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TFP news, stock market booms and the business cycle: Revisiting the evidence with VEC models

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Abstract

Beaudry and Portier (2006) provide support for the "news view" of the business cycle, using a vector error correction model. We show that this result hinges on a cointegrating relationship between TFP and stock prices that is not stationary, thus making the estimates not reliable. If we alter the TFP measure and change the model specification, we can recover the news shock through their identification. However, the news shock leads to a stock market boom with a negligible impact on economic activity. Our findings are in line with studies that identify news shocks without relying on VEC models.

JEL Codes: C32, G12, E32, E44.
Key words: cointegration, technology news shocks, stock prices, TFP, VEC model.

1 Introduction

Can the anticipation of the Artificial Intelligence revolution generate a boom in the economy before the effective technological change takes place? Questions related to whether and to which extent the anticipation of technological changes can affect macroeconomic fluctuations have been at the forefront of business cycle research during the last decades. However, there is no agreement in the economic literature on how much these expectations matter for the business cycle (Beaudry and Portier (2014), Ramey (2016)). A seminal paper that addresses this question empirically is Beaudry and Portier (2006) - BP hereafter. The paper provides support for the "news view" of the business cycle, since positive expectations of future technological changes are found to generate economic booms and account for the majority of the business cycle fluctuations. However, subsequent studies that use different methodologies, starting with Barsky and Sims (2011), challenge this conclusion,

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providing evidence that positive news about future technological changes can actually generate recessions.

Our paper contributes to the literature on news shocks in three ways. First, we improve the identification of news shocks in VEC models. By replicating BP's analysis, we find that their bivariate VEC model with TFP and stock prices (that is not subject to Kurmann and Mertens (2014)'s critique) features a non-stationary long-run relationship, as can be seen in Figure 1.[1] This observation is reinforced by the Johansen test, that does not support the presence of cointegration within the VEC model, making the estimates unreliable. However, this does not mean that one cannot rely on BP's identification strategy for news shocks in a VEC model. We demonstrate that BP's identification of news shocks works well under two conditions: 1) change of the TFP measure, using the one provided by Fernald (2014), and 2) change of model specification.[2] [3]

[Figure 1 here]

Our second contribution is to show that the news shock recovered in this way features the same dynamics as the one identified in Barsky and Sims (2011) and Kurmann and Sims (forthcoming), who use alternative methodologies to identify news shocks. A technology-news-driven stock market boom is associated with a delayed, but positive and sustained, response in TFP, but generates limited economic fluctuations. Consequently, our findings with VEC models are in line with studies that do not rely on VEC models to identify news shocks.

Third, we show that the data support the existence of different types of news shocks within the VEC methodology. Our identified news shock explains less than 10 percent of the variability of output, consumption and investment at business cycle frequencies. Instead, the literature that relies on VEC models to identify news shocks usually assigns them a leading role for the business cycle (e.g. Beaudry and Lucke (2010), Beaudry and Portier (2014), Fève and Guay (2018), Di Casola and Sichlimiris (2018)). For this reason, we compute the correlation of our news shock, identified through stock prices, with the one identified through consumption in Di Casola and Sichlimiris (2018). The two news shocks are uncorrelated, hence different news shocks may be identified in VEC models.

The paper is structured as follows. Section 2 replicates BP's analysis for the bivariate model and discusses the problems with their cointegration assumption and the identification of the news shock. Section 3 shows that by changing the TFP measure and the model specification, the results do not support the news view of the business cycle. Finally, section 4 concludes.

[1]Kurmann and Mertens (2014) highlight issues related to the identification of news shock in the trivariate and quadrivariate VEC models proposed by BP. We focus on the cointegration assumption between TFP and stock prices and the implications for the identification of news shocks in VEC models.

[2]Our results are robust to the different vintage measure of TFP computed by Fernald (2014).

[3]Had we only changed the model specification to correct for non-stationarity in the bivariate VEC model, we would not have been able to recover the news shock, based on BP's criterion. We elaborate more on this issue in section 2.2.

2 BP's bivariate model: a non-stationary long-run relationship

We begin our analysis by replicating the seminal paper by BP.[4] The time series of TFP and stock prices used for the analysis are the ones made available on the AER website by the authors.[5] The data are quarterly and cover the period 1948 - 2000 (Figure B.1 in Appendix B). BP focus on two measures of TFP: one is derived as Solow residuals, and the other one is adjusted for capacity utilization (adjustment carried out by BP, hence we call it BPadjusted-TFP). The key idea of the paper is that stock prices contain information about future changes in TFP - a measure of technology.

From the univariate analysis of the series one cannot reject the hypothesis that they contain a unit root in levels, but are stationary in first difference (Table A.1, A.2 and A.3 in Appendix). BP estimate a bivariate VEC model of the following form, with TFP and stock prices and assuming one cointegrating relationship:

$$\Delta X_t = \Pi X^*_{t-1} + \Gamma_1 \Delta X_{t-1} + \ldots + \Gamma_p \Delta X_{t-p} + \Theta D_t + u_t, \tag{1}$$

where X_t is the vector containing the endogenous variables, X^*_{t-1} is the vector containing the lagged endogenous variables and the deterministic terms that are in a cointegrating relationship, p is the number of lags, D_t is the vector of deterministic terms outside the cointegrating relationship and u_t is the vector of residuals.[6] They use 6 lags and no deterministic terms in the cointegrating relationship.[7] With one cointegrating relationship, as in our case, the matrix Π has reduced rank, equal to one, and can be decomposed as $\Pi = \alpha\beta'$. The vector β is the cointegrating vector and it defines the cointegrating relations, $\beta' X^*_{t-1}$. The vector α contains the loading coefficients, defining how the system adjusts to the long-term relationship among the variables.

Figure 1 shows the long-run equilibrium relationship between stock prices and TFP estimated with the VEC model with 6 lags. The figure raises doubts about the validity of the VEC model. The relationship is clearly not stationary, it is trending up until the 80's, making the estimates of the model spurious. A linear trend seems to be unaccounted for in the long-run relationship, at least for the sample up until the 80's. To verify the result of the visual inspection, we rely on the Johansen test, that is a test for cointegration based on the estimation of a VEC model. Note that the critical values for cointegration tests depend on the choice of the deterministic terms allowed in the relationship among the variables of interest. The best strategy to choose the deterministic components and the cointegration rank is to identify them jointly (see Hendry and Juselius (2000)

[4] The following econometric analysis has been carried out with Winrats 10 and its additional component CATS.

[5] A detailed description of the data used and their construction is provided in BP. In this comment, we focus on the quarterly series. BP use also a series for the technology measure that is annual and should represent a better measure of TFP, because it can control for different rates of factor utilization. The drawback is the limited sample period (1948 - 1989), providing only 41 observations.

[6] If D_t contains a constant term, it means that we have a linear trend in the level of the variables outside the cointegrating relationship.

[7] The authors do not mention the deterministic terms included in the model. In section 2.1 we can replicate exactly their result without any deterministic terms in the long-run relationship. Hence, we conclude that BP did not include any.

Table 1: Cointegration between TFP and stock prices

P-value of cointegration test				
r	4 lags	6 lags	4 lags and linear trend	6 lags and linear trend
0	0.58	0.33	0.26	0.09
1	0.45	0.41	0.43	0.24

Johansen cointegration test corrected for small sample bias (Bartlett correction) for stock prices and TFP series. The sample period is 1948-2000, quarterly data. The null hypothesis is the presence of "r" cointegration rank, versus the alternative hypothesis of a cointegration rank higher than "r".

and Lütkepohl (2005)). We provide results for 4 lags and 6 lags (Table 1).[8] If we allow for a trend only outside the cointegrating relationship, as in BP, the test rejects the hypothesis of cointegration between the two series, either with 4 or 6 lags. Hence, there is no statistical support for estimating the VEC model with TFP and stock prices with linear trend only outside the long-run relationship.

BP provide evidence of cointegration between TFP and stock prices using the Nyblom and Harvey (2000) test. The Nyblom-Harvey test of cointegration has the benefit of not relying on the assumption of a multivariate model. However, when the analysis is based on estimating a VEC model, it is crucial to have evidence of cointegration as implied by the Johansen test, since this test is built on a VEC model. Even if the Nyblom-Harvey test supports the presence of the cointegration without linear trend, the correct estimation of a VEC model requires it.

Figure 2 reports the cointegrating relationship between TFP and stock prices with 6 lags and a linear trend. Comparing Figure 1 and Figure 2, one can conclude that the latter looks more stationary. Indeed, allowing for a linear trend in the cointegrating relationship we find support at 10% level for cointegration between TFP and stock prices with 6 lags (Table 1). The linear trend is significant at 5% level (Table A.5 in Appendix).

The VEC model with BPadjusted-TFP series is not subject to non-stationarity problems. For BPadjusted-TFP series the Johansen test supports the presence of cointegration without a linear trend in the cointegrating relationship only with 6 lags (see Table A.6). Indeed, Figure B.5 in Appendix shows that the cointegrating relationship without linear trend is stationary, in case BPadjusted-TFP measure is used. The VEC model used by BP with BPadjusted-TFP series is based on a stationary cointegrating relationship. Therefore, we can proceed with the estimation of the model and verify how the news shock looks like in the next section.

[Figure 2 here]

Before proceeding with the identification of the news shock, it is worth studying the estimated coefficients of the VEC models. The existence of a long-run relationship between two variables requires that at least one of the variables adjusts in the short run to converge to it. The VEC model estimated in BP features a significant short-run adjustment only for TFP (Table A.4 in Appendix A).

[8]The information criteria suggest the inclusion of 2 lags in level, but there is evidence of autocorrelation in the residuals for such low number of lags.

The variable of stock prices does not adjust to the long-run relationship, hence it is defined weakly exogenous to it. In the better specified model, the cointegrating relationship with linear trend is significant only for the stock price equation, while TFP is weakly exogenous (Table A.5 in Appendix A). Finally, in the case of BPadjusted-TFP, the variable of stock prices is weakly exogenous (Table A.8 in Appendix A). This highlights how sensitive are the results to the modelling choice for the deterministic terms. In the next section, we will discuss the implications for the identification of news shocks in the bivariate VEC model when one variable turns out to be weakly exogenous.

2.1 Identification of technology news shocks in BP's bivariate VEC model

BP apply identifying restrictions to their VEC model to derive the structural shocks of interest. When using short-run restrictions, the relationship between the structural shocks ϵ_t and the reduced-form shocks u_t is given by the impact matrix, B, through $u_t = B\epsilon_t$. The shocks can be also identified through long-run restrictions and therefore depend on the long-run impact matrix, ΞB, through $u_t = \Xi B\tilde{\epsilon}_t$.

In a bivariate system only one restriction is necessary to just-identify the VEC model.[9] BP propose two different, not simultaneous, identification strategies for the VEC model. The first identification is based on a zero restriction on the impact matrix, B. The shock to stock prices is assumed to have no immediate effect on TFP, so the shock is orthogonal to technology. The shocks identified with the short-run restriction are denominated ϵ_1 and ϵ_2. The second identification is based on a zero restriction on the long-run impact matrix, ΞB.[10] The shock to TFP is assumed to be the only one affecting TFP in the long-run, hence it is the permanent (surprise) technology shock. The shocks identified with the long-run restriction are denominated $\tilde{\epsilon}_1$ and $\tilde{\epsilon}_2$. Due to the cointegrating relationship, if one shock has no long-run impact on one variable, it also has no long-run impact on the other variable in the system. Thus, the shock to stock prices $\tilde{\epsilon}_2$ cannot have a long-run impact on TFP and stock prices.

Figure 3 reports the impulse response functions, that coincide with the ones reported in Figure 1 in BP. The impulse responses of both variables to the two different shocks are very similar and the correlation between the two shocks is 0.99. Even if ϵ_2 has no impact effect on TFP by construction, it does have an impact after the first quarter and the effect is as long-lasting as the one of the surprise technology shock. Both shocks have a strong significant impact on stock prices. The similarity between the permanent surprise TFP shock and ϵ_2 is key for BP's work, since it allows the authors to define ϵ_2 as a technology news shock. The impulse responses are consistent with the idea that market participants anticipate the effects of technological improvements before they actually take place.

Figure 3 also reveals that the surprise technology shock has a negative effect on TFP on impact.

[9]Given that our model contains two variables and one cointegrating relationship, there can be at most one transitory shock and at least one permanent shock in the model.

[10]This type of identification strategy to disentangle temporary from permanent shocks was first proposed by Blanchard and Quah (1989) and applied to VEC models by King et al. (1991).

We argue that the surprise technology shock is poorly identified, after inspecting its companion shock, $\tilde{\epsilon}_2$, that is identified as a temporary shock. This shock is orthogonal to the surprise technology shock and its impulse responses are not reported in BP, because the shock is not of interest for the study of TFP news. Nevertheless, the impulse responses to this shock become of interest to verify that the restriction on the long-run matrix works well.[11] As reported in Figure B.2 in Appendix, the response of stock prices becomes zero after few quarters, but the response of TFP stays positive for more than 100 quarters, that means 25 years. The magnitude of the impact for the first 100 quarters is not very different from the impact of the surprise technology shock reported in Figure 3. Given that the sample period covers 50 years, this behaviour raises doubts on the effectiveness of the identification with the long-run restriction both for $\tilde{\epsilon}_1$ and $\tilde{\epsilon}_2$. These identification problems can be related to the size of the model and the specification of the deterministic component. This motivates the analysis we carry out in the rest of the paper, where we show how the identification problems disappear with better specified VEC models.

[Figure 3 here]

BP consider the robustness of their analysis to the use of a different TFP measure, adjusted for capacity utilization. They argue that measurement issues in their original variable may explain why the TFP responds so quickly to the technology news shock. When the adjusted measure of TFP is used, the impulse responses of TFP to $\tilde{\epsilon}_1$ do not lie within the confidence bands of the responses to ϵ_2, as shown in Figure B.6.[12] Therefore, the similarity between the two shocks, visible in Figure 3 for the original TFP measure, is weaker with the adjusted measure of TFP.

[Figure 4 here]

Figure B.4 in Appendix reports the impulse response to the temporary shock, $\tilde{\epsilon}_2$, for this model. The responses of TFP and stock prices become zero within 75 quarters following the shock. The long-run restriction seems more reliable when the adjusted-TFP measure is used with respect to the original measure. However, the long time needed for the effects of the temporary shock to die out raises doubts about the effectiveness of the long-run restriction. Overall, the results in BP are sensitive to the series of TFP measure used. In the next section, we investigate the role of the model specification for the identification of news shocks, using the original TFP measure.

2.2 The role of deterministic terms for VEC models

Can we recover the news shock with the original TFP measure, once we have made the cointegrating relationship stationary? Figure 4 shows the impulse responses to the news shock, ϵ_2, and the

[11] In order to improve the performance of the long-run identification strategy, Blanchard and Quah (1989) remove the deterministic terms before the identification of the model takes place and do a sensitivity analysis to consider different possible breaks in the deterministic components.

[12] BP report only the impulse responses to ϵ_2 in Figure 7, because they compare them with the ones obtained with the original measure of TFP.

surprise technology shock, $\tilde{\epsilon}_1$, when a linear trend is included in the cointegrating relationship, which is a specification that makes the cointegrating relationship stationary within the VEC model.[13] The impulse responses look very different, and the correlation between the shocks is equal to -0.29. In particular, the surprise technology shock does not seem well identified, because it has a negative effect on stock prices.[14] The negative correlation between the two shocks is related to the estimated coefficients of the VEC model.

An important aspect of the structural identification in bivariate VEC models is related to the weak exogeneity of the variables to the long-term relationship. Ribba (1997) and Fisher and Huh (1999) have proved that if the first variable of a bivariate VEC model is weakly exogenous, the zero short-run restriction we used to identify the news shock is equivalent to the zero long-run restriction we used to identify the surprise technology shock. In our case, this means that if TFP is weakly exogenous, the shocks ϵ_1 and ϵ_2 (identified with short-run restriction) are equivalent to $\tilde{\epsilon}_1$ and $\tilde{\epsilon}_2$ (identified with long-run restriction), respectively. As a consequence, ϵ_1 and $\tilde{\epsilon}_2$ are orthogonal and the same holds for $\tilde{\epsilon}_1$ and ϵ_2. In section 2 we have shown that the TFP is weakly exogenous to the long-term relationship when the linear trend is allowed in the cointegrating relationship (Table A.5 in Appendix A). BP's criterion for the identification of the news shock is to find high correlation between $\tilde{\epsilon}_1$ and ϵ_2. However, these shocks are orthogonal due to the estimated coefficients that imply weak exogeneity. This means that the technology news shock is not well identified in the bivariate VEC model with the original TFP measure and a stationary cointegrating relationship.

Overall, the results in BP are sensitive to the series of TFP measure used and rely on a VEC model specification with non-stationary long-run relationship between TFP and stock prices. In the next section, we provide results from a new approach, that takes into account these two weaknesses.

3 Changing data and model specification

Up to now we have shown that the measure of TFP and the model specification are equally important for the identification of news shocks in VEC models. Here we consider the real-time measure of TFP, computed by Fernald (2014). We re-estimate the VEC model over a longer sample period, going from the first quarter of 1948 to the third quarter of 2017. Furthermore, we consider a trivariate VEC model, where we add output, consumption or investment in order to study the role of news shocks for economic fluctuations.

[13] Figure B.3 in Appendix reports the impulse response to the temporary shock, $\tilde{\epsilon}_2$, for this model. Also in this case, as with the adjusted-TFP series, the long-run restriction seems to be working well.

[14] A similar result is obtained if we detrend our variables before estimating the VEC model and do not include a linear trend. The results with detrended variables are not reported here, but are available upon request.

3.1 Bivariate VEC model

We estimate a bivariate VEC model with the measure of TFP adjusted for capital utilization, by Fernald (2014), and the same stock price series as above, but for a longer sample period.[15] The information criteria suggest 2 or 4 lags. We choose 4 lags to eliminate residual autocorrelation. The cointegration test suggests the presence of 1 cointegrating relationship at 5% level with or without the linear trend in the cointegrating vector (Table A.10 in Appendix). Moreover, the trend is significant and we proceed with this specification (Table A.9 in Appendix).

The responses of TFP and stock prices to the surprise technology shock and the shock identified with short-run restrictions look extremely similar (Figure B.7 in Appendix B). Given this similarity and following BP's criterion, we can argue that ϵ_2 is the technology news shock. Therefore, we can recover the news shock when using Fernald (2014)'s measure of adjusted TFP. This result, though, requires the introduction of a linear trend in the cointegrating relationship.

3.2 News shocks and the business cycle revisited

Once identified the news shock, we can evaluate its effect on the main macroeconomic aggregates. In fact, the literature on news shocks has not reached an agreement on its role for the economic fluctuations. Following BP's findings in support of the news view, Kurmann and Mertens (2014) have shown that their identification scheme for systems with more than two variables does not provide unique identification, therefore raising doubts about their results. Using a different methodology, Barsky and Sims (2011) are the first to argue that the news shock generates a recession, followed more recently by Kurmann and Sims (forthcoming).

We consider per-capita measures of output, consumption and investment. The Johansen cointegration test for the trivariate system, including TFP, stock prices and one macroeconomic variable at a time, finds a cointegration rank equal to one with or without the linear trend (Table A.11 in Appendix) and 4 lags. Since the trend in the cointegrating relationship is not significant, we argue that the trend included in the bivariate system was actually used to capture a missing variable in the long-run relationship between stock prices and TFP. Our specification is a VEC model with one cointegrating relationship, hence two common stochastic trends among three variables.[16] In order to obtain full identification of the underlying system, we impose three restrictions. We assume that the technology news shock has no instantaneous effect on TFP. The third shock, related to the macroe-

[15] The estimation of TFP provided by Fernald featured an important revision in March 2014, due to the change in the utilization measurement. This revision turns out to affect the estimation of news shocks with the methodology proposed in Barsky and Sims (2011), as discussed in Sims (2016) and Kurmann and Sims (forthcoming). Our results, instead, hold also with Fernald's TFP data prior to the revision of 2014.

[16] BP consider two cointegrating relationships among three variables, hence allowing for at least one permanent shock and at most two temporary shocks. The three identifying restrictions proposed actually amount to two, due to the cointegration rank equal to two. Therefore, their identification strategy is not unique, as pointed out in Kurmann and Mertens (2014). Beaudry and Portier (2014) reconsider the trivariate VEC model first used in BP as a reply to Kurmann and Mertens (2014)'s comment and propose a different identification of the shocks. They restrict the shock identified through the macroeconomic variable to be a temporary shock. Since this restriction is not enough to identify the system fully, they further assume that the temporary shock does not affect TFP in the short run as well, hence it is a temporary non-TFP shock. Here we can proceed with BP's original identifying restrictions because of the lower cointegration rank.

conomic variable, has no long-run effect on TFP and the macroeconomic variable, but can affect TFP on impact. Hence, we allow for at least two permanent shocks and at most one temporary shock.

We find that positive news are associated with a small drop in output, nearly unchanged consumption and a drop in investment (Figure 5).[17] Differently from the bivariate VEC model, the response of TFP to the surprise TFP shock is now always positive. This points to a better identification of the surprise TFP shock. Moreover, the news shock is not the main source of business cycle fluctuations. It explains less than 10 percent of variation in output, consumption and investment at business cycle frequencies. We contribute to the literature on technology news shocks by showing that the news shock identified in a VEC model through stock prices does not provide support for the news view of the business cycle, once the improved TFP measure is used and the model specification is adjusted accordingly. Our results are closer in spirit to Barsky and Sims (2011) and Kurmann and Sims (forthcoming). Therefore, our paper demonstrates that different methodologies used to identify news shocks lead to similar conclusions.

Most of the studies that use VEC models to identify news shocks do assign them a leading role for the business cycle (e.g. Beaudry and Lucke (2010), Beaudry and Portier (2014), Fève and Guay (2018), Di Casola and Sichlimiris (2018)). In particular, Di Casola and Sichlimiris (2018) use consumption, instead of stock prices, to identify TFP news shocks in VEC models that contain TFP with real and nominal variables. A TFP news shock is found to account for the majority of business cycle fluctuations, whereas positive news generate a boom in the economy. Hence, we analyse the correlation between our and Di Casola and Sichlimiris (2018)'s TFP news shock. The two shocks are found to be roughly uncorrelated (correlation equal to 0.1). Hence, the data favour the existence of different types of news shocks within the same methodological framework.

[Figure 5 here]

4 Conclusion

The specification of the bivariate VEC model adopted by Beaudry and Portier (2006) in their analysis of technology news shocks relies on a non-stationary long-run relationship between TFP and stock prices. Therefore, the estimates are subject to spuriousness. Motivated by this finding, we investigate alternative model specifications that lead to a stationary long-run relationship. One such specification entails the introduction of a linear trend in the long-run relationship between TFP and stock prices. In this case, though, we cannot recover the technology news shock. If we change the TFP measure and the model specification, we can recover the news shock. However, a technology-news-driven stock market boom that is accompanied by a delayed, but positive and sustained, increase in TFP is found to generate limited economic fluctuations. The identified news shock is not the main source of business cycle fluctuations, similarly to what is found with different methodologies in Barsky and Sims (2011) and Kurmann and Sims (forthcoming). Finally, we provide evidence for the existence of more than one type of news shocks within the VEC framework.

[17] In Appendix B we report the impulse response to all the shocks in all the trivariate systems we have considered.

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Figures

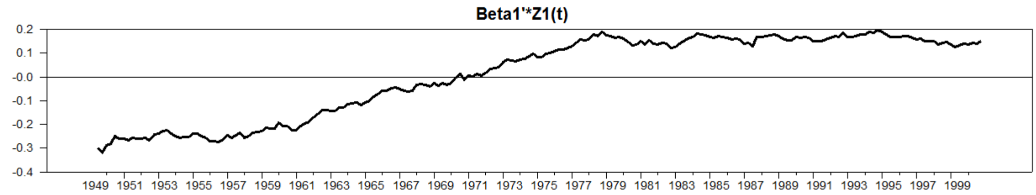

Figure 1: Cointegrating relation between stock prices and TFP with linear trend outside the cointegrating relationship, with 6 lags in levels. The sample period is 1948-2000, quarterly data.

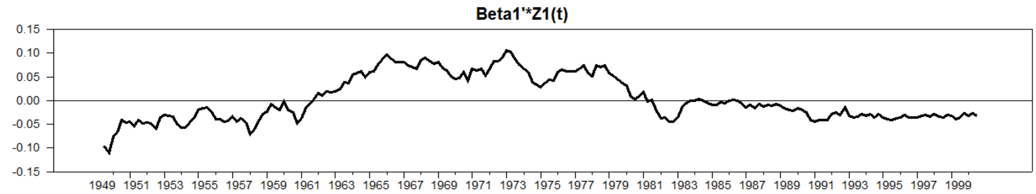

Figure 2: Cointegrating relations for stock prices and TFP with linear trend inside the cointegrating relationship, with 6 lags in levels. The sample period is 1948-2000, quarterly data.

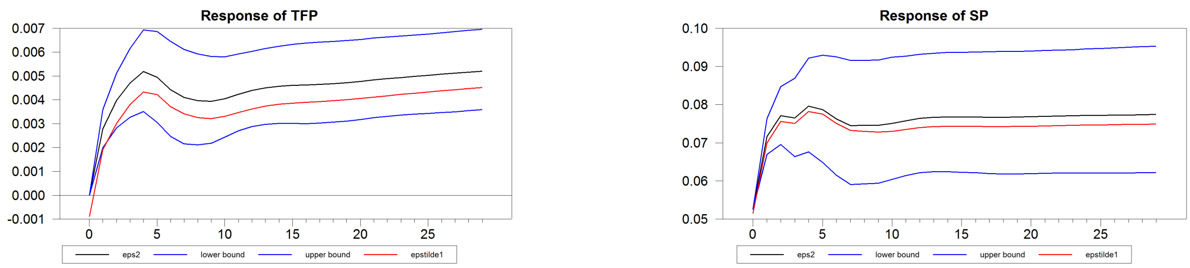

Figure 3: Impulse responses for TFP and stock prices to $\tilde{\epsilon}_1$ (red lines) and ϵ_2 (black lines). The VEC model allows for a linear trend only outside the cointegrating relationship, with 6 lags in levels. The sample period is 1948-2000, quarterly data. Blue lines represent the 10% and 90% quantiles of distribution of IRFs for short-run identification. The distribution is the Bayesian simulated distribution obtained by Monte-Carlo integration with 2500 replications.

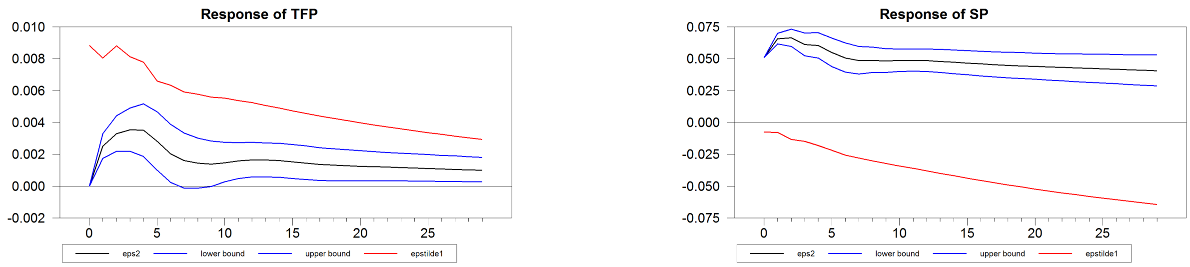

Figure 4: Impulse responses for TFP and stock prices to $\tilde{\epsilon}_1$ (red lines) and ϵ_2 (black lines). The VEC model allows for a linear trend in the cointegrating relationship, with 6 lags in levels. The sample period is 1948-2000, quarterly data. Blue lines represent the 10% and 90% quantiles of distribution of IRFs for short-run identification. The distribution is the Bayesian simulated distribution obtained by Monte-Carlo integration with 2500 replications.

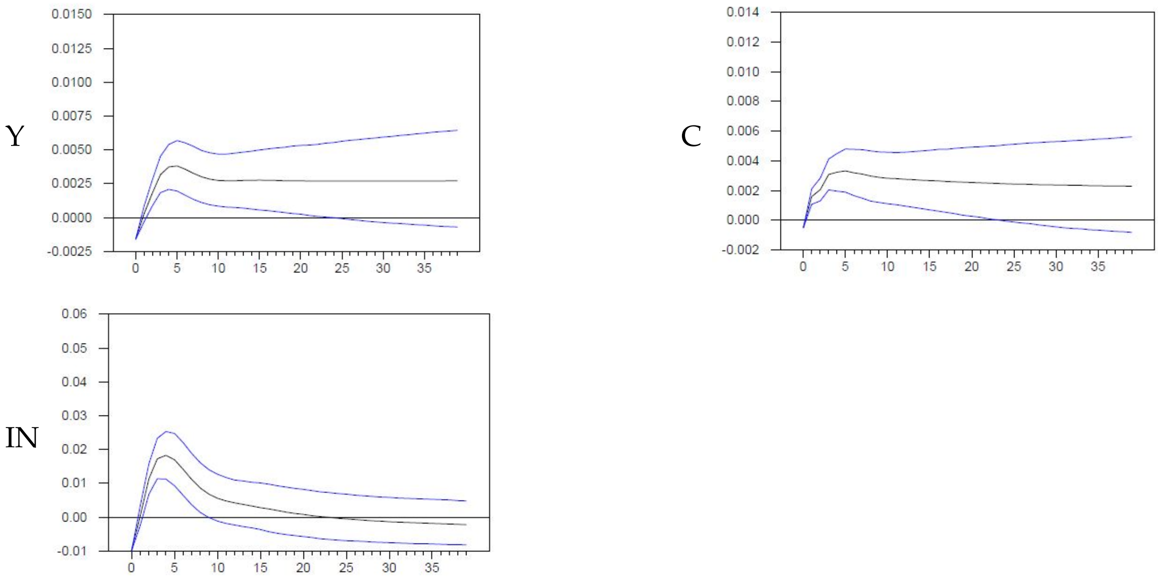

Figure 5: Impulse responses of output, consumption and investment to the news shock from the trivariate VEC model with Fernald's adjusted-TFP and stock prices, with one cointegrating relationship and 4 lags in levels. The sample period is 1948-2017q3, quarterly data. Blue lines represent the 10% and 90% quantiles of distribution of IRFs. The distribution is the Bayesian simulated distribution obtained by Monte-Carlo integration with 2500 replications.

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Conflict of interest

None.

APPENDIX

A Additional tables

Table A.1: Unit root test for stock prices

	With intercept and trend	With intercept
	1 lag chosen by AIC	1 lag chosen by AIC
Sig Level	Crit Value	Crit Value
1%	-4.00445	-3.46259
5%	-3.43214	-2.87526
10%	-3.13953	-2.57402
T-Statistic	**-1.12041**	**-0.71177**

Dickey-Fuller unit root test for the series of stock prices, in log terms, with intercept only (right column) or intercept and linear trend (left column). The sample period is 1948-2000, quarterly data. The null hypothesis is the presence of a unit root. Bold numbers report the value of T-statistic.

Table A.2: Unit root test for TFP

	With intercept and trend	With intercept
	2 lags chosen by AIC	5 lags chosen by AIC
Sig Level	Crit Value	Crit Value
1%	-4.00465	-3.46316
5%	-3.43224	-2.87552
10%	-3.13959	-2.57415
T-Statistic	**-2.35543**	**-2.54317**

Dickey-Fuller unit root test for TFP series, in log terms, with intercept only (right column) or intercept and linear trend (left column). The sample period is 1948-2000, quarterly data. The null hypothesis is the presence of a unit root. Bold numbers report the value of T-statistic.

Table A.3: Unit root test for BPadjusted-TFP

	With intercept and trend	With intercept
	1 lag chosen by AIC	1 lag chosen by AIC
Sig Level	Crit Value	Crit Value
1%	-4.00445	-3.46259
5%	-3.43214	-2.87526
10%	-3.13953	-2.57402
T-Statistic	**-2.13785**	**-2.69417**

Dickey-Fuller unit root test for BPadjusted-TFP series, in log terms, with intercept only (right column) or intercept and linear trend (left column). The sample period is 1948-2000, quarterly data. The null hypothesis is the presence of a unit root. Bold numbers report the value of T-statistic.

Table A.4: Estimates of VEC model with stock prices and TFP

β'		
	TFP	SP
Beta	1.000	-0.127
	$[NA]$	$[-0.967]$

	α
DTFP	-0.012
	$[-2.985]$
DSP	-0.017
	$[-0.768]$

Cointegrating vector, β, and vector of loading coefficients, α, for the model with stock prices and TFP series, with linear trend only outside the cointegrating relationship, with 6 lags in levels. The sample period is 1948-2000, quarterly data. The numbers in bracket report the T-statistic.

Table A.5: Estimates of VEC model with stock prices and TFP, including trend

β'			
	TFP	SP	TREND
Beta	1.000	-0.002	-0.003
	$[NA]$	$[-0.076]$	$[-14.532]$

	α
DTFP	-0.018
	$[-1.188]$
DSP	-0.335
	$[-3.984]$

Cointegrating vector, β, and vector of loading coefficients, α, for the model with stock prices and TFP series, with linear trend in the cointegrating relationship, with 6 lags in levels. The sample period is 1948-2000, quarterly data. The numbers in bracket report the T-statistic.

Table A.6: Cointegration between stock prices and BPadjusted-TFP

P-value of cointegration test				
r	4 lags	6 lags	4 lags and linear trend	6 lags and linear trend
0	0.21	0.06	0.10	0.01
1	0.48	0.50	0.14	0.03

Johansen cointegration test corrected for small sample bias (Bartlett correction) for stock prices and BPadjusted-TFP series. The sample period is 1948-2000, quarterly data. The null hypothesis is the presence of "r" cointegration rank, versus the alternative hypothesis of a cointegration rank higher than "r".

Table A.7: Additional estimates from VEC model with stock prices and TFP

Estimated long-run matrix	
-0.0101 $[-0.1096]$	0.0000 $[0.0000]$
-0.0810 $[-0.1096]$	0.0000 $[0.0232]$

Long-run matrix for the VEC model containing TFP and stock prices and linear trend only outside the cointegrating relationship, with 6 lags in levels. The sample period is 1948-2000, quarterly data. The VEC is identified with long-run identification á la Blanchard and Quah (1989). Bootstrapped values with 2500 replications are used. The numbers in bracket report the T-statistic.

Table A.8: Estimates of VEC model with stock prices and BPadjusted-TFP

β'		
	TFP-adj	SP
Beta	1.000 $[NA]$	-0.321 $[-3.251]$

	α
DTFP-adj	-0.011 $[-3.337]$
DSP	0.024 $[1.062]$

Cointegrating vector, β, and vector of loading coefficients, α, for the model with stock prices and BPadjusted TFP series, with linear trend only outside the cointegrating relationship, with 6 lags in levels. The sample period is 1948-2000, quarterly data. The numbers in bracket report the T-statistic.

Table A.9: Estimates of VEC model with stock prices and TFP, new data

β'			
	TFP	SP	TREND
Beta	1.000 $[NA]$	-0.131 $[-2.525]$	-0.002 $[-5.134]$

	α
DTFP	-0.027 $[-4.451]$
DSP	0.002 $[0.045]$

Cointegrating vector, β, and vector of loading coefficients, α, for the model with stock prices and Fernald's adjusted-TFP series, with linear trend in the cointegrating relationship, with 4 lags in levels. The sample period is 1948q1-2017q3, quarterly data. The numbers in bracket report the T-statistic.

Table A.10: Cointegration between stock prices and TFP, new data

P-value of cointegration test		
r	4 lags	4 lags and linear trend
0	0.01	0.01
1	0.19	0.27

Johansen cointegration test corrected for small sample bias (Bartlett correction) for stock prices and TFP series. The sample period is 1948q1-2017q3, quarterly data. The null hypothesis is the presence of "r" cointegration rank, versus the alternative hypothesis of a cointegration rank higher than "r".

Table A.11: Cointegration among TFP, stock prices and macroeconomic quantity

P-value of cointegration test						
	with output		with consumption		with investment	
r	4 lags	4 lags and linear trend	4 lags	4 lags and linear trend	4 lags	4 lags and linear trend
0	0.01	0.04	0.01	0.01	0.01	0.02
1	0.28	0.40	0.28	0.17	0.15	0.11
2	0.15	0.56	0.30	0.68	0.30	0.17

Johansen cointegration test corrected for small sample bias (Bartlett correction) for stock prices, Fernald's adjusted-TFP series and output, consumption or investment, alternatively. The sample period is 1948q1-2017q3, quarterly data. The null hypothesis is the presence of "r" cointegration rank, versus the alternative hypothesis of a cointegration rank higher than "r".

B Additional figures

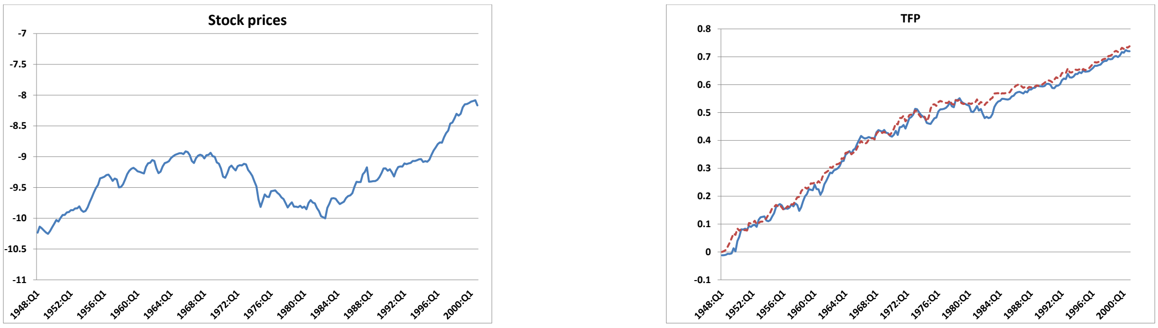

Figure B.1: Series of stock prices (left side) and Total Factor Productivity (right side), in real per-capita terms and logarithmic form. The solid blue line is the original TFP measure, the red dotted line is BPadjusted-TFP. The sample period is 1948-2000, quarterly data.

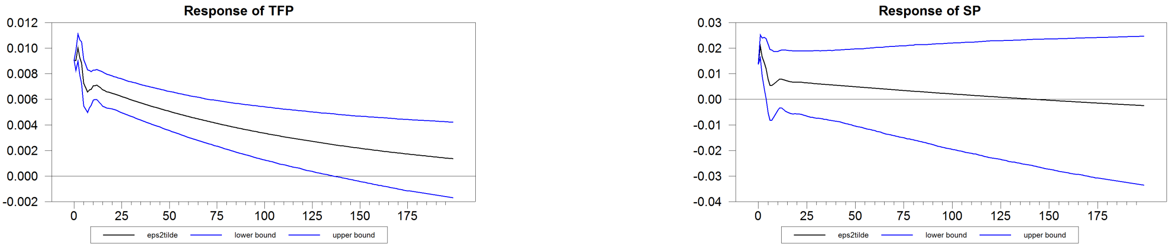

Figure B.2: Impulse responses for TFP and stock prices to $\tilde{\varepsilon}_2$ (black lines). The VEC model allows for a linear trend only outside the cointegrating relationship, with 6 lags in levels. The sample period is 1948-2000, quarterly data. Blue lines represent the 10% and 90% quantiles of distribution of IRFs for short-run identification. The distribution is the Bayesian simulated distribution obtained by Monte-Carlo integration with 2500 replications.

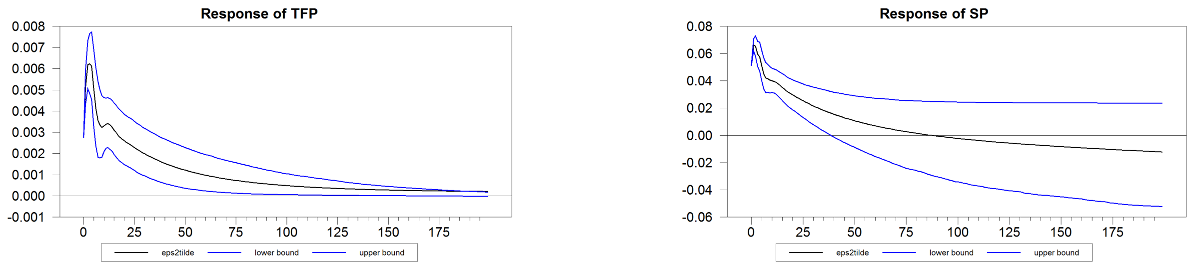

Figure B.3: Impulse responses for TFP and stock prices to $\tilde{\varepsilon}_2$ (black lines). The VEC model allows for a linear trend inside the cointegrating relationship, with 6 lags in levels. The sample period is 1948-2000, quarterly data. Blue lines represent the 10% and 90% quantiles of distribution of IRFs for short-run identification. The distribution is the Bayesian simulated distribution obtained by Monte-Carlo integration with 2500 replications.

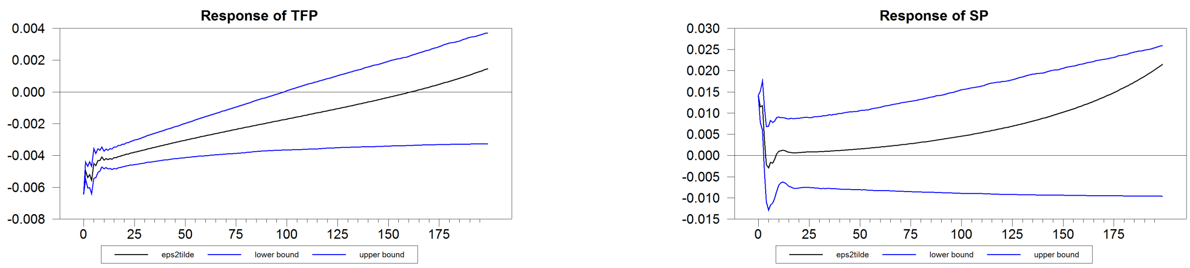

Figure B.4: Impulse responses for BPadjusted-TFP and stock prices to $\tilde{\varepsilon}_2$ (black lines). The VEC model allows for a linear trend only outside the cointegrating relationship, with 6 lags in levels. The sample period is 1948-2000, quarterly data. Blue lines represent the 10% and 90% quantiles of distribution of IRFs for short-run identification. The distribution is the Bayesian simulated distribution obtained by Monte-Carlo integration with 2500 replications.

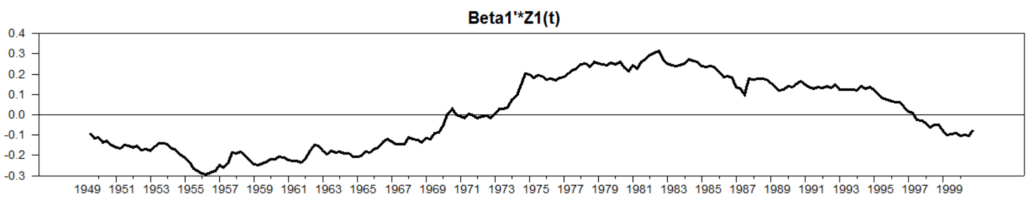

Figure B.5: Cointegrating relation between stock prices and BPadjusted-TFP with linear trend outside the cointegrating relationship, with 6 lags in levels. The sample period is 1948-2000, quarterly data.

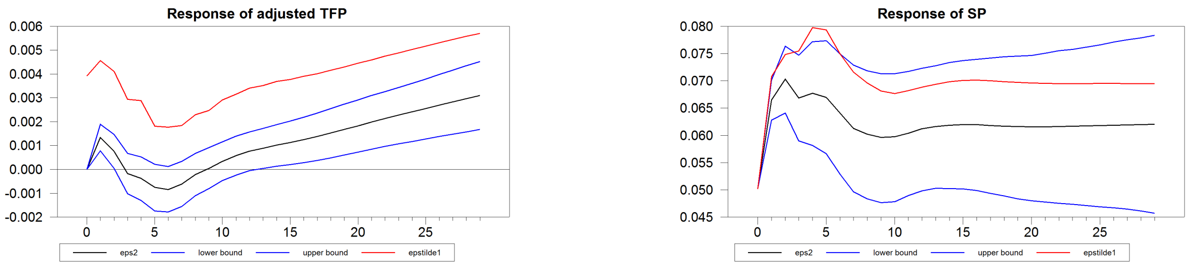

Figure B.6: Impulse responses for BPadjusted-TFP and stock prices to $\tilde{\epsilon}_1$ (red lines) and ϵ_2 (black lines). The VEC model allows for a linear trend only outside the cointegrating relationship, with 6 lags in levels. The sample period is 1948-2000, quarterly data. Blue lines represent the 10% and 90% quantiles of distribution of IRFs for short-run identification. The distribution is the Bayesian simulated distribution obtained by Monte-Carlo integration with 2500 replications.

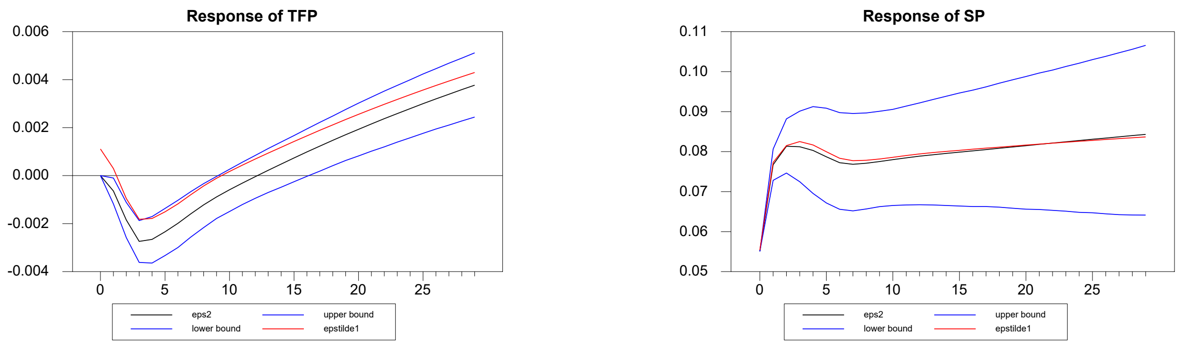

Figure B.7: Impulse responses for Fernald's adjusted-TFP and stock prices to $\tilde{\epsilon}_1$ (red lines) and ϵ_2 (black lines). The VEC model allows for a linear trend inside the cointegrating relationship, with 4 lags in levels. The sample period is 1948-2017q3, quarterly data. Blue lines represent the 10% and 90% quantiles of distribution of IRFs for short-run identification. The distribution is the Bayesian simulated distribution obtained by Monte-Carlo integration with 2500 replications.

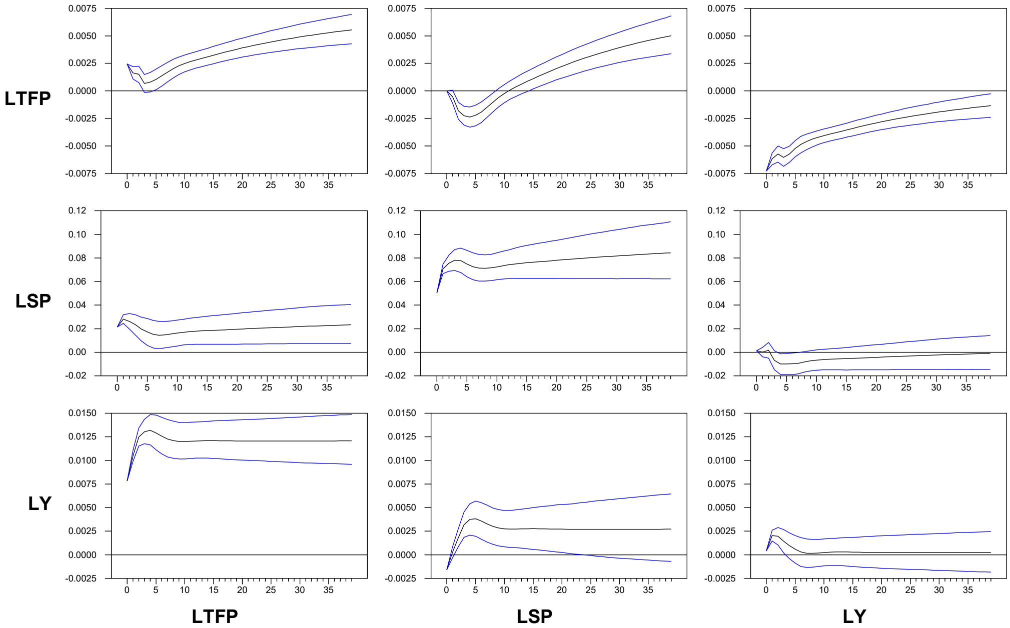

Figure B.8: Impulse responses of trivariate VEC model with Fernald's adjusted-TFP, stock prices and output, with one cointegrating relationship and 4 lags in levels. The sample period is 1948-2017q3, quarterly data. Blue lines represent the 10% and 90% quantiles of distribution of IRFs. The distribution is the Bayesian simulated distribution obtained by Monte-Carlo integration with 2500 replications.

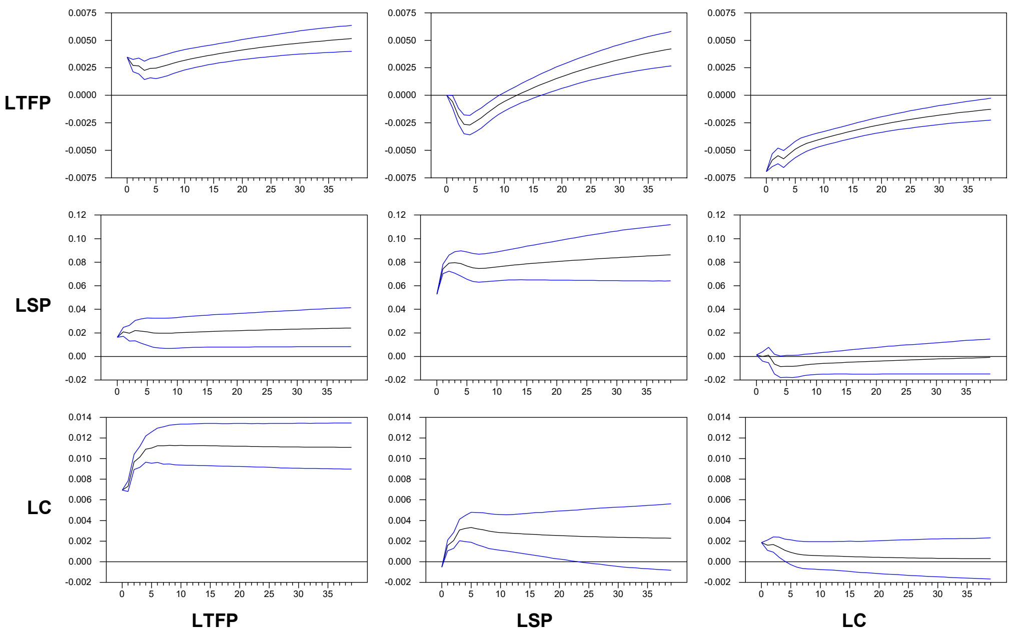

Figure B.9: Impulse responses of trivariate VEC model with Fernald's adjusted-TFP, stock prices and consumption, with one cointegrating relationship and 4 lags in levels. The sample period is 1948-2017q3, quarterly data. Blue lines represent the 10% and 90% quantiles of distribution of IRFs. The distribution is the Bayesian simulated distribution obtained by Monte-Carlo integration with 2500 replications.

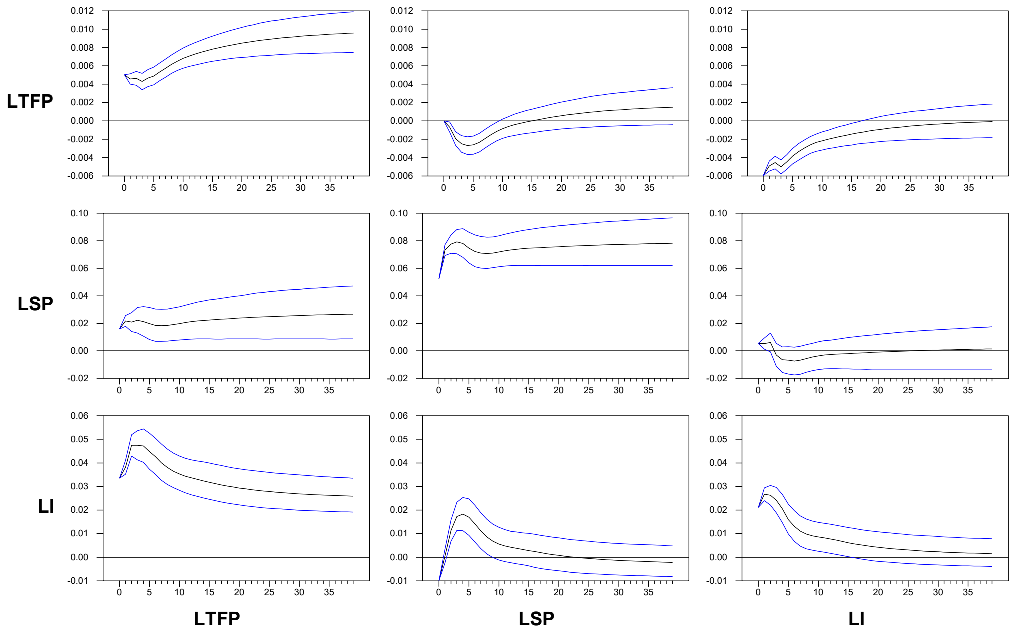

Figure B.10: Impulse responses of trivariate VEC model with Fernald's adjusted-TFP, stock prices and investment, with one cointegrating relationship and 4 lags in levels. The sample period is 1948-2017q3, quarterly data. Blue lines represent the 10% and 90% quantiles of distribution of IRFs. The distribution is the Bayesian simulated distribution obtained by Monte-Carlo integration with 2500 replications.

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