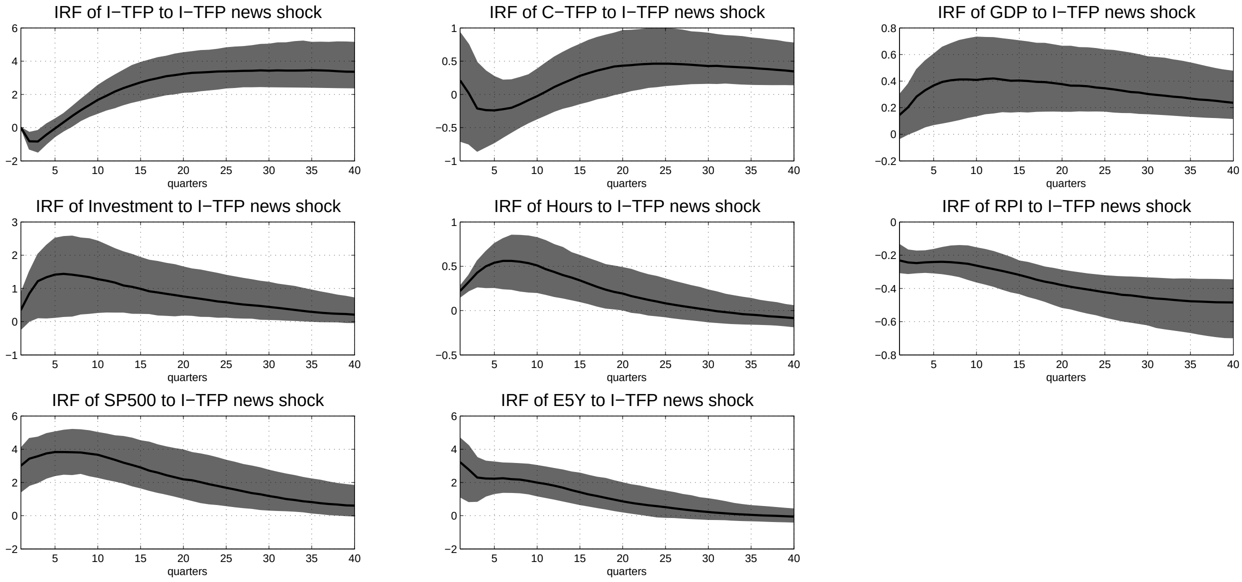

Figure 13: **Responses to an investment sector-specific TFP news shock. VAR specification II extended by consumption sector TFP.** Median responses to an investment-specific TFP news shock from an eight variable VAR (black solid line). The shaded gray areas are the 16% and 84% posterior bands. The units of the vertical axes are percentage deviations.

C Data Sources and Time Series Construction

Table 1 provides an overview of the data used to construct the observables. All the data transformations we have made in order to construct the dataset are described in detail below. As described in the main body, the VAR specifications are estimated with time series in levels.

Total Factor Productivity The data series for aggregate and sectoral utilization adjusted TFP are taken from John Fernald's website $(www.frbsf.org/economic{-}research/economists/jfernald/quarterly_{t}$ and are described in Fernald (2014). The construction of the TFP series is based on the growth accounting methodology in Basu et al. (2006) and corrects for unobserved capacity utilization. Throughout the paper we use the 2015 vintage which contains updated corrections on utilization from industry data following Basu et al. (2013).

Real and nominal variables. Consumption (in current prices) is defined as the sum of

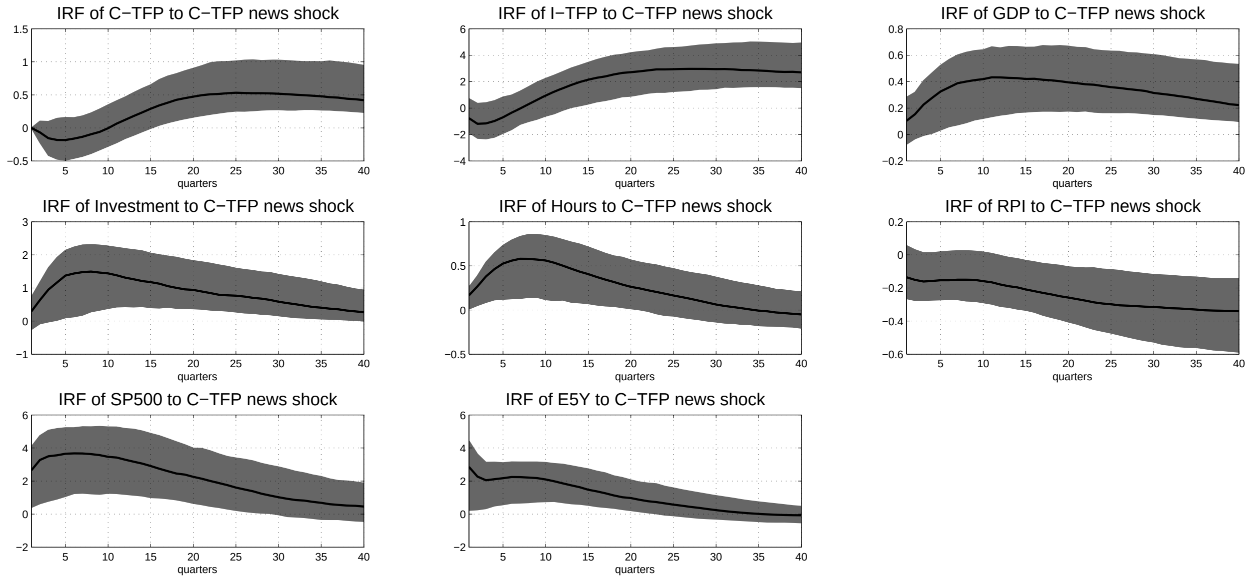

Figure 14: **Responses to a consumption sector-specific TFP news shock. VAR specification II extended by investment sector TFP.** Median responses to a consumption-specific TFP news shock from an eight variable VAR (black solid line). The shaded gray areas are the 16% and 84% posterior bands. The units of the vertical axes are percentage deviations.

personal consumption expenditures on services and personal consumption expenditures on non-durable goods. The times series for real consumption is constructed as follows. First, we compute the shares of services and non-durable goods in total (current price) consumption. Then, total real consumption growth is obtained as the chained weighted (using the nominal shares above) growth rate of real services and growth rate of real non-durable goods. Using the growth rate of real consumption we construct a series for real consumption using 2005 as the base year. The consumption deflator is calculated as the ratio of nominal over real consumption. We use the log change in the GDP deflator as our inflation measure, however results are nearly identical when we use the consumption deflator or CPI inflation. Analogously, we construct a time series for the investment deflator using series for (current price) personal consumption expenditures on durable goods and gross private domestic investment and chain weight to arrive at the real aggregate. The relative price of investment is the ratio of the investment deflator and the consumption deflator. Real output is GDP expressed in consumption units by dividing current price GDP with the consumption deflator.

Hours worked is given by hours of all persons in the non-farm business sector. All series described above are expressed in per capita terms using the series of non-institutional population, ages 16 and

Table 1: Time Series used to construct the dataset

Time Series Description	Units	Code	Source
Gross domestic product	CP, SA, billion $	GDP	BEA
Gross Private Domestic Investment	CP, SA, billion $	GPDI	BEA
Real Gross Private Domestic Investment	CVM, SA, billion $	GPDIC1	BEA
Personal Consumption Exp.: Durable Goods	CP, SA, billion $	PCDG	BEA
Real Personal Consumption Exp.: Durable Goods	CVM, SA, billion $	PCDGCC96	BEA
Personal Consumption Expenditures: Services	CP, SA, billion $	PCESV	BEA
Real Personal Consumption Expenditures: Services	CVM, SA, billion $	PCESVC96	BEA
Personal Consumption Exp.: Nondurable Goods	CP, SA, billion $	PCND	BEA
Real Personal Consumption Exp.: Nondurable Goods	CVM, SA, billion $	PCNDGC96	BEA
Civilian Noninstitutional Population	NSA, 1000s	CNP160V	BLS
Non-farm Business Sector: Hours of All Persons	SA, Index 2005=100	HOANBS	BLS
S&P 500 Index			Robert Shiller
E5Y Confidence Indicator		Table 29	Michigan Survey
BAA corporate spread			St. Louis FED FRED

CP = current prices, CVM = chained volume measures (2005 Dollars), SA = seasonally adjusted, NSA = not seasonally adjusted. BEA = U.S. Department of Commerce: Bureau of Economic Analysis, BLS = U.S. Department of Labor: Bureau of Labor Statistics.

over.

Financial variables. The BAA spread is obtained from the Federal Reserve Bank of St. Louis online database FRED (*https://fred.stlouisfed.org.*). The S&P 500 index is obtained from Robert Shiller's website (*http://www.econ.yale.edu/ shiller/data.htm*) and has been converted to a real per capita index by dividing with the consumption deflator and non-institutional population, ages 16 and over.

Survey data. The Michigan consumer confidence indicator data (E5Y) we use summarizes responses to the following question: "Looking ahead, which would you say is more likely – that in the country as a whole we'll have continuous good times during the next 5 years, or that we'll have periods of widespread unemployment or depression, or what?" The variable is constructed as the percentage giving a favorable answer minus the percentage giving an unfavorable answer plus 100.

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