Why Do Countries Experience Housing Booms? Spain vs Germany *

Laurentiu Guinea †

This Draft: July 7, 2018

Abstract

This paper investigates the contribution of news shocks on relative prices of investment in the business cycles. First, news shocks on residential investment, business structures, and equipment are identified for the Spanish and German economies using structural vector autoregressions (SVARs). The findings for Spain are that news shocks to relative prices of residential investment explain 59% of output's variance, 65% of aggregate investment, and 80% of residential investment. In contrast, for Germany, there are the news shocks to relative prices of business structures and equipment that explain a higher fraction of the variance of output, consumption and investment in business structures and equipment than the news shocks on residential investment. Then, I propose a two-sector model augmented with home production to interpret the propagation mechanisms described in the SVAR. The decomposed effects show that in Spain news shocks on relative prices of housing stimulate investment in residential structures, whereas in Germany the news enhances investment in equipment and structures. My results suggest news shocks contribution to aggregate fluctuations is relatively more important in Spain than in Germany. In addition, I provide evidence that news shocks propagation mechanism is consistent with the housing boom in Spain.

JEL classification: E32

Keywords: relative prices of investment; news shocks; housing boom

*I am very grateful to Luis Puch and Jesús Ruiz, my supervisors, for their continuous support, encouragement and advices.

†PhD candidate, Universidad Complutense Madrid. Email: lguinea@ucm.es; phone number: +34 60 62 784 90

1 Introduction

The Spanish recent economic expansion has been characterized by sustained growth of residential investment (Díaz and Franjo (2016)[1], Aspachs-Bracons and Rabanal (2009)). In fact, Spain is just one of the many other European countries that experienced a housing boom in the early/mid-2000s. In contrast, Germany, a peer Euro Zone economy, had an economic performance very different from that of Spain (Fernández-Villaverde and Ohanian (2009)). While Spanish households consider real estate investment as a mean of storage of wealth[2], Germany, even during years of expansion, did not experience a housing boom. At the same time, in the last three decades German housing prices have been more stable than elsewhere in Europe (Fernández-Villaverde and Ohanian (2009), OECD 2014). In fact, looking at the residential investment sector, Spain and Germany present fundamental differences.[3] The empirical evidence illustrate that households have undergone large shifts since 1970. In the figure 5, I use data from the *EU KLEMS* the 2017 release, to plot the relative prices of investment for Spain and Germany from 1970 to 2015. It is evident that until 1998 all three factor prices of both countries shared a common tendency. From that point on, that coincides with the "1998 Spanish Land Law", the relative prices of residential investment and of business structures diverge in the two economies. A wide gap is opened until 2012 between Spain and Germany on those relative prices of investment. When we look only at the relative prices of equipment, the positive correlated downward trend indicates that the business cycles between the two economies are very much correlated.

Analyzing further the empirical evidence, this paper aims at providing an answer to the following question: why do some countries experience housing booms and other not?

The "news shocks" is an appealing hypothesis adopted in much of the macro literature to explain business cycle fluctuations. The news shocks change agent's expectations about the future, affecting their current investment, consumption, and work decisions. In this paper, I argue that the "news shocks" might explain most

[1]Díaz and Franjo (2016) documented that Spain grow in spite of stagnant TFP due to an inefficient high investment rate in subsidized residential structures.

[2]In Spain the house ownership is at 86.28% (2005) as in "Encuesta continua de presupuestos familiares. Base 1997. Resultados anuales 2005". http://www.ine.es/jaxi/Datos.htm?path=/t25/e437/p02/a2005/l0/&file=04001.px

[3]In Germany the house ownership is at 48% (2008) as in "Sample survey of income and expenditure (EVS)". https://www.destatis.de/EN/FactsFigures/SocietyState/IncomeConsumptionLivingConditions/AssetsDebts/Tables/HouseholdOwningRealProberty_EVS.html

of the investment differences between countries. Specifically, I extract news about future investment decisions in Spain and Germany from the observed movements of the relative prices of investment. I start from the hypothesis that the extent to which news shocks contribute to housing booms, depends on the household's willingness to substitute consumption for investment in the residential structures, business structures or equipment.

Spain and Germany are natural candidates to prove the interrelation between news shocks and short-run investment dynamics. They both are Euro Zone economies that share the same institutional framework. Consequently, as the propagation mechanism is different due to technology and preferences, I show that news shocks effects on short-run investment dynamics in the two countries are important, but qualitatively and quantitatively different.

The contribution of this paper is the introduction of news shocks to relative prices investment: news shocks to relative prices of residential investment, business structures, and equipment.

First, I identify news shocks using structural vector autoregression (SVAR). I start the empirical analysis by applying the identification strategy of news shocks proposed by Barsky and Sims' (2011). This approach imposes minimum of theoretical restrictions. Basically, I estimate the model and identify the news shock as the shock that best anticipates the relative prices of investment in the long-run and does not move it on impact. Then, I quantify how the news shocks propagate into the macroeconomic variables, and how it affect households investment decisions.

The findings for the Spanish economy are that news shocks to relative prices of residential investment account for 59% of the forecast-error variance of output, and 65% of aggregate investment. Additionally, the news shocks to relative prices of residential investment explain 80% of the housing investment. On impact, output, aggregate investment, consumption and hours worked have a statistically significant positive response, confirming the role for news shocks as a source of cyclical fluctuations. Such effects are essentially similar to those obtained by Beaudry and Portier (2004) who find shock-induced aggregate comovement.

In contrast, for Germany, the effects are reversed. The news shocks to relative prices of business structures and equipment are those that explain the highest fraction of the variance of output, consumption and investment in business structures and equipment, even though, the shares are much smaller compared with Spanish economy.

Second, I propose a model to interpret the propagation mechanism of news shocks. For that reason, I write a stylized version of Díaz and Franjo (2016) two-sectors model economy. The utility function employs Jaimovich and Rebello (2009) preferences augmented with home production in the line of Benhabib, Rogerson and Wright (1991), Greenwood and Hercowitz (1991) and McGrattan, Rogerson, and Wright (1997). In the standard macro model, agents can substitute between leisure and labor and between consumption and investment. Rather, following the home production literature, in my model households can substitute between leisure and working in the market or working at home, and between consumption and investment in market capital or residential capital. The home production sector reallocates labor and capital between market and non-market activity. In addition, households, optimally decide how much to invest and to accumulate from the three types of capital: either equipment and business structures or residential structures.

Finally, I include news shocks that impact on individuals' expectations in each country. The news shocks on the relative prices of investment allow to distinguish how agents adapt theirs willingness to substitute current consumption for future investment in housing, structures or equipment. Therefore, the news shocks effects on each country depend critically on the parameters that control the elasticities of substitution, between household and market variables in utility and production functions, and those that control the labour supply elasticity set in the Jaimovich and Rebello (2009) preferences specification. Indeed, in this setting, the model will generate two important forms of comovement in response to news shocks to relative prices of residential investment. The first one is the aggregate variables comovement: output, consumption, aggregate investment, and hours worked rise and fall together. The other is the sectoral comovement: output, employment, investment and capital accumulation rise and fall together on each of the two sectors of the model economy.

Several interesting findings emerge. The wealth effect in Spain translates into increased residential investment. At the same time, if the elasticity of intertemporal substitution is high enough, then the substitution effect dominates the wealth effect which in Germany translates into investment in equipment and business structures.

This paper is linked with three literatures. First, it is related to empirical literature suggesting news about the future might be an important driver of the business cycle.[4] Many macroeconomists have recognized the importance of the news impact on the economic fluctuations after Beaudry and Portier (2006) called the attention toward news-driven business cycles [5]. The empirical part of this

[4] Pigou (1927) was one of the first authors to propose that agents' expectations about the future are an important source of business cycle fluctuations.

[5] Recent papers document the importance of news shocks (Beaudry and Portier, 2006, 2004, 2014; Schmitt-Groh and Uribe, 2008; Jaimovich and Rebelo, 2009; Christiano et al., 2008; Fujiwara et al., 2008; Barsky and Sims, 2008; Kurmann and Otrok, 2013; Forni, Gambetti, and Sala, 2014).

literature relies on reduced form time series techniques, while the other part uses dynamic stochastic general equilibrium (DSGE) models. In the context of vector autoregressive (VAR) methodologies, Beaudry and Portier (2006) and Beaudry and Lucke (2010) find that total factor productivity (TFP) news shocks are important drivers of the US business cycles, while Barsky and Sims (2011) and Forni et al. (2012) find they are not. The estimated DSGE methodology (Fujiwara et al. (2011), Khan and Tsoukalas (2012), Schmitt-Grohe and Uribe (2012)), find them to be negligible sources of fluctuations.

Second, I have many points of contact with the literature that studies investment specific technological change (ISTC). Greenwood, Hercowitz, and Huffman (1988) were the first to suggest that investment shocks could be a viable alternative to neutral technology shocks as sources of business cycles in a general equilibrium environment and consider ISTC's relevance for growth, business cycles, and asset prices. Greenwood, Hercowitz, and Krusell (1997) show that investment-specific technological progress, considered as the trend reductions in the price of investment relative to consumption, is responsible for the major share of growth in the post-war U.S. More recently, using data on the real price of investment, Fisher (2006) identifies in a structural VARs framework that unanticipated IST shocks have accounted for over two-thirds of business cycle fluctuations in output over the 1982-2000 period.

Closely related to my research it is Ben Zeev and Khan (2015). They identified ISTC news shocks using a VAR methodology and determined theirs relative importance. Ben Zeev and Khan (2015) do provide strong support for ISTC news shocks when investigating the role of news in driving U.S. business cycles. Although in this paper my focus is on specific news shocks on the relative price of residential investment, they find similar variance decomposition for the aggregate variables in the US with the one that I present for the Spanish economy; in the US, the news shocks account for 70% of the business cycle variation in output, hours, and consumption, and 60% of the variation in investment.

Third, this paper is related to the home production models that starts with Benhabib et al. (1991) and Greenwood and Hercowicz (1991). They show that home production models match key business-cycle moments better than models without home production.

My results provide evidence that news shocks about future relative prices of residential investment constitute a significant force behind Spanish economic business cycles. Even though the news shocks affect in a less measure the German economic business cycles, do seem to explain the investment and capital accumulation increase in equipment and business structures. An important conclusion of the paper is that the news shocks are consistent with the housing boom in the Spanish economy. My paper suggests that news shocks may help explain on one hand the increase of investment in residential structures, and on other hand the economic growth of the Spanish economy in the period 1970 - 2015.

The rest of this paper is structured as follows. Section 2 reviews the news shocks identification scheme. Section 3 reports the empirical evidence. Section 4 outlines the baseline theoretical model and describes the calibration. Section 5 reports the results of the theoretical model. Section 6 concludes.

2 The Empirical Approach

The central insight for the purpose of this paper is to show that the news about relative prices of investment might lead to predictable changes in investment decisions. To prove my case, I focus on three relative price of investment, q_{it}. In terms of notation in this paper, I call residential investment, q_{rt}, business structures, q_{st}, and equipment, q_{et}.

To proceed, I estimate a vector autoregression (VAR) model on Spanish and German annual data in the period 1970 - 2015. I follow Barsky and Sims (2011) methodology[6] to identify the news shock as the combination of VAR prediction errors that has zero contemporaneous impact on investment prices but accounts for the maximum share of the forecast error variance (FEV) of the relative prices of investment over a ten year horizon. Specifically, Barsky and Sims (2011) apply the strategy proposed by Uhlig (2004) for the purpose of identifying news shock.

Although in the literature are proposed other news shocks identification strategies (i.e. Beaudry and Portier (2006)[7]), in this paper I consider the maximum forecast error variance (FEV) identification approach for several advantages given my data sample. First, the approach allows but does not require that either the contemporaneous shock or the news shock or both have a permanent impact on relative investment prices. Second, the approach does not make any restriction

[6] Barsky and Sims' (2011) methodology is based on the FEV maximization approach of Uhlig (2003) who chooses the shock that maximally explains a weighted average of future levels of productivity. In this paper I attach equal weights to the various horizons over which news shocks are to be explained.

[7] Beaudry and Portier using bivariate VAR, imposed two identifying restrictions: first, that one shock has no long-run effects on TFP and label the orthogonal shock as the news shock; second, that one shock has zero short-run effect and label that shock as the news shock. As it turns out, the two restrictions lead to similar results. They find that the identified news shock leads to positive conditional comovement among macroeconomic aggregates on impact, that aggregate variables strongly anticipate movements in technology, and that news shocks account for a large fraction of the variance of aggregate variables at business cycle frequencies.

about common trends in the different VAR variables. Third, because it is a partial identification method, the approach can be applied to VARs in many variables without imposing additional assumptions about other shocks.

2.1 The Identification Strategy

Since Barsky and Sims (2011) approach already exists in the literature, in this section I describe the basics of the methodology and relegate the details to the appendix.

I assume that the relative prices of investment follows a stochastic process driven by two shocks. First, an unanticipated shock which impacts investment prices level in the same period in which agents observe it. I refer to this as the unanticipated shock. Second, a shock which the agents observe in advance but it impacts the level of investment prices in the future. I refer to this as the relative price of investment news shock, q_{it}.

This identifying assumption can be expressed in terms of the univariate moving average representation:

$$\ln\, q_{it} = [B_{11}(L) \quad B_{12}(L)] \begin{bmatrix} \varepsilon_t \\ \nu_t^n \end{bmatrix} \tag{1}$$

ε_t - traditional surprise relative prices shock - that impacts it in the same period in which agents see it, while ν_t^n - news shock - which agents observe in advance.

The only restriction on the moving representation is that $B_{12}(0) = 0$, so that news shocks have no contemporaneous effect on relative prices. The following is an example process satisfying this assumption:

$$\ln\, q_{it} = g + \ln\, q_{it-1} + \varepsilon_t + \nu_{t-j}^n \tag{2}$$

Here log q_{it} follows a random walk with drift, with g describing the drift term.

ν_t^n, the news shock, has no immediate impact on the level of q_{it}, but in j periods into the future. ε_t is the conventional surprise q_{it} shock. Given the timing assumption, ν_t^n has no immediate impact on the level of q_{it} but portends a change in q_{it} some j periods into the future.

In a univariate context, it would not be possible to separately identify ε_t and ν_{t-j}^n.

The identification of news shocks must come from surprise movements in variables other than q_{it}. As such, estimation of a vector autoregression (VAR) seems sensible in this context. In a system featuring an empirical measure of q_{it} and macro variables, I identify the surprise shock as the reduced-form innovation in q_{it}.

The news shock is then identified as the shock that best explains future movements in q_{it} not accounted for by its own innovation.

3 Empirical evidence of news shocks

In this section I present the main results of the VAR model for the economies of Spain and Germany. The benchmark VAR includes the logs of eight variables: relative price of investment, q_{it}[8], total output, GDP_t, consumption, C_t, aggregate investment, X_t, hours worked, H_t, residential investment, X_{rt}, business structures investment, X_{st} and equipment investment, X_{et}. Although in this section I present results only for the q_{rt} news shock (i.e. one which portends future increase in relative price of residential investment), in the the Appendix B.3 there are shown the estimations of the news shocks on relative prices of business structures and on relative prices of equipment investment. In addition in the Appendix B.3, I estimate news shocks on an alternative VAR.[9]

The system is estimated in levels. The Akaike criteria, the Hannan-Quinn information and Schwartz criteria favor two lags. As a benchmark, I choose to estimate a VAR with two lags; the results are robust to using a different number of lags. I estimate a Bayesian VAR (BVAR) using the MATLAB main program routine provided by Kurmann and Otrok (2013)[10].

In the figures representing the impulse response functions, (IRF), and the forecast error variance, (FEV), the solid lines correspond to the posterior median estimates, while the grey bands display the 16%-84% posterior coverage intervals. These bands are constructed from a residual based bootstrap procedure repeated 1000 times.

As described in Section 2, I extract the shocks that maximize the fraction of the FEV of q_{it} explained by the news shocks over the forecast horizon of 10 periods[11], weighting the importance of each of the forecasts equally. This choice is motivated by the fact that I want to capture short- and medium-run movements of q_{it} while providing at the same time reliable estimates at the long end of the forecasting

[8] i stands q_{rt}-residential investment, q_{st} - business structures, q_{et} - equipment investment

[9] The alternative VAR includes the logs of eight variables: relative price of investment, q_{it}, GDP, GDP_t, consumption, C_t, aggregate investment, X_t, equipment investment, X_{et}, business structures investment, X_{st}, residential investment, X_{rt}, and IBEX 35 for Spain, or DAX for Germany.

[10] Kurmann, A. and C. Otrok . "News Shocks and the Slope of the Term Structure of Interest rates." American Economic Review (2013)

[11] When using the method of Barsky and Sims to identify future q_{it} news shocks, I find that the results are not sensitive to the choice of forecast horizons (i.e. the results are very similar regardless of the forecast horizons used).

horizon.

3.1 Forecast Error Variance and Impulse Response Functions

Figure 9 and 10 in Appendix B.2 display the fraction of the FEV of the benchmark VAR explained by the relative prices of residential investment shock for the Spanish and German economy. Figures 7 and 8 in Appendix B.2 display the IRF of the benchmark VAR explained by the q_{rt} shock for the Spanish and German economy. I consider that a positive realization of the news shock means an expected future increase in relative price of residential investment.

3.1.1 Aggregate effects of q_{rt} news shocks

The figures 9 and 10 in Appendix B.2 depict the contribution to forecast error variance at all horizons up to the 10 year. It is evident that favorable news shock on the relative prices of residential investment, q_{rt}, increase significantly on impact all the real aggregates and display persistent dynamics, even though they are different for Spain than for Germany.

For the Spanish economy, the news shock[12] explains 61% of the variation of relative prices of residential investment, 59% of output, 65% of aggregate investment, and more then 40% of hours worked, on witch all the effect is on impact. On output, aggregate investment and consumption, the hump-shaped effect of the news shocks variance decomposition suggests that the news effect is accumulating in time. The relative prices of residential investment news shock explain very little of the consumption, only 15%.

The fraction of variation explained by German news shock shows a very different picture than the Spanish one. The news shock[13] explains less of the variation of output compared with the Spanish economy, 51% for Germany against 59% for Spain. Even less for the aggregate investment and hours: 39% and 11% respectively. Contrary to the Spanish economy, the highest fraction of variation is explained for the consumption, 48%, which effect is on impact.

Figures 7 and 8 in Appendix B.2 show the estimated IRF of the Spanish and German variables to a positive one standard deviation relative prices of residential investment news shock from the benchmark VAR. Following a positive realization

[12] Table 4 shows the median impact percentile and the forecast horizon period in which that is achieved for Spain

[13] Table 5 in Appendix B.2 shows the median impact percentile and the forecast horizon period in which that is achieved for Germany

of the news shock, the housing prices do not change on impact by construction, after which they grow gradually and peak after 6 years.

The Spanish output, investment, consumption, and hours worked jump on impact, with highly statistically significative responses. Output, consumption, investment reach their peak after three periods. Hours worked, after the initial jump is decreasing and become insignificant after 5 periods. Output and aggregate investment, are particularly persistent, with hump-shaped effects.

For Germany, the output, consumption, investment and hours worked jump on impact with statistically significative responses. After the initial jump, all four variables exhibit low persistence, decaying rapidly and becoming insignificant after 4-5 periods. Contrary to Spain, the German hours worked are statistically significant just for the first period.

3.1.2 The q_{rt} news shocks effects on the desagreggated investment variables

Figures 7 and 8 in Appendix B.2 show the estimated impulse responses of the Spanish and German variables to a positive one standard deviation q_{rt} news shock from the benchmark VAR. The news shock effects of a relative price of residential investment on different investment categories variables for the Spanish and German economies are the following: for Spain, the residential investment variance explained by the news shock is 80%, while the fraction of FEV for the equipment and business structures it is much lower, around 43% and 46% respectively. The picture of decomposed IRF of investment in investment in residential structures, business structures and equipment shows that all three responses are statistically significant, all three jumping on impact. Residential investment is the one that presents the highest amplitude and persistence being significant even after 10 periods. It reaches the peak in the third period, at more than 6.5% higher than its pre-shock value. In contrast, although the equipment investment reaches the peak rapidly, it shows the lowest degree of amplitude and persistence.

For the German data, the residential investment is not statistically significant. The business structures and equipment IRF are statistically significant, both jump on impact and decay shortly after that. The business structures IRF shows the highest degree of persistence to a news shock.

3.2 Benchmark VAR results interpretation

The key result of this section is that a positive q_{rt} news shock implies positive comovement among macroeconomic aggregates in line with the positive unconditional comovement of these series in the data. For both countries, a positive realization of the q_{rt} news shock (i.e. one which portends future increase in relative prices of residential investment) is associated an initial increase of output, investment, consumption, and hours worked. Compared with the German responses, the Spanish ones exhibit a much higher persistency and amplitude. The results match closely the findings in Beaudry and Portier (2006) who find comovement following a TFP news shock. According to Beaudry and Portier (2006), an initial comovement of output, investment, consumption, and hours is consistent with a favorable interpretation of the news-driven business cycle hypothesis. In the same time my results contradict Barsky and Sims' (2011) who do not find the aggregate comovement following to a TFP news shock. For Barsky and Sims (2011), the news shocks constitute a main driver of business cycles when a positive news shock leads to comovement in consumption and hours on impact.

A number of interesting results emerge from the analysis. From the IRF and FEV decomposition analysis between Spain and Germany, I conclude the q_{rt} news is a driver of the business cycle, with a strong reaction for Spain, and a softer reaction for Germany. There is an important difference of the effects of a q_{rt} news shock at the desagreggated investment level. In Spain an q_{rt} news shocks beside increasing all aggregate variables, it is increasing very strong the residential investment, confirming the recent economic growth of the Spanish economy due to housing sector. At this point, it appears that a news shock on the relative price of residential investment has the effect of increasing on one hand the residential investment, and on the other hand, its complements: business structures and equipment.

In Germany, on contrary, the same news shock it propagates itself stimulating equipment and business structures investment with an effect that seems to indicates that might be a substitution effect: the residential investment is substituted by investment in business structures and especially in equipment.

All those findings hold across different VAR specifications in my paper. Included in the Appendix B.3 are the FEV and IRF of the news shocks estimated on q_{st} and q_{et} that are enforcing my results. As well there is an alternative VAR estimation, where I include a forward-looking variable, the IBEX 35 for Spain, and DAX for Germany. The alternative VAR specification also confirms the benchmark VAR results.

In the next figure 1 there are represented the innovations from the empirical identification together with the first difference of the log of GDP. It can be seen that the news shock innovations have predictability characteristics for the business cycle fluctuations. The Spanish crises in '92, '08 and '11 are anticipated by the news shock with one period.

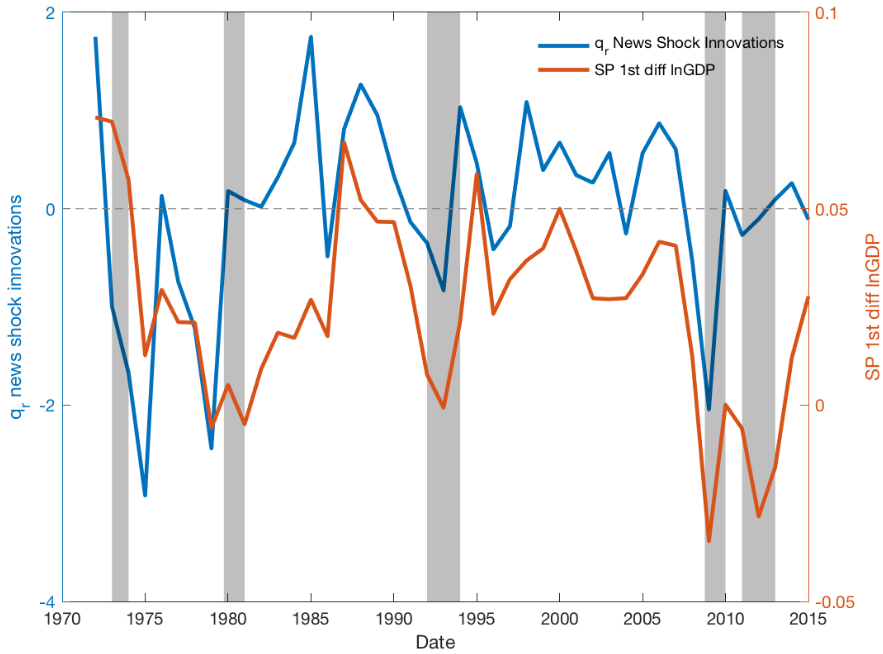


Figure 1: Spain: q_r news shock innovations against 1st diff log GDP

Note: The shaded areas correspond to recession dates for Spain; The units of the right vertical axes is the log difference of GDP per capita.

4 A model with home production & relative prices of investment

This section describes the theoretical model proposed to interpret the news propagation mechanism of the empirical SVARs. The real business cycle model is based on a stylized version of Díaz and Franjo (2016) augmented with Jaimovich and Rebello (2008) preferences, home production and news shocks. The model has two productive sectors: the market sector and the home production sector. The market production function distinguishes between two different capital categories, equipment and structures, and labour market hours, while in the home sector, consumers produce home goods with home labour and residential capital. Key assumptions for the model are that home production is not perfect substitute for market goods and services, and is not tradable in the market.

The driving forces in the business cycle model include country - specific stochastic stationary contemporaneous shocks and news shocks. The news shocks, q_{it}, are hitting the relative price of residential investment, business structures, and equipment. In particular, as the empirical analysis suggests, the news shock on the relative prices of investment has different long-run implications, but the contemporaneous effects are essentially zero. Therefore, the specification, through parameters ρ_i that are relative prices-specific, captures well news processes in response to the q_{it} shock; although this is a common shock, it propagates differently to the relative prices of investment in each economy.

As is standard in growth and business cycle models, the decentralized competitive equilibrium can be characterized by the solution of a planning problem. The planner chooses the representative household's stochastic sequences of consumption and leisure to maximize the utility of the representative agent, subject to the technological constraints of the economy.

4.1 Preferences

There is a continuum of households indexed by $j \in (0,1)$. Each household consumes, supplies labour, makes investment and capital utilization decisions. The preferences are defined as followed:

$$E_t \sum_{t=0}^{\infty} \beta^t U \left[C_t \Big(C_{mt}, C_{rt}(K_{rt}, N_{rt}) \Big), N_{mt} + N_{rt}, \chi_t \right] \tag{3}$$

The total consumption, C_t, is a composite consumption of market goods and services, C_{mt}, and residential production for consumption, C_{rt}. It is assumed that total consumption is given by a CES function such as:

$$C_t = \left(\omega C_{mt}^{\eta} + (1-\omega) C_{rt}^{\eta} \right)^{1/\eta}, \quad \eta \in (-\infty, 1] \tag{4}$$

Note that ω is the proportion of each good in the total consumption, and η is the parameter measuring the willingness of agents to substitute between the market consumption and home production consumption. The parameter η is key for the relationship between the two activities since the elasticity of substitution between market goods and home production goods is defined as $\epsilon = 1/(1-\eta)$.

Following Jaimovich and Rebello (2008) preferences, the presence of χ_t makes preferences non-time-separable in consumption and hours worked, allowing to parameterize the strength of short-run wealth effects on the labor supply:

$$\chi_t = C_t^{\gamma} \chi_{t-1}^{1-\gamma}; \quad \gamma \in [0,1] \tag{5}$$

Jaimovich and Rebello (2008) preferences nest two of the most popular utility functions in the business cycle literature. When $\gamma = 1$ the preferences are those proposed by King, Plosser, and Rebelo (1988), which I refer as KPR. In change, when $\gamma = 0$ the preferences are those proposed by Greenwood, Hercowitz, and Huffman (1988), which I refer as GHH. The characteristics of the GHH preferences are that the labor effort is determined independently of the intertemporal consumption-saving choice.

Therefore χ_t becomes:

$$\chi_t = \left(\omega C_{m,t}^{\eta} + (1-\omega)C_{r,t}^{\eta}\right)^{\frac{\gamma}{\eta}} \chi_{t-1}^{1-\gamma} \tag{6}$$

Each household supplies labour to labour market, N_{mt}, and to residential production, N_{rt}.

$$N_t = N_{mt} + N_{rt} \tag{7}$$

The household combines residential capital with hours according to the home production function:

$$C_{rt} = A_t K_{rt+1}^{1-\theta_r} N_{rt}^{\theta_r} \tag{8}$$

where A_t is the home production productivity, which is assumed to follow a stochastic process driven by a shock, ε_{At}, i.i.d. process with zero mean and standard deviation σ_{ε}.

$$ln\ A_t = (1-\rho_A)\ ln\ \bar{A} + \rho_A\ ln\ A_{t-1} + \varepsilon_{At}$$

K_{rt} represents residential structures. The parameter θ_r represents the labour share in the home production function. The constrain says that home consumption must be produced at home and cannot be bought or sold on the market.

Therefore, I write the utility function as

$$U(C_t, N_t, \chi_{t-1}) = \frac{\left(C_t - \psi N_t^{\theta}\left(\omega C_{mt}^{\eta} + (1-\omega)C_{rt}^{\eta}\right)^{\frac{\gamma}{\eta}} \chi_{t-1}^{1-\gamma}\right)^{1-\sigma} - 1}{1-\sigma} \tag{9}$$

4.2 Technology

The production of final output, Y_t, requires of market labor, N_{mt}, and two types of capital, equipment and business structures. Production technology is described by:

$$Y_t = Z_t K_{et}^{\alpha_e} K_{st}^{\alpha_s} N_{mt}^{1-\alpha_e-\alpha_s}, \quad 0 < \alpha_e, \alpha_s;\ \alpha_e + \alpha_s < 1. \tag{10}$$

where Z_t is the total factor productivity (TFP). The technology is assumed to follow a stochastic process driven by a shock, ε_{Zt}, i.i.d. process with zero mean and standard deviation σ_ε: $ln\ Z_t = (1-\rho_Z)ln\bar{Z} + \rho_Z ln\ Z_{t-1} + \varepsilon_{Zt}$

The household owns the total capital, K_t, divided between capital used to produce market goods and services and home production capital as follow:

$$K_t = K_{et} + K_{st} + K_{rt}, \tag{11}$$

The capital for market goods and services K_{mt} is split between equipment, K_{et}, and business structures, K_{st}, while the share of capital used in the house production function includes residential structures, K_{rt}. The household's capital stock evolves according to the law of motion:

$$K_{it+1} = (1-\delta_i)K_{it} + \Theta_{it}X_{it},\ \text{where } 0 < \delta_i < 1, \tag{12}$$

where X_{it} is the investment, and i that stands for equipment, X_{et} , business structures, X_{et}, and residential structures, X_{rt}.

Θ_{it} represents the level of investment-specific technology. Following Greenwood *et al.* (1997), Θ_{it} determines the amount of capital that can be purchased for one unit of output, representing the current state of the technology to produce capital. Changes in Θ_{it} represent investment-specific technological change and we assume that it affects all types of capital. The higher Θ_{it}, greater the amount of capital that can be incorporated into the economy with an investment unit, reflecting the fact that the quality of capital has increased. A technological news shock that increases Θ_{it} is associated expectations of future reduction of the cost of producing investment capital with respect to the cost of producing consumption goods.

In equilibrium, the inverse of the investment-specific technology shock, $q_{it} = 1/\Theta_{it}$, could be thought of as the relative price of capital in terms of consumption.

Final output, Y_t, can be used for four purposes: market consumption, C_{mt}, investment in business structures, X_{st}, investment in equipment, X_{et} or residential investment, X_{rt}:

$$Y_t = C_{mt} + X_{et} + X_{st} + X_{rt} \tag{13}$$

This is a closed economy.

The household maximizes utility subject to the global constraint of resources :

$$C_t + X_t = Z_t K_{et}^{\alpha_e} K_{st}^{\alpha_s} N_{mt}^{1-\alpha_e-\alpha_s} \tag{14}$$

where $X_t = X_{et} + X_{st} + X_{rt}$,

4.3 News shocks

In this setting I introduce the news shocks on q_{it} as follows:

$ln\ q_{et} = (1-\rho_{q_e})\bar{q}_e + \rho_{q_e} ln\ q_{et-1} + \varepsilon_{q_e t} + \varepsilon_{news,t-4}$, where q_{et} stands for the relative price of equipment.

$ln\ q_{st} = (1-\rho_{q_s})\bar{q}_s + \rho_{q_s} ln\ q_{st-1} + \varepsilon_{q_s t} + \varepsilon_{news,t-4}$, where q_{st} stands for the relative price of business structures.

$ln\ q_{rt} = (1-\rho_{q_r})\bar{q}_r + \rho_{q_r} ln\ q_{rt-1} + \varepsilon_{q_r t} + \varepsilon_{news,t-4}$, where q_{rt} stands for the relative price of residential investment. Although I report only results on the news shocks on the relative prices of residential investment, $\nu_{n_r t-4}$, I also consider contemporaneous i.i.d. shock, $\varepsilon_{q_i t}$ and news shocks on the relative prices on investment in business structures and equipment.

The news shocks hits as the economy is in the steady state. Agents receive news about one percent increase in the relative prices of investment in residential investment up four periods ahead: $\varepsilon_{news,t-4}$ is an innovation to the level of q_{rt} that materializes in period t, but that agents learn about in period $t-4$.

4.4 Social Planner's Problem

The planner chooses $\{Y_t, C_t, N_m, N_r, X_t\}$ to maximize 9 subject to 10 - 14 given $K_{i,0}$.

I solve the first-order conditions of equilibrium around the non-stochastic steady state of the model and solve numerically the system of stochastic difference equations in DYNARE.

4.5 Calibration

This section explores the reasonable setting of the parameters to be useful in studying the news shocks propagation mechanism. I calibrate my model so that in steady state to match the average values in the Spanish and German annual data for the 1970 - 2015 sample. The stochastic structure that governs the evolution of the news shocks is taken from the time series properties in the *EU KLEMS*[14] data base 2017 release.

Table 1: Calibration - Spain vs Germany

Param.	Spain	Germany		Target
β	0.95	0.98	discount factor	$1/(1+r_t)$
α_e	0.13	0.14	equipment capital share	DF(2016)
α_s	0.10	0.11	structures capital share	DF(2016)
θ_r	0.20	0.18	capital share in residential production	Calibrated
δ_e	0.11	0.13	equipment depreciation	EU KLEMS
δ_s	0.03	0.04	structures depreciation	EU KLEMS
δ_r	0.02	0.02	residential depreciation	EU KLEMS
$\bar{Z}$	0.65	0.89	average TFP	Estimated
ρ_Z	0.85	0.95	autocorr.TFP process	Estimated
$\bar{A}$	0.81	0.71	average home productivity process	Calibrated
ρ_A	0.98	0.93	autocorr. home productivity process	Calibrated
$\bar{q}_e$	0.15	0.5	average relative price of equipment	Estimated
ρ_{q_e}	0.88	0.96	autocorr. rel. price of equipment process	Estimated
$\bar{q}_s$	0.35	0.42	average relative price of structures	Estimated
ρ_{q_s}	0.94	0.92	autocorr. rel. price of structures process	Estimated
$\bar{q}_r$	0.38	0.42	average relative price of residential	Estimated
ρ_{q_r}	0.78	0.94	autocorr. rel. price of residential process	Estimated

To compare the two economies I make them equal in certain dimensions equalizing the parameters that are not essential for my argument. First, I fix the intertemporal elasticity of substitution (IES) to be the same in both economies. In the literature, it is fairly common to implicitly set $\sigma = 1$ which corresponds to the case of logarithmic utility.

[14]Díaz and Franjo (2016) use the same data base for the Spanish economy in theirs paper

Table 2: Common specification

Param.	Value		Target
σ	1	Intertemporal Elasticity of Substitution (IES)	Jaimovich & Rebelo (2009)
ω	0.54	measures the weight of C_m in the utility function	Calibrated
ψ	0.45	scale parameter	Working time 1/3 of time endowment

Then, it seems natural to set equal the following two parameters: $\omega = 0.54$, which is the utility function parameter that measures the weight of the market consumption, C_m, and the labour disutility scale parameter, $\psi = 0.45$.

The news shocks propagation mechanism depends on γ, η, and θ. Help the model to capture main features of the data, in order to achieve the comovement (γ) and persistency (θ) observed in the empirical identification. The next three parameters are key to better understand the implications of news shocks reproducing the observed investment process. There are, the parameter that governs the short run wealth-effect, γ, the parameter η that governs the elasticity of substitution between C_m and C_h, and the intertemporal labor supply elasticity parameter, θ.

γ helps to mimic the individual characteristics of the two economies. In the same line as Jaimovich and Rebello (2008), in order to obtain comovement, the short-run wealth effects should be somewhat weaker than those implied by KPR (< 0.6). For that reason, I consider intermediate values of γ for both countries. For Spain, I set weak short-run wealth effects, close to GHH preferences, $\gamma = 0.06$, while for Germany, $\gamma = 0.56$.

As η governs the elasticity of substitution between market and home production, the news effects become more important in the model under a low elasticity of substitution between market and home production. - the elasticity of substitution between C_m and C_h is defined as $\epsilon_h = 1/(1-\eta)$. The reason for employing those particular values for η is based on one hand on the fact that it should reflect the believes about the complementarity and sustituibility between the market activity and home activity in the two economies. On other hand, because there is a lack of consistent and long time time series on time use in the home production for the two countries in my data set.

Given the empirical market labour differences of the two economies, I set for Germany a much responsive labor supply ($\theta < 1.3$) than for Spain, for which I set it not very responsive ($\theta < 7.2$).

Table 3: Key parameters

	SPAIN	GERMANY	
γ	0.06	0.56	governs the short-run wealth effect on the labor supply
η	-1.31	0.85	$\epsilon_h = 1/(1-\eta)$ elasticity of substitution between C_m and C_h
θ	7.2	1.25	intertemporal labor supply elasticity

5 Theoretical model results

Next, I inspect the theoretical impulse response functions of relative prices of investment in response to news shocks in our benchmark model. I start with news shocks on relative prices of residential investment, q_{rt}. In Appendix C, I include the estimations of news shocks on relative prices of business structures, q_{st}, and on news shocks on relative prices of equipment investment, q_{et}.

For the purpose of analyzing a news shock propagation mechanism, there are various moments of interest: the variable movement on impact, meaning at $t = 1$, at the period t between $2 < t < 4$, at the time of the realization, $t = 4$, and after the shock.

5.1 News Shocks on q_{rt}

5.1.1 Effects on aggregate variables of a q_{rt} news shock effects

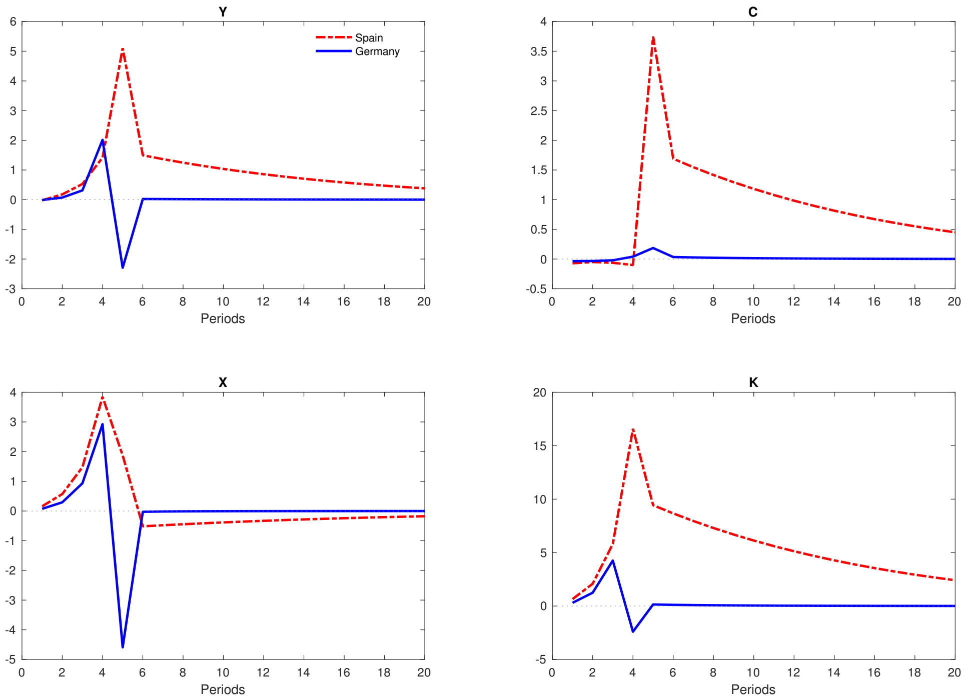


Figure 2: q_r news shock effect on aggregate variables

Figure 2 shows the IRFs of aggregate model's variables following a news shock on the relative prices of residential investment increase of 1%.

On impact at time t the Spanish and German output, consumption, investment, and capital accumulation, do not move. For both economies, starting from the second period, the output, investment and capital accumulation start increasing, though the positive shock only occurs in period four. The aggregate consumption does not react for either economy. The Spanish output, consumption and capital accumulation peak only after the realization of the news shock. That means, in the fifth period, when they reach the maximum after which persistently stay above the steady state for many periods. Starting with the sixth period, the Spanish aggregate investment falls slightly under the steady state where it stays for 15 periods. For Germany, most of the aggregate variables increase occurs between period two and four, when the news arrives, not in period four, when the q_{rt} shock materializes. After the forth period, the German output, investment and capital accumulation are falling, returning to the log run equilibrium already from the sixth period, while consumption response, even it is very small, it is positive.

The Spanish IRF output, consumption, and capital accumulation are positive and persistently above the steady state, indicating a long and persistent economic growth and capital accumulation already from the second period. For Germany, the initial increase of the variables is followed by a fall and an rapid return to the log run equilibrium after that.

At the aggregate level, if in the period before the shock realization the variables are positively correlated, after the shock materializes, effects are opposite for the two economies, with much stronger fluctuation for Spain, and less for Germany.

5.1.2 Investment decomposition of a q_{rt} news shock

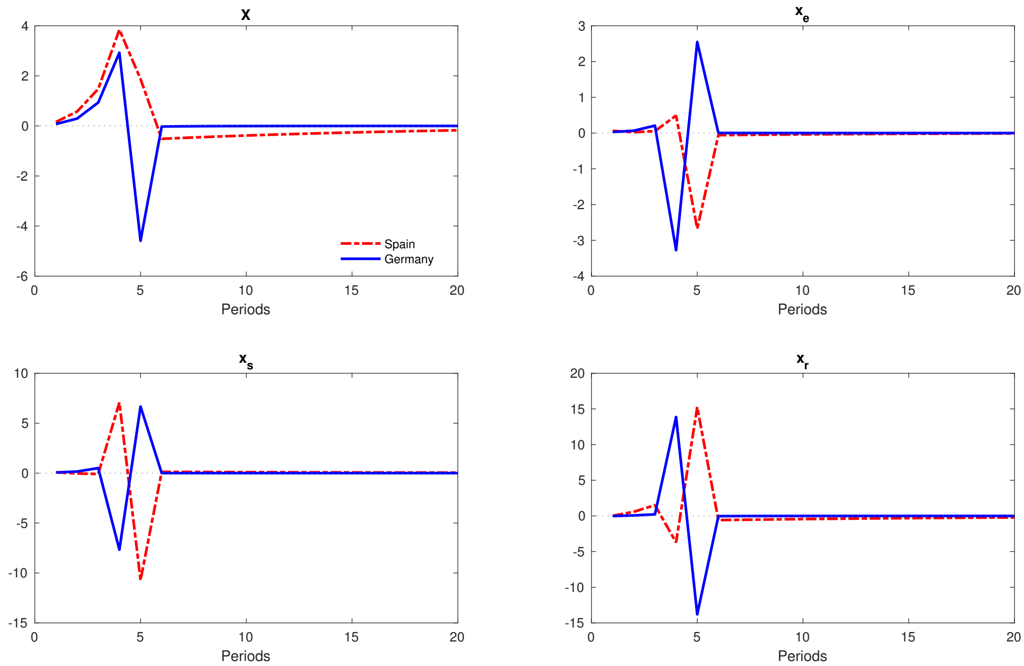


Figure 3: q_{rt} news shock effect on decomposed investment variables

Figure 3 shows the IRFs of decomposed investment variables following a news shock on the relative prices of residential investment increases of 1%. The first observation is that the model is able to mimic the negative correlation between the two countries found in the data, especially starting from the 2000s.

For the propagation mechanism, there are three moments of interest: the variable movement before, at the time of the realization, and after the shock.

For the Spanish economy, the equipment, X_e, and structures investment, X_s, are increasing on the realization of the shock, after which they both are falling. The initial increase in the structures investment is stronger than the equipment one, but also fall is deeper, even they are not persistent. The residential investment,

X_r, is increasing strongly after the realization of the news shock, even thought in the period before the realization of the shock, there are two opposite very week movements; one of a light increase starting from the second period, followed by a very short fall exactly on the realization of the shock.

For the German economy the movements are exactly opposite. Equipment and structures are decreasing on the shock realization, to increase in the following periods. The residential investment is increasing only on the realization of the shock after which is followed by a fall. For Germany, it appears that the news shock effect on the equipment and structural investment is positive, while seems to be negative for the residential investment.

5.1.3 Capital accumulation decomposition of a q_{rt} news shock

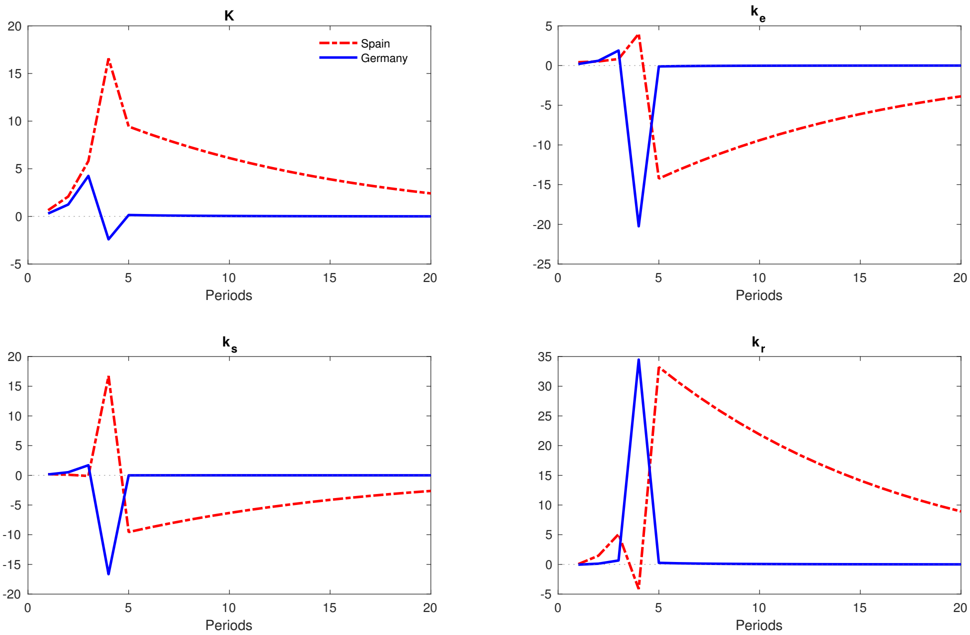


Figure 4: q_{rt} news shock effects on decomposed capital accumulation variables

Figure 4 shows the IRFs of decomposed capital accumulation model's variables following a news shock on the relative prices of residential investment decrease of 1%. Practically, the capital accumulation is negatively correlated for the two economies.

Again, I analyze the effects looking at the three moments of interest: the variable movement before, at the time of the realization, and after the chock. For the German economy, the capital accumulation is negative at the time of news shock realization for the equipment, k_e, and business structures, k_s, while is positive for the residential capital, k_r. None of the variable movement is persistent. On contrary, the Spanish variables are showing nice persistent movements; negative for the equipment and business structures, and positive and very persistent for the residential capital accumulation.

6 Conclusion

This paper provides evidence that relative prices of residential investment news shocks are the main force behind business cycle fluctuations in the Spanish economy. To obtain these results, I first applied the Barsky and Sims (2011) approach. The empirical impulse responses produce significant positive business cycle comovement in Spain. The news shocks that explain in a high measure the variation of output, investment and hours, are robust to different lag election and to an alternative VAR specification. A significant forecast error variance contributions (80%) of the residential investment in the Spanish economy is explained by news shocks on relative prices of residential investment. For the German economy, the news shocks explain the variance of the aggregate variables in a less measure.

Then, the theoretical RBC model that I propose to interpret the empirical results confirm the contribution of the news shocks to relative prices of residential investment to the housing boom in Spain. The propagation mechanism of the news socks is consistent with the recent economic growth due to residential investment. At the same time, in Germany the wealth effect induced by the news shocks is increasing the investment in the equipment and business structures.

References

[1] S. Boraan Aruoba, Morris A. Davis, and Randall Wright. Homework in monetary economics: Inflation, home production, and the production of homes. *Review of Economic Dynamics*, 21:105 – 124, 2016.

[2] Oriol Aspachs-Bracons and Pau Rabanal. The Drivers of Housing Cycles in Spain. *IMF Working Paper*, WP/09/203, 2009.

[3] Oriol Aspachs-Bracons and Pau Rabanal. The Effects of Housing Prices and Monetary Policy in a Currency Union. *IMF Working Paper*, WP/11/6, 2011.

[4] Robert B. Barsky and Eric R. Sims. News shocks and business cycles. *Journal of Monetary Economics*, 58(3):273 – 289, 2011.

[5] Paul Beaudry and Franck Portier. An exploration into Pigou's theory of cycles. *Journal of Monetary Economics*, 51(6):1183 – 1216, 2004.

[6] Paul Beaudry and Franck Portier. Stock Prices, News, and Economic Fluctuations. *American Economic Review*, 96(4):1293–1307, September 2006.

[7] Nadav Ben Zeev and Hashmat Khan. Investment-Specific News Shocks and U.S. Business Cycles. *Journal of Money, Credit and Banking*, 47(7):1443–1464, 2015.

[8] Jess Benhabib, Richard Rogerson, and Randall Wright. Homework in Macroeconomics: Household Production and Aggregate Fluctuations. *Journal of Political Economy*, 99(6):1166–87, 1991.

[9] Olivier J. Blanchard, Jean-Paul L'Huillier, and Guido Lorenzoni. News, Noise, and Fluctuations: An Empirical Exploration. *American Economic Review*, 103(7):3045–70, December 2013.

[10] Morris A. Davis and Jonathan Heathcote. Housing and the Business Cycle. *International Economic Review*, 46(3):751–784, August 2005.

[11] Antonia Díaz and Luis Franjo. Capital goods, measured TFP and growth: The case of Spain. *European Economic Review*, 83(C):19–39, 2016.

[12] Jesus Fernandez-Villaverde and Lee Ohanian. The spanish crisis from a global perspective. Working Papers 2010-03, FEDEA, 2010.

[13] Mario Forni, Luca Gambetti, and Luca Sala. No News in Business Cycles. *The Economic Journal*, 124(581):1168–1191, 2014.

[14] Stefano Gnocchi, Daniela Hauser, and Evi Pappa. Housework and fiscal expansions. *Journal of Monetary Economics*, 79:94 – 108, 2016.

[15] Jeremy Greenwood and Zvi Hercowitz. The Allocation of Capital and Time over the Business Cycle. *Journal of Political Economy*, 99(6):1188–214, 1991.

[16] Jeremy Greenwood, Zvi Hercowitz, and Gregory W. Huffman. Investment, Capacity Utilization, And The Real Business Cycle. *The American Economic Review*, 78(3):402, 06 1988. Copyright - Copyright American Economic Association Jun 1988;.

[17] Jeremy Greenwood, Zvi Hercowitz, and Per Krusell. Long-run implications of investment-specific technological change. *The American Economic Review*, 87(3):342–362, 06 1997. Copyright - Copyright American Economic Association Jun 1997;.

[18] Jeremy Greenwood, Zvi Hercowitz, and Per Krusell. The role of investment-specific technological change in the business cycle. *European Economic Review*, 44(1):91 – 115, 2000.

[19] Jeremy Greenwood, Richard Donald Rogerson, and Randall Wright. *Household Production in Real Business Cycle Theory.* Number 347. Rochester Center for Economic Research, 1993.

[20] Matteo Iacoviello and Stefano Neri. Housing Market Spillovers: Evidence from an Estimated DSGE Model. *American Economic Journal: Macroeconomics*, 2(2):125–64, April 2010.

[21] Nir Jaimovich and Sergio Rebelo. Can News about the Future Drive the Business Cycle? *American Economic Review*, 99(4):1097–1118, September 2009.

[22] RYO JINNAI. R&D Shocks and News Shocks. *Journal of Money, Credit and Banking*, 46(7):1457–1478, 2014.

[23] Alejandro Justiniano, Giorgio E. Primiceri, and Andrea Tambalotti. Investment shocks and business cycles. *Journal of Monetary Economics*, 57(2):132 – 145, 2010.

[24] Alejandro Justiniano, Giorgio E. Primiceri, and Andrea Tambalotti. Investment shocks and the relative price of investment. *Review of Economic Dynamics*, 14(1):102 – 121, 2011. Special issue: Sources of Business Cycles.

[25] Loukas Karabarbounis. Home production, labor wedges, and international business cycles. *Journal of Monetary Economics*, 64:68 – 84, 2014.

[26] Hashmat Khan and John Tsoukalas. The Quantitative Importance of News Shocks in Estimated DSGE Models. *Journal of Money, Credit and Banking*, 44(8):1535–1561, 2012.

[27] André Kurmann and Christopher Otrok. News shocks and the slope of the term structure of interest rates. *American Economic Review*, 103(6):2612–32, October 2013.

[28] Luisa Lambertini, Caterina Mendicino, and Maria Teresa Punzi. Expectation-driven cycles in the housing market: Evidence from survey data. *Journal of Financial Stability*, 9(4):518 – 529, 2013. Re-examining the role of the state in the financial sector.

[29] Ellen McGrattan, Richard Rogerson, and Randall Wright. An Equilibrium Model of the Business Cycle with Household Production and Fiscal Policy. *International Economic Review*, 38(2):267–90, 1997.

[30] OECD. Economic outlook, analysis and forecasts: Focus on house prices. Retrieved 14 Oct 2016 2014.

[31] Monika Piazzesi and Martin Schneider. Momentum Traders in the Housing Market: Survey Evidence and a Search Model. *American Economic Review*, 99(2):406–11, May 2009.

[32] Luis A. Puch and Omar Licandro. Are there any special features in the Spanish business cycle? *Investigaciones Economicas*, 21(3):361–394, 1997.

[33] V.A. Ramey. Chapter 2 - Macroeconomic Shocks and Their Propagation. volume 2 of *Handbook of Macroeconomics*, pages 71 – 162. Elsevier, 2016.

[34] Stephanie Schmitt-Grohé and Martín Uribe. What's News in Business Cycles. *Econometrica*, 80(6):2733–2764.

[35] Robert Topel and Sherwin Rosen. Housing Investment in the United States. *Journal of Political Economy*, 96(4):718–740, 1988.

7 Appendix A. DATA

My data sources are the *EU KLEMS*[15] and *OECD* data base. I use the period 1970 - 2015.

7.1 The relative price of investment goods and the stock of capital

The EU KLEMS September 2017 release is based on the NACE 2 industry classification and the new European System of National Accounts (ESA 2010). Compared with the previous one, ESA 1995, ESA 2010 includes more assets in the definition of Gross Fixed Capital Formation (GFCF). The database structure of capital and investment is organized in eleven categories, provides deflators for all categories and calculates the capital stock using a perpetual inventory method.

The procedure to construct the **Residential Investment**, **Business Structures** and the composite **Equipment** follows Díaz and Franjo (2016):

Residential Investment contains category *Residential structures*,
Business Structures contains *Total Non-residential investment*,
Equipment contains all other categories corresponding to various types of business equipment, computer software and research and development as intellectual property, weapons systems, and investment in cultivated assets:

1. *Computing equipment*
2. *Communications equipment*
3. *Computer software and databases*

[15]Examples of research based on this database: Mary O'Mahony and Marcel P. Timmer (2009), "Output, Input and Productivity Measures at the Industry Level: the EU KLEMS Database", Economic Journal.
Bart van Ark, Mary O'Mahony and Marcel P. Timmer (2008), "The Productivity Gap between Europe and the U.S.: Trends and Causes", Journal of Economic Perspectives, 22(1), pp. 25-44.
Robert Inklaar, Marcel P. Timmer and Bart van Ark (2008), "Market Services Productivity", Economic Policy, 23, pp. 141-194.
The EU KLEMS project is funded by the European Commission, Research Directorate General as part of the 6th Framework Programme, Priority 8, "Policy Support and Anticipating Scientific and Technological Needs".
O'Mahony, Mary and Marcel P. Timmer (2009), "Output, Input and Productivity Measures at the Industry Level: the EU KLEMS Database", Economic Journal, 119(538), pp. F374-F403.

4. *Transport Equipment*
5. *Other Machinery and Equipment*
6. *Cultivated assets*
7. *Research and development*
8. *Other IPP assets*

I construct the implicit price deflator of *non durable goods* and *services*, $D_{nd,t}$ using the data from OECD.Stat[16], IPC series of ECOICOP.

To construct the composite *Equipment* (Paasche index), I take the implicit price deflator of each type of investment good, $D^j_{i,t}$ from EU KLEMS (base year 2010). I define the relative price of the investment good i in category e (*equipment)* as $q^e_{i,t} = D^e_{i,t}/D_{nd,t}$.

I construct a constant-price measure of investment in equipment as $X_{e,t} = \sum_i q^e_{i,0} X^e_{i,t}$.

Thus, the implicit price deflator of equipment is:

$$q_{e,t} = \frac{\sum_i q^e_{i,t} X^e_{i,t}}{X_{e,t}} \tag{15}$$

Next, I calculate the real stock so that

$$K_{e,t} = \frac{\sum_i q^e_{i,t} K^e_{i,t}}{q_{e,t}}, \tag{16}$$

where $K^e_{I,t}$ is the real capital stock calculated by EU KLEMS for each type of investment good. EU KLEMS constructs the stocks of structures and housing. I have calculated their relative price using the deflator of non durable goods and services.

The figure 5 shows the relative prices of investment for each category (in units of non durable consumption goods and services) for Spain and Germany. I have normalized the relative prices so that 1970 is the base year for both countries.

[16] http://stats.oecd.org/index.aspx

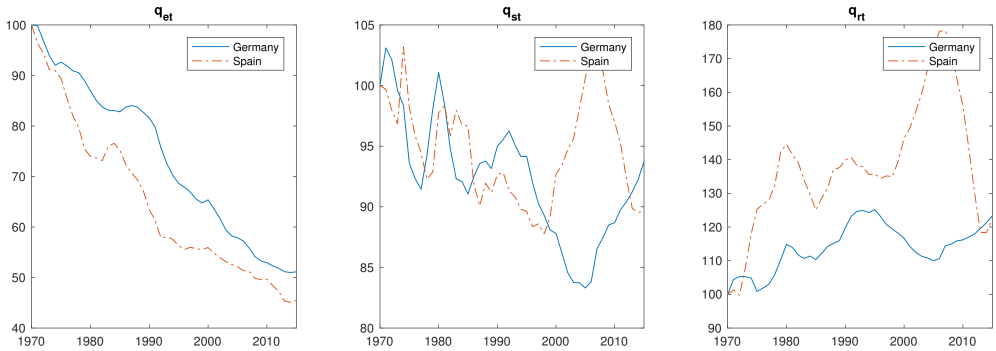


Figure 5: Relative Prices of Investment, q_{it} - Spain vs Germany

The behavior of the relative price of equipment, shown in the left panel exhibits a downwards trend for both countries. It is interesting to note that as both prices have similar fluctuations, it implies that business cycles are correlated. The fall in the relative price in Spain is higher than Germany's in two periods: from 1970 to 1979 and from 1985 to 1991. Those two periods coincide exactly with the periods of housing boom in Spain, as we observe in the right panel.

The relative price of business structures, shown in the central panel exhibit a similar pattern until the 2000s. The coefficient of correlation from 1970 to 1998 is 0.60, while from 1999 to 2015 the coefficient of correlation is negative, -0.70. In Germany, however, the relative prices of structures is much more volatile than that of relative prices of residential investment; it fluctuate seven more than that of relative prices of residential investment.

The relative price of residential investment is shown in right panel. It is interesting to note that in Spain there were two small booms before the 2000s: the price reached to 144.6 in 1979, and there was a minor surge in 1991, when the price rose to 139.80 prior to the peak in 2007, reaching the value 178.4. The coefficient of correlation between the two countries is 0.65 from 1970 to 1998, while from 1999 to 2015 the coefficient of correlation is strongly negative, - 0.85.

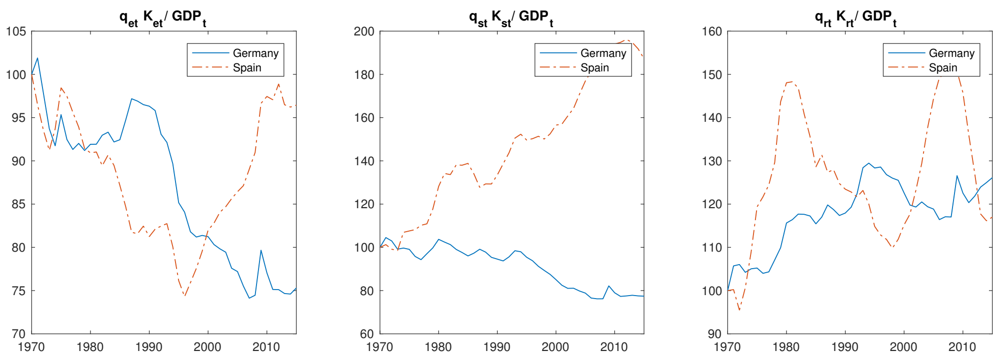


Figure 6: $q_{it}K_{it}/GDP_t$

The figure 6 shows the ratio of capital to GDP for each investment category for Spain and Germany. I have normalized them so that 1970 is the base year for both countries just as a counterfactual exercise to observe what would have happened if they had started at the same level. As we can see in the left panel, until 1999 Germany is more intensive in equipment than Spain. From 2000, Spain is more intensive in equipment capital than the German economy since the 2000s.

In the central panel, the ratio of business structures to GDP of Spain exhibit an increasing trend, while for Germany, the trend is slightly downward, though very stable.

The right panel in figure 6 shows the ratio of residential capital to GDP. It is very noticeable the volatility in the housing stock in Spain that exhibit two period of strong increase in the ratio of residential capital to GDP: the first one from 1973 to 1981, and from 2000 until 2009. As for business structures, the most striking feature of the data is the relative stability of the German of the ratio of residential capital to GDP.

8 Appendix B.1 VAR IDENTIFICATION

8.1 Identifying News Shocks - Barsky and Sims (2011) methodology

Let $\mathbf{y}_t$ be a $k \times 1$ vector of observables of length T. Let the reduced form moving average representation in the levels of the observables be given as

$$\mathbf{y}_t = \mathbf{B}(\mathbf{L})\mathbf{u}_t \tag{17}$$

where $B(L)$ is a $k \times k$ matrix polynomial in the lag operator, L, of moving average coefficients and u_t is the $k \times 1$ vector of reduced-form innovations. We assume there exists a linear mapping between innovations and structural shocks, ε_t, given as:

$$\mathbf{u}_t = \mathbf{A}_0 \varepsilon_t \tag{18}$$

This implies the following structural moving average representation:

$$\mathbf{y}_t = \mathbf{C}(\mathbf{L})\varepsilon_t \tag{19}$$

Where $\mathbf{C} = \mathbf{B}(\mathbf{L})\mathbf{A}_0$ and $\varepsilon_t = \mathbf{A}_0^{-1}\mathbf{u}_t$. The impact matrix must satisfy $\mathbf{A}_0\mathbf{A}_0^{'} = \mathbf{\Sigma}$, where $\mathbf{\Sigma}$ is the variance-covariance matrix of reduced-form innovations. There are, however, an infinite number of impact matrices that solve the system. In particular, for some arbitrary orthogonalization, $\tilde{A}$ (we choose the convenient Choleski decomposition), the entire space of permissible impact matrices can be written as $\tilde{A}D$, where D is a orthonormal matrix ($D' = D^{-1}$ and $DD' = I$, where I is the identity matrix).

The h step ahead forecast error is:

$$\mathbf{y}_{t+h} - E_{t-1}\mathbf{y}_{t+h} = \sum\nolimits_{\tau=0}^{h} \mathbf{B}_\tau \tilde{\mathbf{A}}_0 \mathbf{D} \varepsilon_{t+h-\tau} \tag{20}$$

where $B\tau$ is the matrix of moving average coefficients at horizon τ. The contribution to the forecasterror variance of variable i attributable to structural shock j at horizon h is then:

$$\Omega_{i,j}(h) = \frac{\mathbf{e}_i' \left(\sum_{\tau=0}^{h} \mathbf{B}_\tau \tilde{\mathbf{A}}_0 \mathbf{D} \mathbf{e}_j \mathbf{e}_j' \mathbf{D}' \tilde{\mathbf{A}}_0' \mathbf{B}_\tau{}' \right) \mathbf{e}_i}{\mathbf{e}_i' \left(\sum_{\tau=0}^{h} \mathbf{B}_\tau \mathbf{\Sigma} \mathbf{B}_\tau' \right) \mathbf{e}_i} \tag{21}$$

$$= \frac{\sum_{\tau=0}^{h} \mathbf{B}_{i,\tau} \tilde{\mathbf{A}}_0 \gamma \gamma' \tilde{\mathbf{A}}_0' \mathbf{B}_{i,\tau}'}{\sum_{\tau=0}^{h} \mathbf{B}_{i,\tau} \mathbf{\Sigma} \mathbf{B}_{i,\tau}'}$$

The $\mathbf{e}_i$ denote selection vectors with one in the ith place and zeros elsewhere. The selection vectors inside the parentheses in the numerator pick out the jth column of $\mathbf{D}$, which will be denoted by γ. $\tilde{\mathbf{A}}_0\gamma$ is $k \times 1$ is a vector corresponding to the jth column of a possible orthogonalization and has the interpretation as an impulse vector. The selection vectors outside the parentheses in both numerator and denominator pick out the ith row of the matrix of moving average coefficients, which is denoted by $\mathbf{B}_{i,\tau}$.

Let q_t^i occupy the first position in the system, and let the unanticipated shock be indexed by 1 and the news shock by 2. Our identifying assumption implies that these two shocks account for all variation of q_t^i at all horizons:

Eqs. (1) and (2), imply that these two shocks account for all variation in q_t^i

$$\Omega_{1,1}(h) + \Omega_{1,2}(h) = 1 \quad \forall h \tag{22}$$

It is general not possible to force this restriction to hold at all horizons. Instead, we propose picking parts of the impact matrix to come as close as possible to making this expression hold over a finite subset of horizons. With the surprise shock identified as the innovation in observed technology, $\Gamma_{1,1}(h)$ will be invariant at all h to alternative identifications of the other $k-1$ structural shocks. As such, choosing elements of A_0 to come as close as possible to making the above expression hold is equivalent to choosing the impact matrix to maximize contributions to $\Gamma_{1,2}(h)$ over h.

Since the contribution to the forecast error variance depends only on a single column of the impact matrix, this suggests choosing the second column of the impact matrix to solve the following optimization problem:

$$\gamma* = \arg\max \sum_{\mathbf{h=0}}^{\mathbf{H}} \Omega_{1,2}(h) = \frac{\sum_{\tau=0}^{h} \mathbf{B}_{i,\tau} \tilde{\mathbf{A}}_0 \gamma\gamma' \tilde{\mathbf{A}}_0' \mathbf{B}_{i,\tau}'}{\sum_{\tau=0}^{h} \mathbf{B}_{i,\tau} \mathbf{\Sigma} \mathbf{B}_{i,\tau}'} \tag{23}$$

s.t.

$$\tilde{\mathbf{A}}_0(1,j) = 0 \quad \forall j > 1$$

$$\gamma(1,1) = 0 \tag{24}$$

$$\gamma'\gamma = 1 \tag{25}$$

So as to ensure that the resulting identification belongs to the space of possible orthogonalizations of the reduced form, the problem is expressed in terms of choosing γ conditional on an arbitrary orthogonalization, $\tilde{A}_0$. H represents the finite truncation horizon[17]. The first two constraints impose that the news shock has no contemporaneous effect on the level of q_t^i. The third restriction (that γ have unit length) ensures that γ is a column vector belonging to an orthonormal matrix.

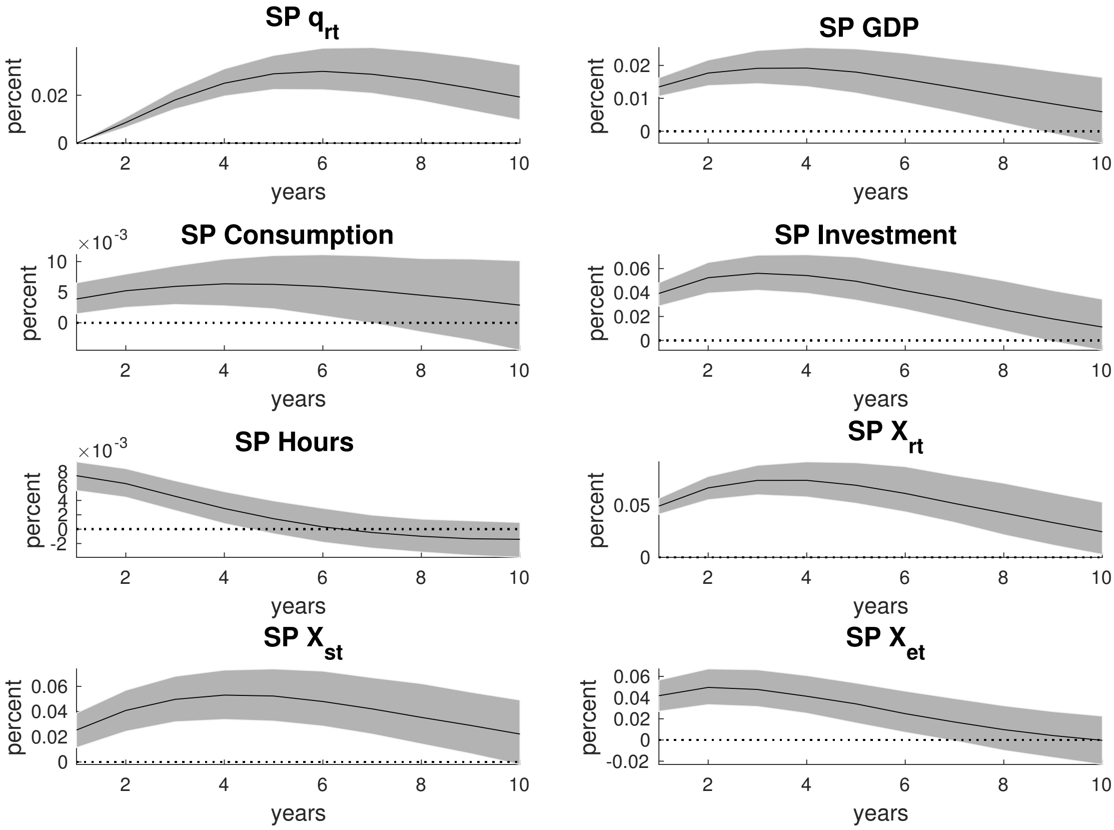
[17]The finite truncation horizon in this paper is 10 periods

9 Appendix B.2 VAR IDENTIFICATION

9.1 Benchmark Var

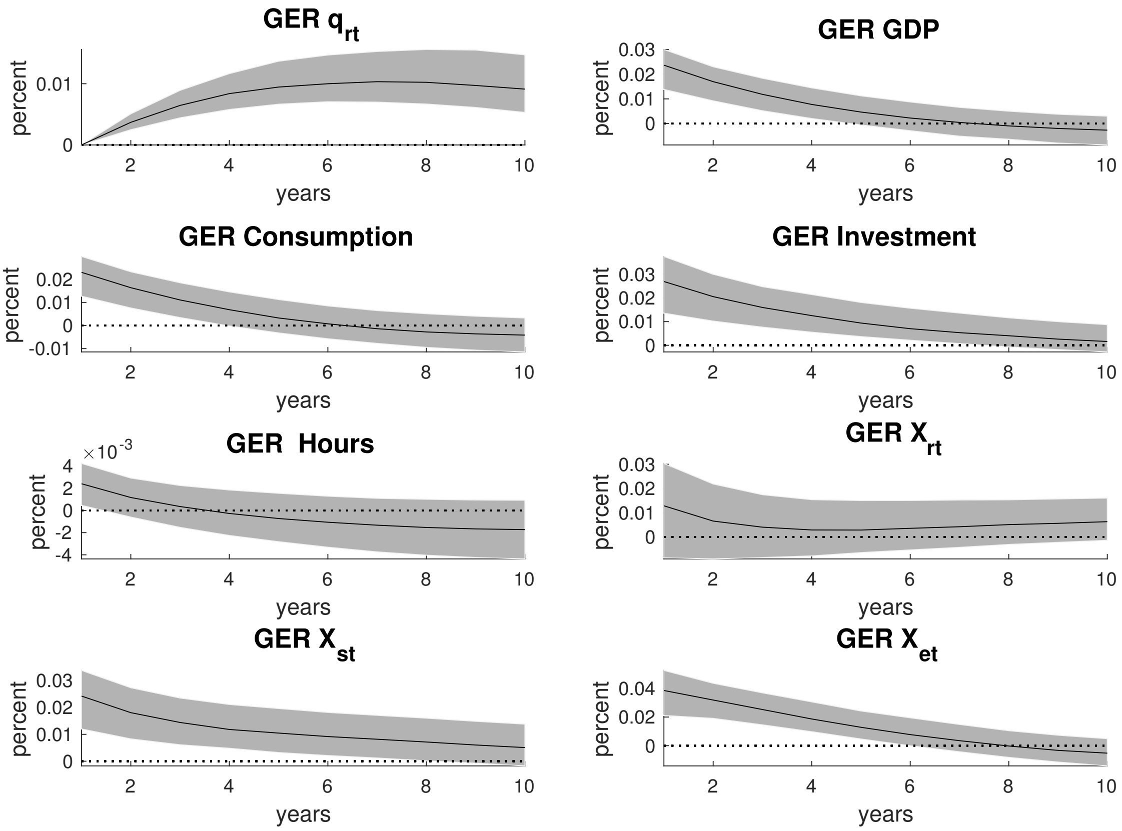
9.1.1 SPAIN - q_{rt} news shock

Figure 7: Impulse Response Functions: q_{rt} news shock



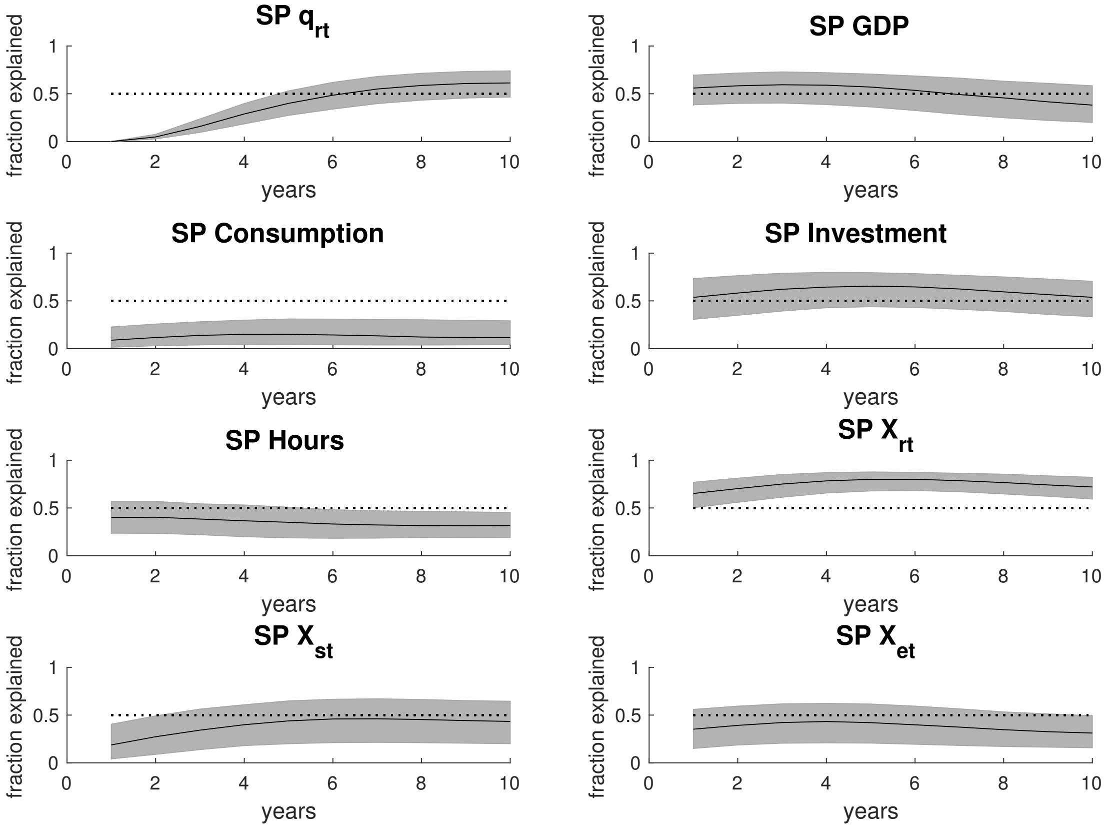
Notes: Median responses to a news shock on relative prices of residential investment (solid line). The shaded gray areas are the 16% and 84% posterior bands generated from the posterior distribution of VAR parameters. The units of the vertical axes are percentage deviations.

Figure 8: Impulse Response Functions: q_{rt} news shock



Notes: Median responses to a news shock on relative prices of residential investment (solid line). The shaded gray areas are the 16% and 84% posterior bands generated from the posterior distribution of VAR parameters. The units of the vertical axes are percentage deviations.

Figure 9: Forecast Error Decomposition: q_{rt} news shock

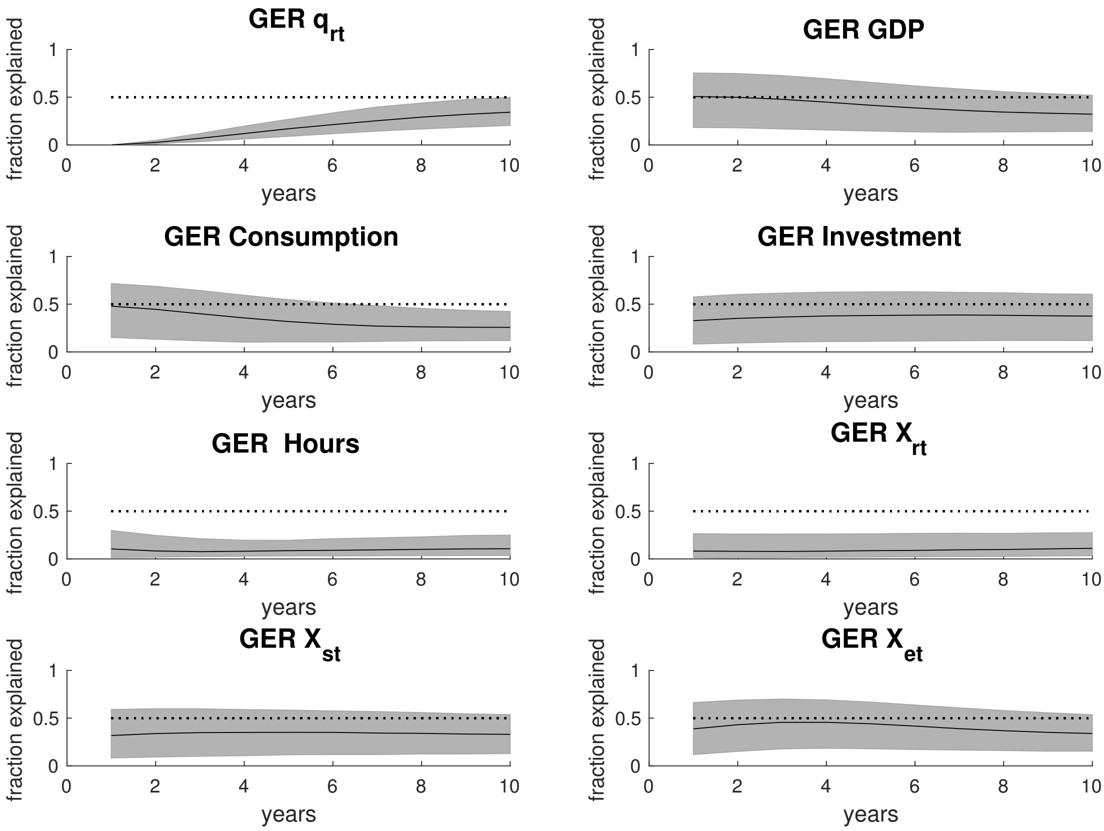


Notes: Median responses to a news shock on relative prices of residential investment (solid line). The shaded gray areas are the 16% and 84% posterior bands generated from the posterior distribution of VAR parameters. The units of the vertical axes are percentage deviations.

Spain	q_{rt}	GDP_t	C_t	I_t	Hours	X_r	X_s	X_e
Median contribution	0.61	0.59	0.15	0.65	0.40	0.80	0.46	0.43
Year	10	3	5	5	1	4	7	5

Table 4: SPAIN - Maximum Forecast Error Variance (FEV) - q_t^r news shock; benchmark VAR

Figure 10: Forecast Error Decomposition: q_{rt} news shock



Notes: Median responses to a news shock on relative prices of residential investment (solid line). The shaded gray areas are the 16% and 84% posterior bands generated from the posterior distribution of VAR parameters. The units of the vertical axes are percentage deviations.

Germany	q_{rt}	GDP_t	C_t	I_t	Hours	X_r	X_s	X_e
Median contribution	0.31	0.51	0.48	0.39	0.11	-	0.35	0.46
Year	10	2	1	9	10	3	4	10

Table 5: GERMANY - Maximum Forecast Error Variance (FEV) - q_t^r news shock; benchmark VAR -

10 Appendix B.3 VAR IDENTIFICATION

10.1 Alternative VAR

10.1.1 SPAIN - q_{rt} news shock

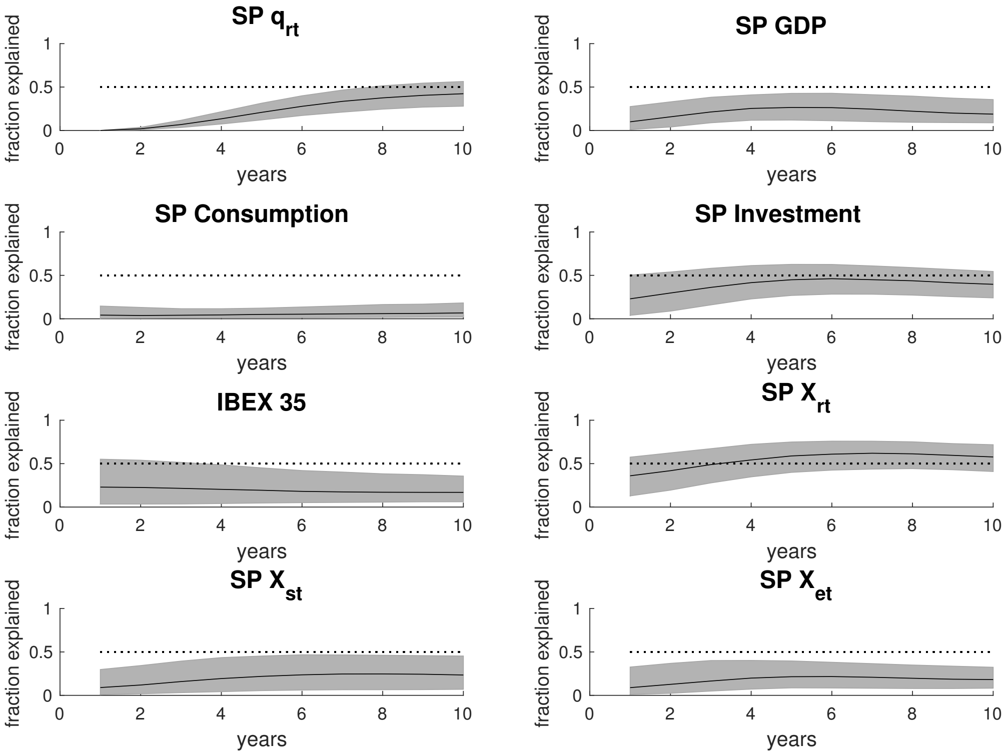


Figure 11: SPAIN - Forecast Error Variance (FEV) - q_{rt} news shock - alternative VAR

Spain	q_{rt}	GDP_t	C_t	I_t	IBEX 35	X_e	X_s	X_r
Median contribution	0.41	0.27	0.06	0.46	0.21	0.22	0.23	0.62
Year	10	5	10	5	1	5	7	6

Table 6: SPAIN - Maximum Forecast Error Variance (FEV) - q_{rt} news shock; alternative VAR

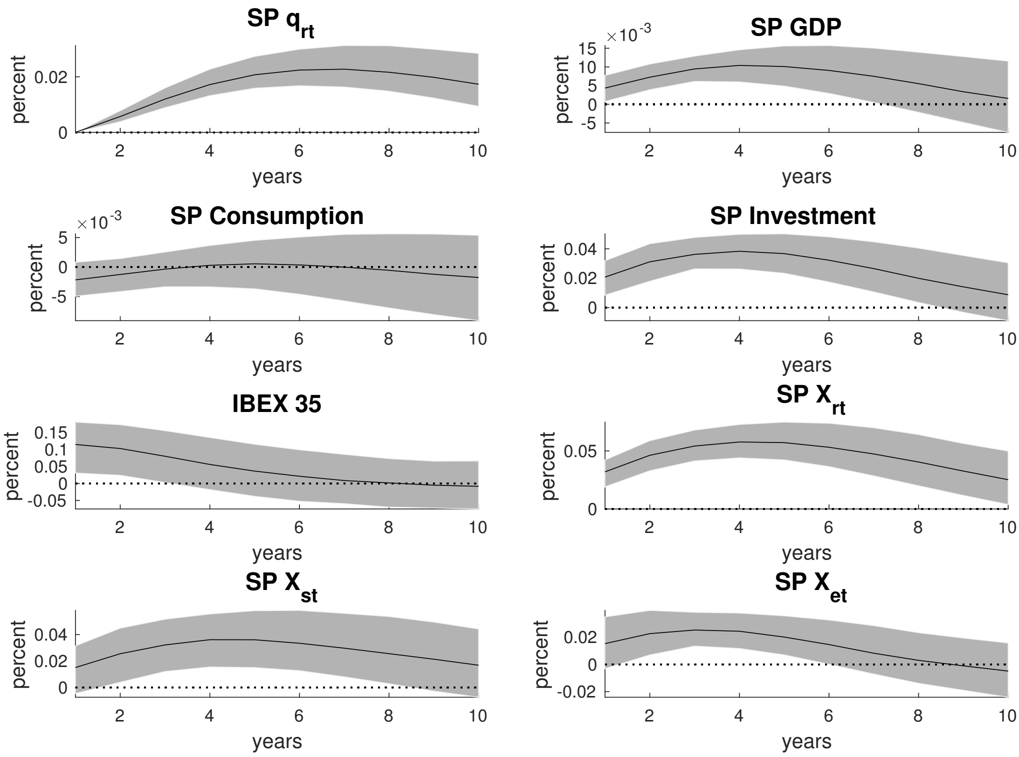


Figure 12: SPAIN - Impulse responses to a 1% innovation in the q_{rt} news shock - alternative VAR

10.1.2 Germany

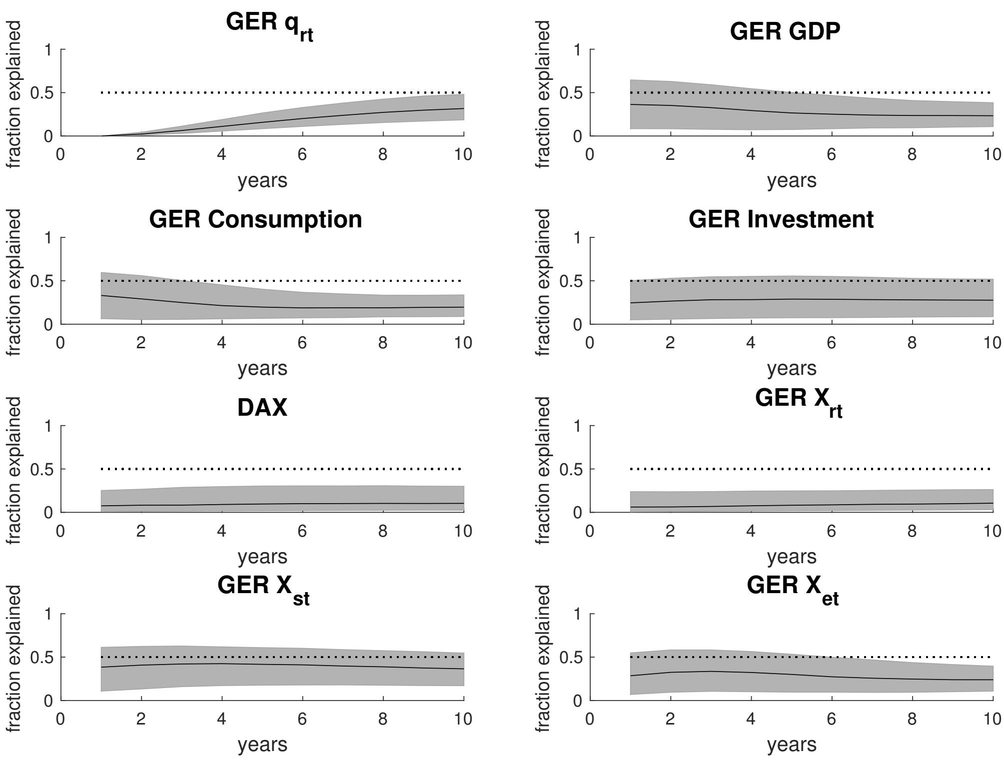


Figure 13: GERMANY - Forecast Error Variance (FEV) - q_{rt} news shock; alternative VAR

Germany	q_{rt}	GDP_t	C_t	I_t	DAX	X_e	X_s	X_r
Median contribution	0.32	0.38	0.41	0.20	0.11	0.19	0.41	0.12
Year	10	1	1	6	10	4	5	10

Table 7: GERMANY - Maximum Forecast Error Variance (FEV) - q_{rt} news shock; alternative VAR

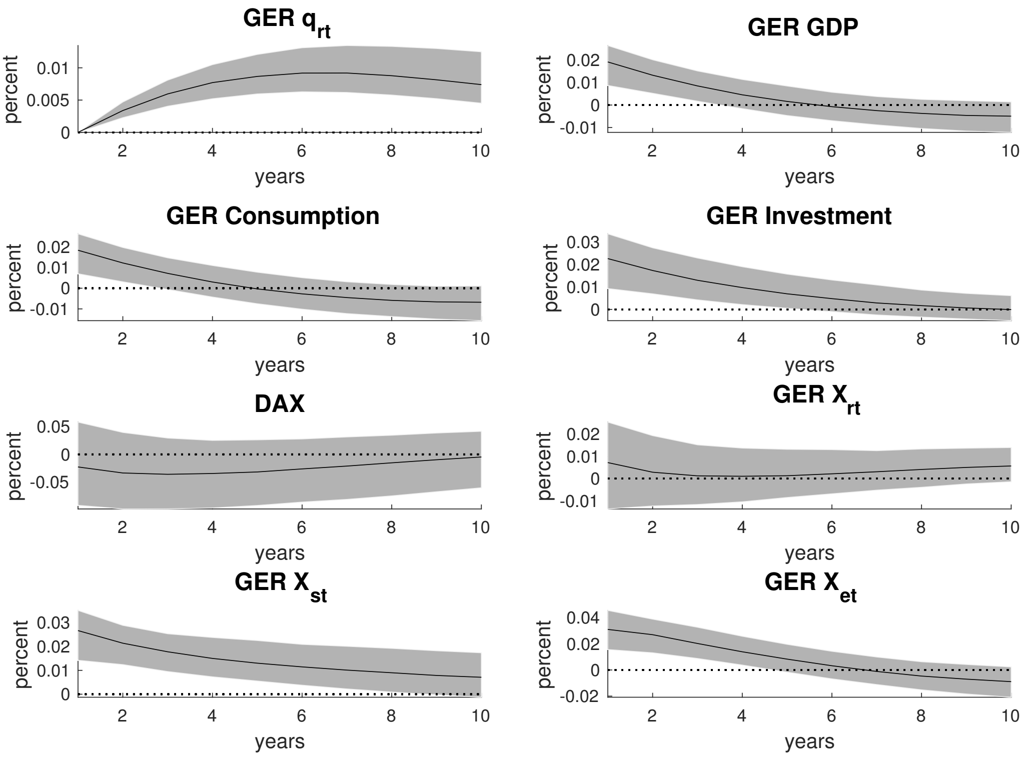


Figure 14: GERMANY - Impulse responses to a 1% innovation in the q_{rt} news shock; alternative VAR

10.2 q_{st} news shocks - benchmark var

10.2.1 Spain

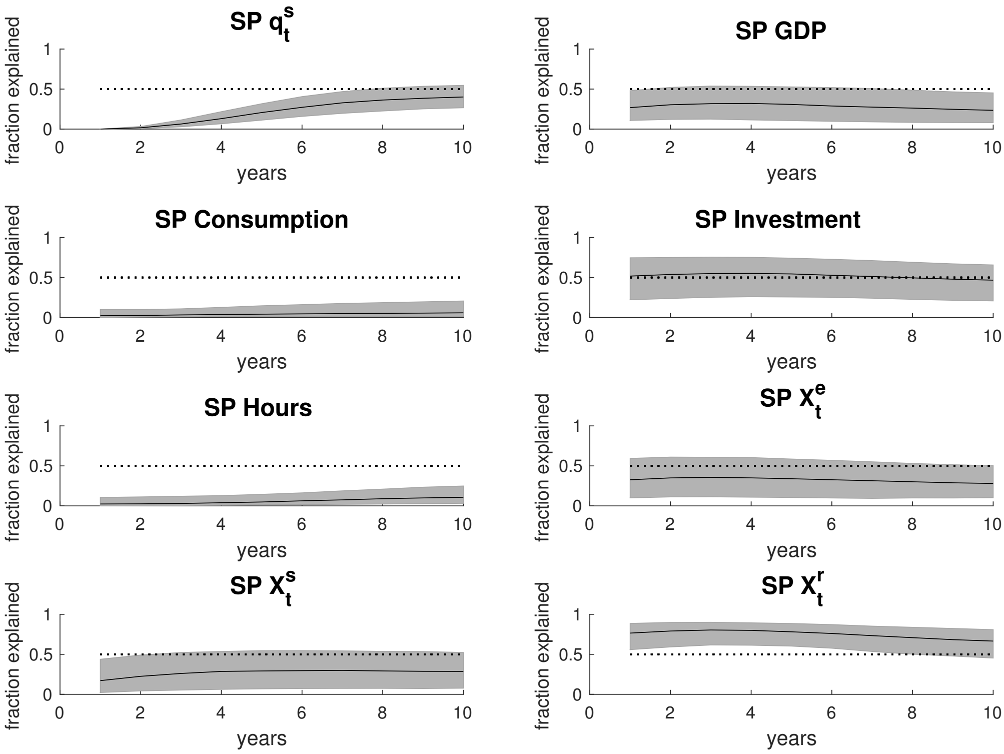


Figure 15: SPAIN - Forecast Error Variance (FEV) - q_{st} news shock; benchmark VAR

Spain	q_{st}	GDP	Consumption	Investment	Hours	X_e	X_s	X_r
Median contribution	0.40	0.32	0.06	0.55	0.11	0.36	0.30	0.80
Year	10	4	10	4	10	3	7	3

Table 8: SPAIN - Maximum Forecast Error Variance (FEV) - q_{st} news shock benchmark VAR

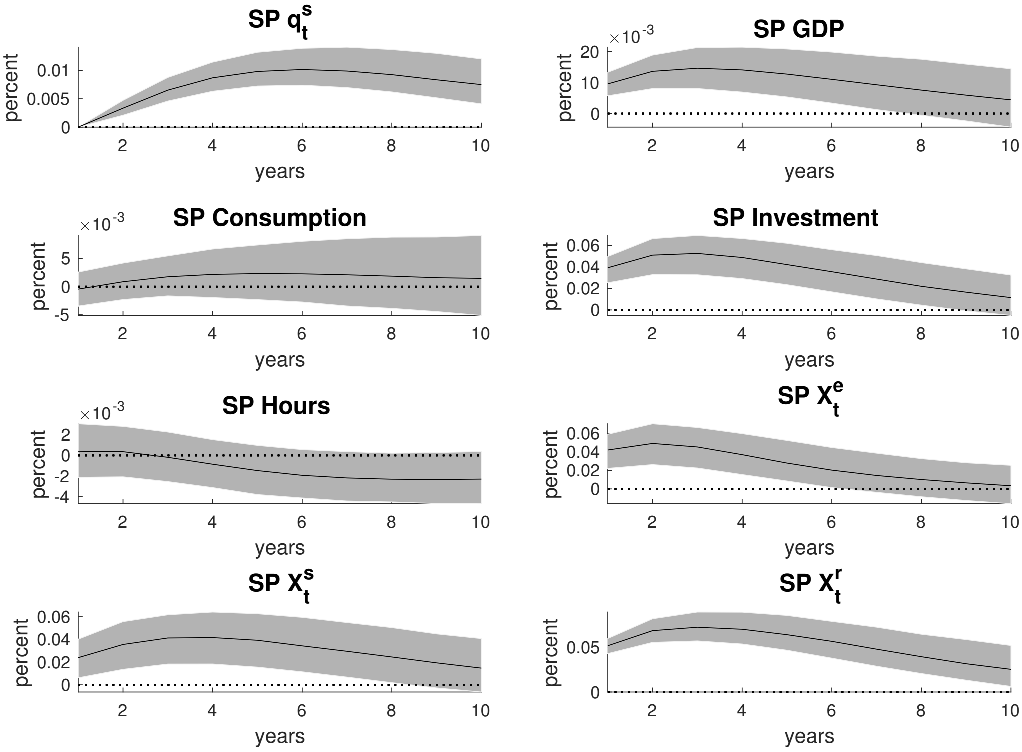


Figure 16: SPAIN - Impulse responses to a 1% innovation in the q_{st} news shock; benchmark VAR

10.2.2 Germany

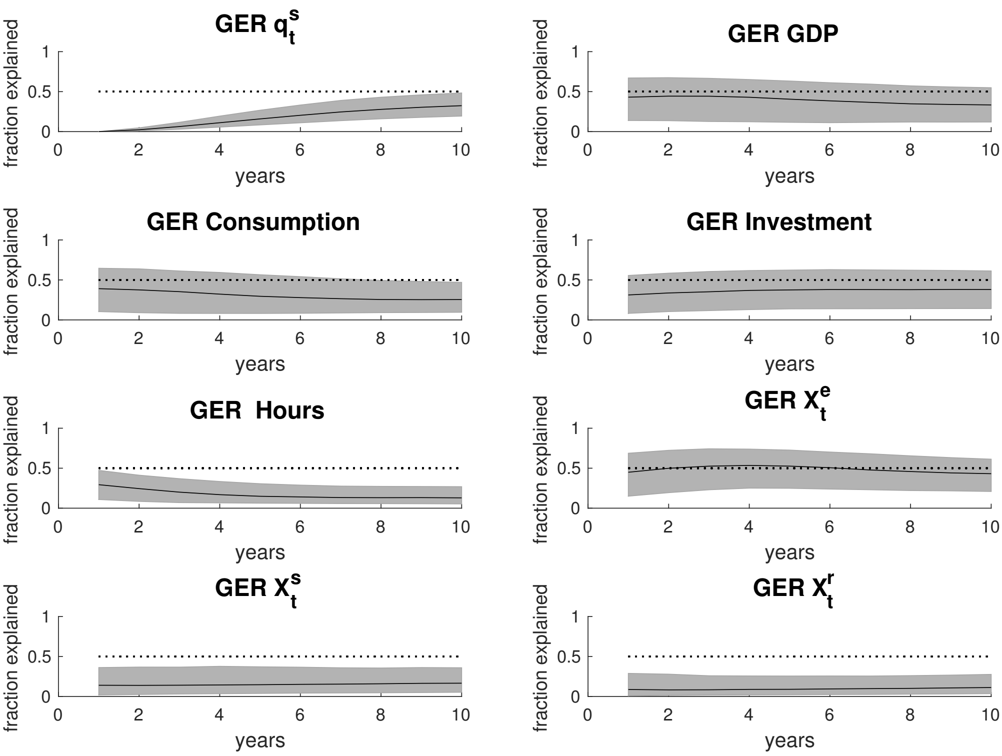


Figure 17: GERMANY - Forecast Error Variance (FEV) - q_{st} news shock; benchmark VAR

Germany	q_{st}	GDP	Consumption	Investment	Hours	X_e	X_s	X_r
Median contribution	0.32	0.44	0.39	0.38	0.29	0.53	0.17	0.11
Year	10	2	1	9	1	4	10	10

Table 9: GERMANY - Maximum Forecast Error Variance (FEV) - q_{st} news shock; benchmark VAR

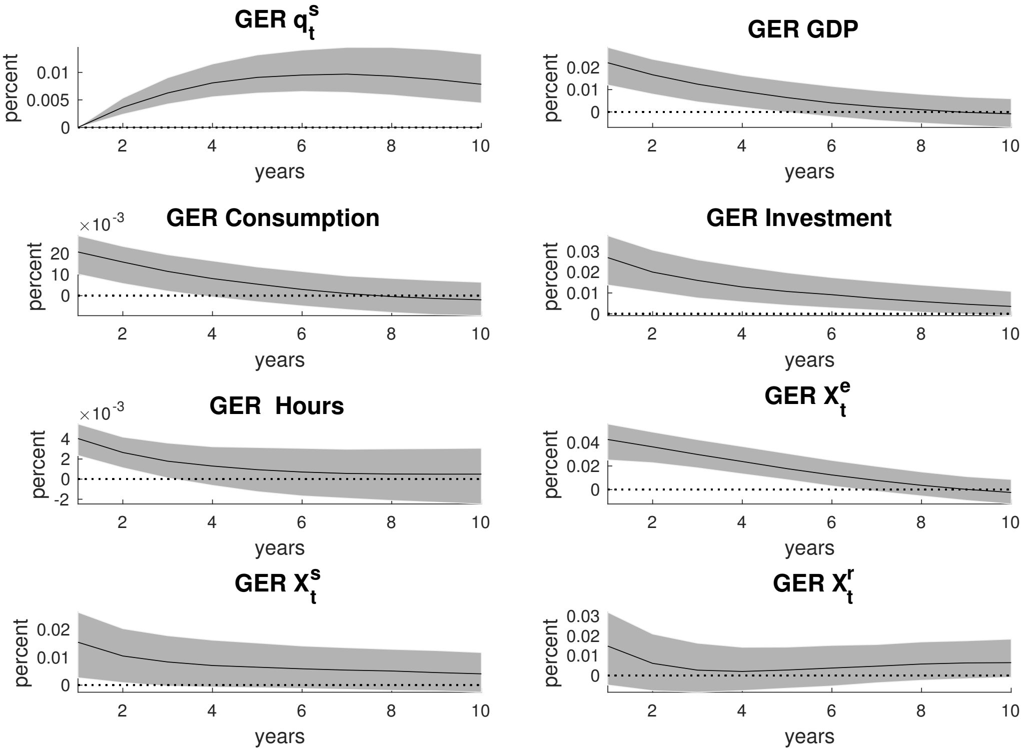


Figure 18: GERMANY - Impulse responses to a 1% innovation in the ISTC news shock - q_{st} news shock; benchmark VAR

10.3 Alternative VAR - q_{st} news shock

10.3.1 Spain

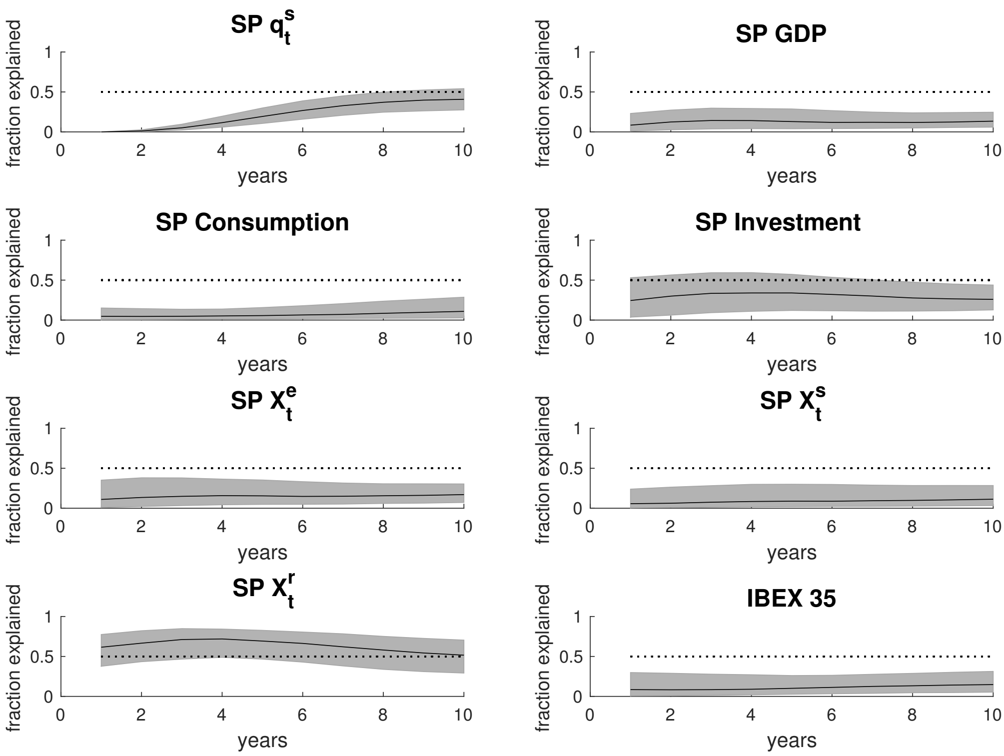


Figure 19: SPAIN - Forecast Error Variance (FEV) - q_{st} news shock - alternative VAR

Spain	q_{st}	GDP	Consumption	Investment	X_e	X_s	X_r	IBEX 35
Median contribution	0.41	0.14	0.11	0.34	0.17	0.11	0.72	0.15
Year	10	3	10	5	10	10	4	10

Table 10: SPAIN - Maximum Forecast Error Variance (FEV) - q_{st} news shock; alternative VAR

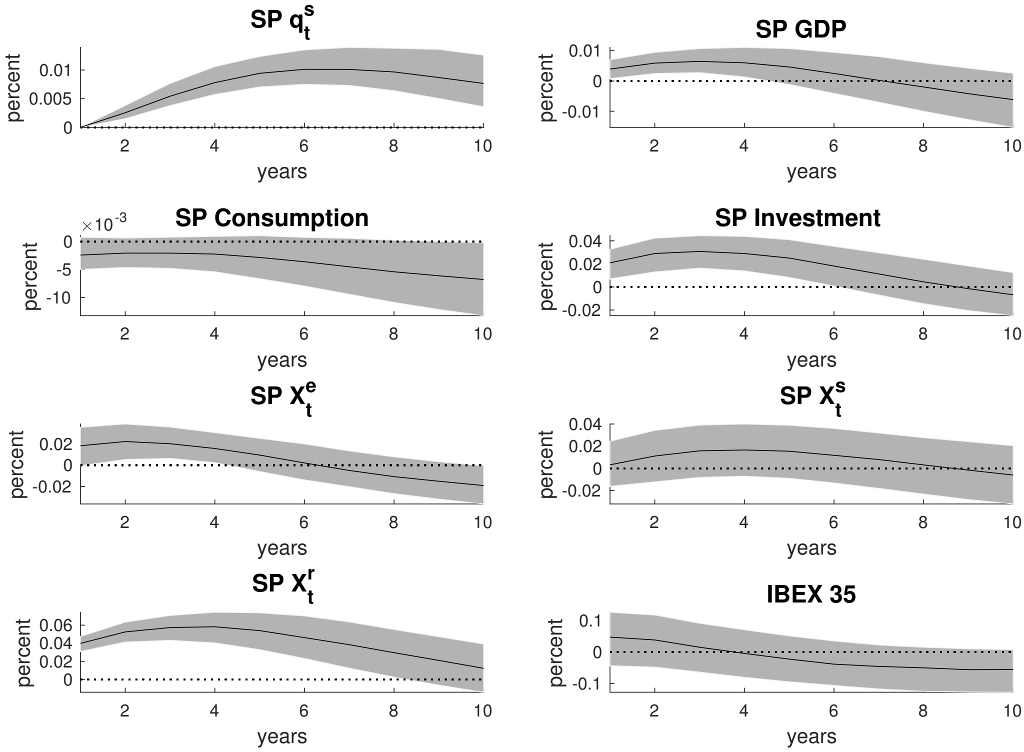


Figure 20: SPAIN - Impulse responses to a 1% innovation in the q_{st} news shock; alternative VAR

10.3.2 Germany

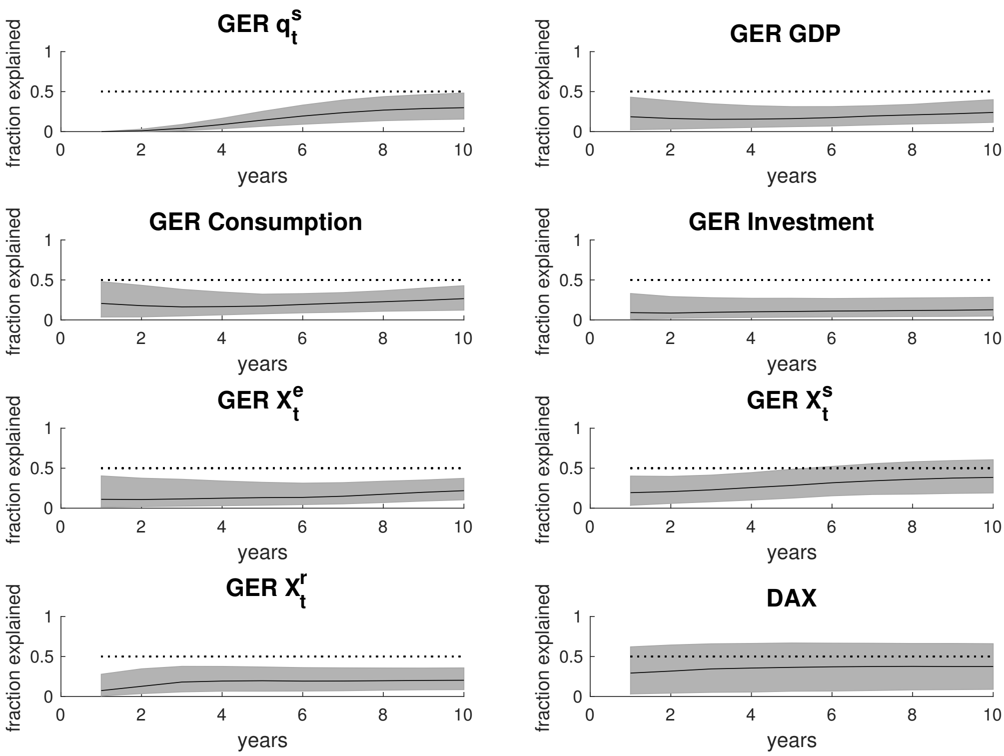


Figure 21: GERMANY - Forecast Error Variance (FEV) - q_{st} news shock; alternative VAR

Germany	q_{st}	GDP	Consumption	Investment	X_e	X_s	X_r	DAX
Median contribution	0.30	0.24	0.27	0.13	0.22	0.38	0.20	0.38
Year	10	10	10	10	10	10	10	8

Table 11: GERMANY - Maximum Forecast Error Variance (FEV) - q_{st} news shock; alternative VAR

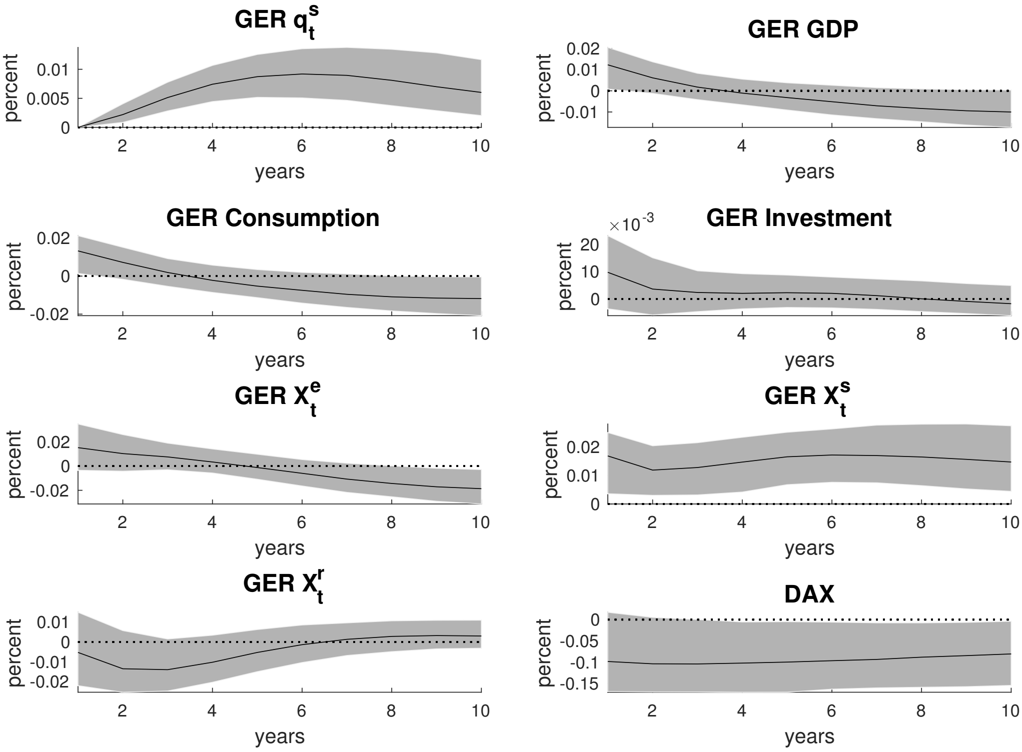


Figure 22: GERMANY - Impulse responses to a 1% innovation in the q_{st} news shock - alternative VAR

10.4 q_{et} news shocks - benchmark var

10.4.1 Spain

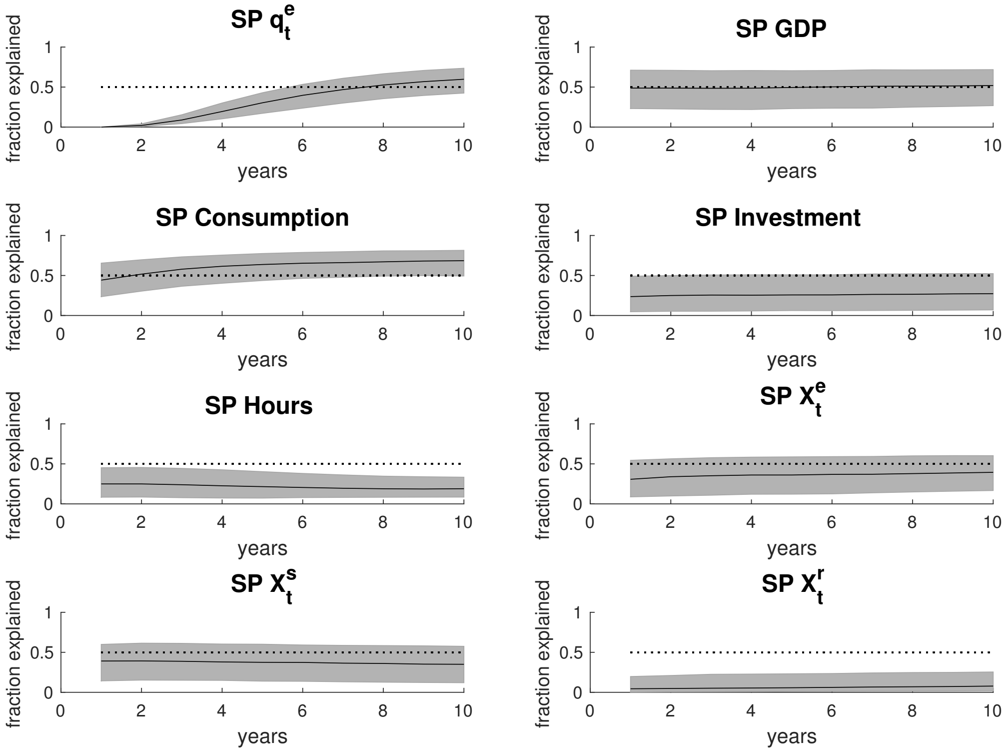


Figure 23: SPAIN - Forecast Error Variance (FEV) - q_{et} news shock; benchmark VAR

Spain	q_{et}	GDP	Consumption	Investment	Hours	X_e	X_s	X_r
Median contribution	0.60	0.52	0.68	0.27	0.25	0.39	0.39	0.08
Year	10	10	10	10	1	10	2	10

Table 12: SPAIN - Maximum Forecast Error Variance (FEV) - q_{et} news shocks; benchmark VAR

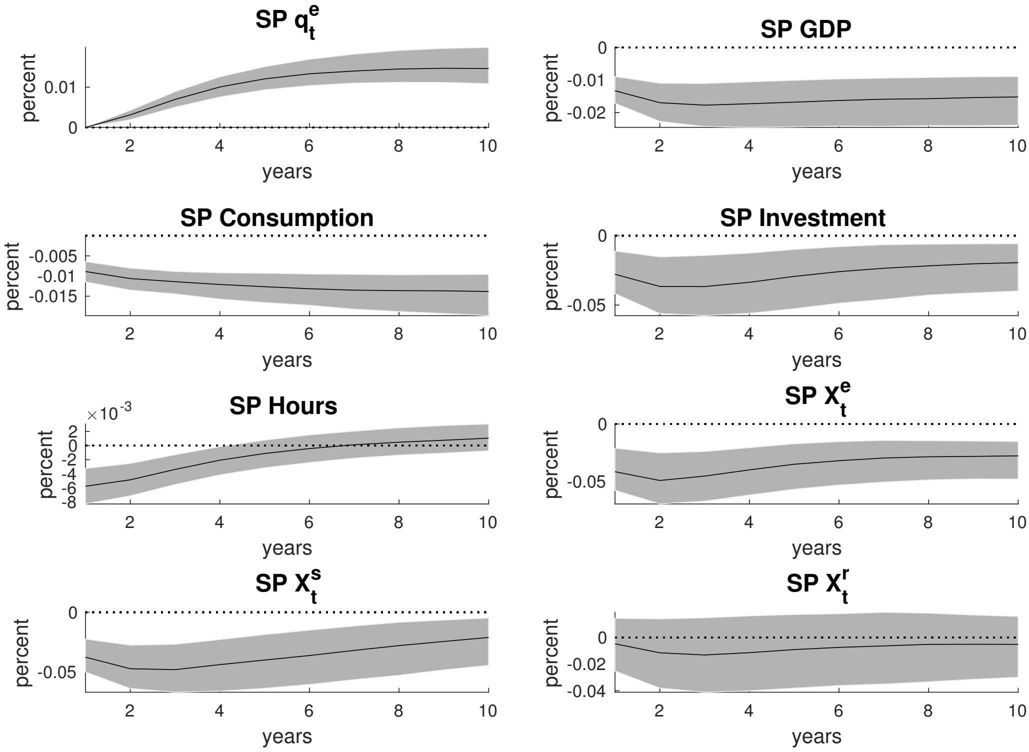


Figure 24: SPAIN - Impulse responses to a 1% innovation in the q_{et} news shock; benchmark VAR

10.4.2 Germany

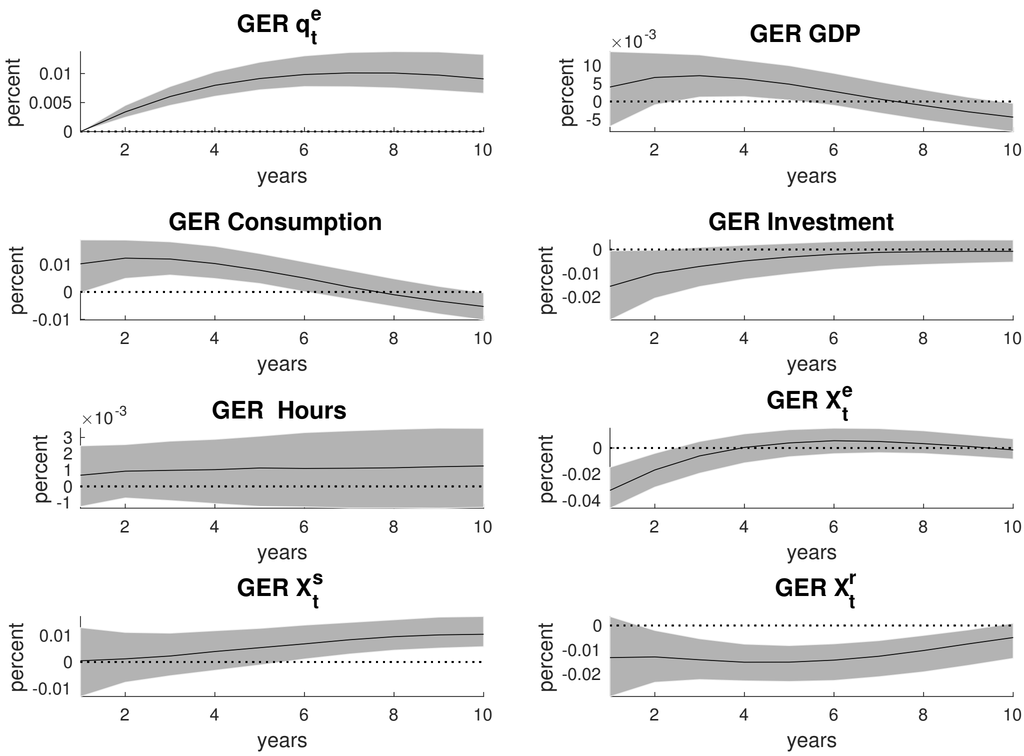


Figure 25: GERMANY - Forecast Error Variance (FEV) - q_{et} news shock; benchmark VAR

Germany	q_{et}	GDP	Consumption	Investment	Hours	X_e	X_s	X_r
Median contribution	0.59	0.14	0.24	0.16	0.09	0.27	0.18	0.26
Year	10	10	5	10	10	1	10	9

Table 13: GERMANY - Maximum Forecast Error Variance (FEV) - q_{et} news shock; benchmark VAR

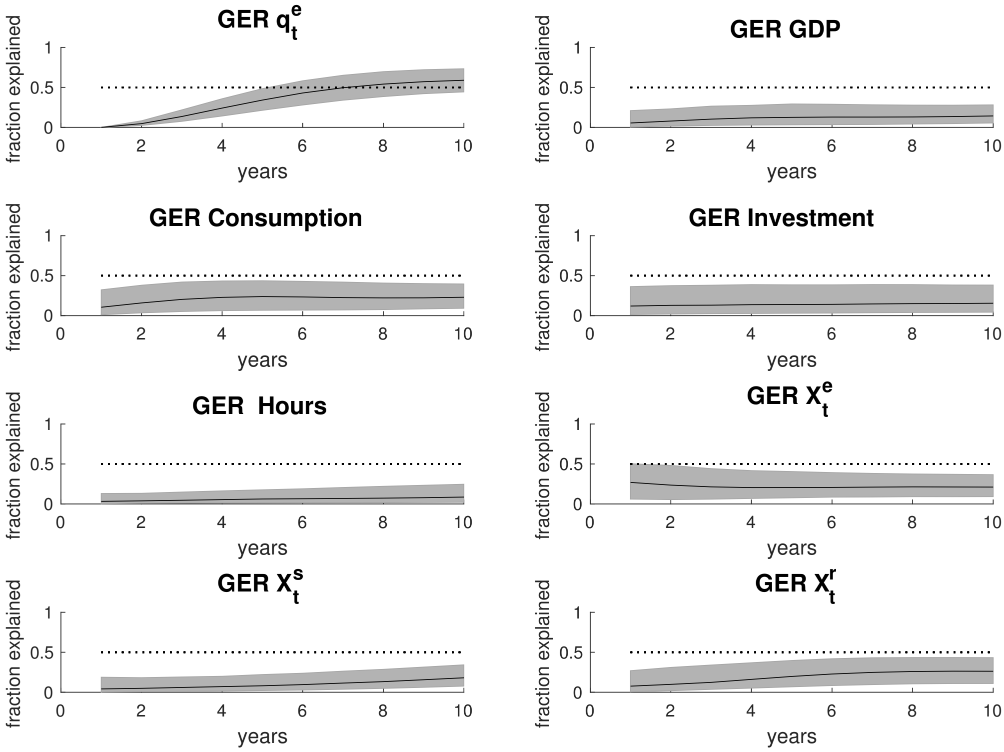


Figure 26: GERMANY - Impulse responses to a 1% innovation in the ISTC news shock - q_{et} news shock; benchmark VAR

10.5 q_{et} news shock - alternative VAR

10.5.1 Spain

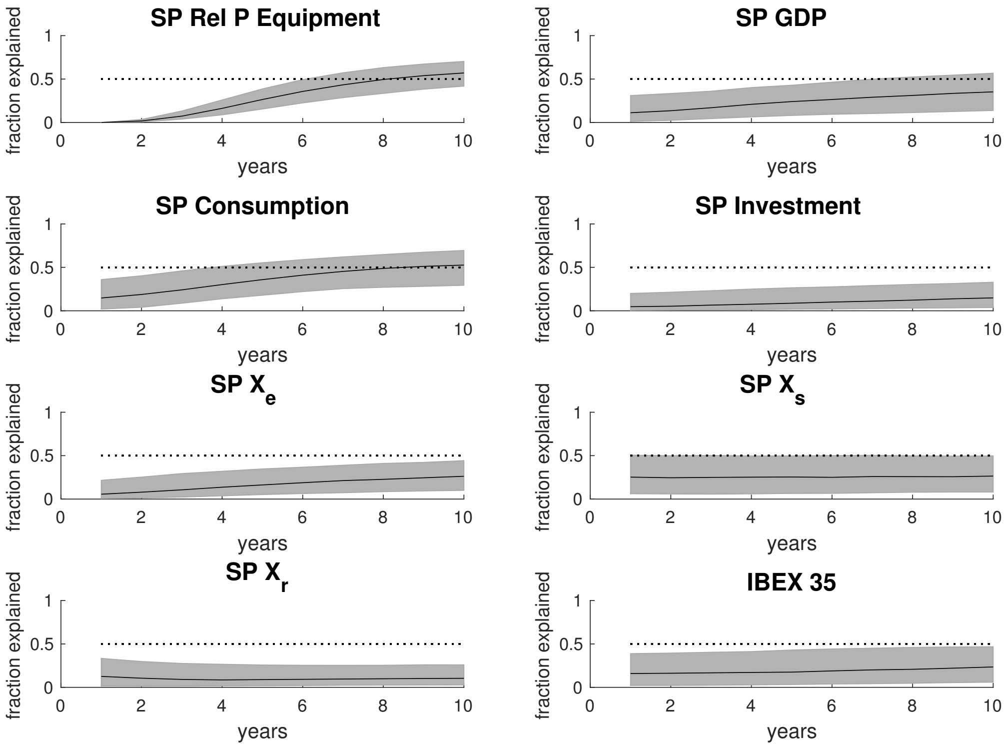


Figure 27: SPAIN - Forecast Error Variance (FEV) - q_{et} news shock - alternative VAR

Spain	q_{et}	GDP	Consumption	Investment	X_e	X_s	X_r	IBEX 35
Median contribution	0.67	0.32	0.57	0.11	0.24	0.26	0.27	0.32
Year	10	10	10	10	10	1	1	10

Table 14: SPAIN - Maximum Forecast Error Variance (FEV) - q_{et} news shock; alternative VAR

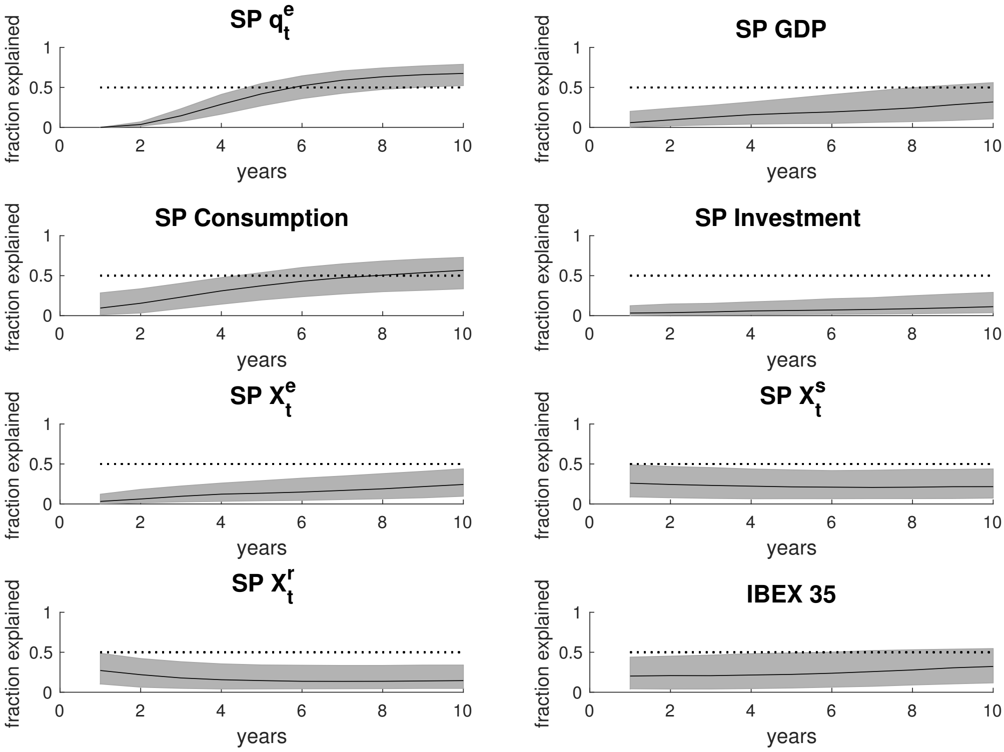


Figure 28: SPAIN - Impulse responses to a 1% innovation in the q_{et} news shock; alternative VAR

10.5.2 Germany

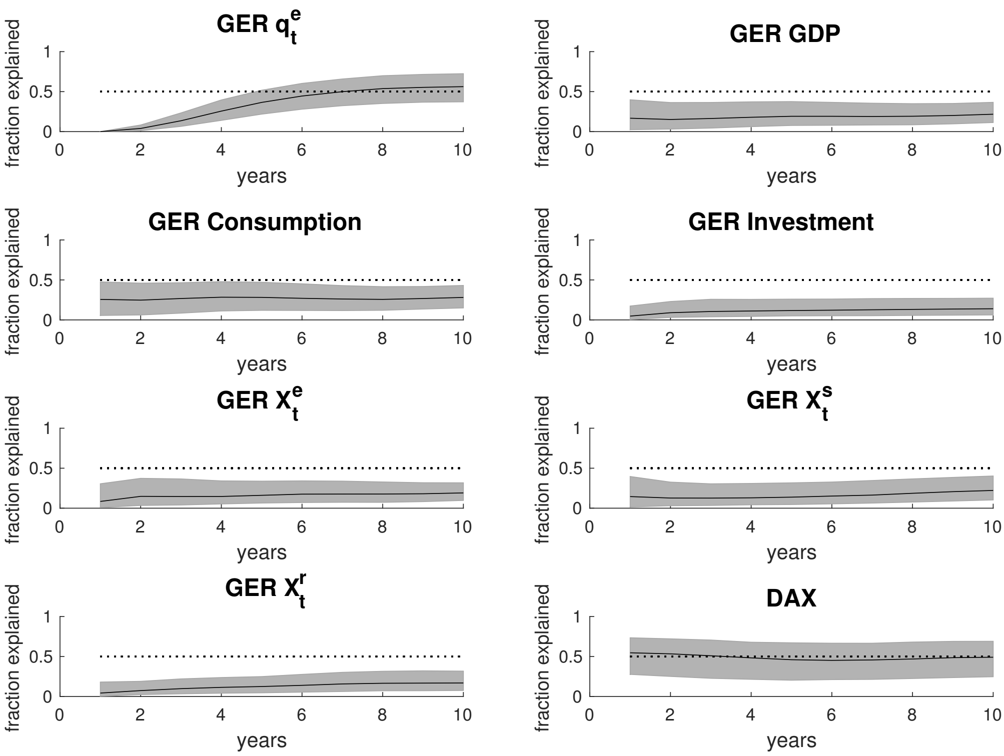


Figure 29: GERMANY - Forecast Error Variance (FEV) - q_{et} news shock; alternative VAR

Germany	q_{et}	GDP	Consumption	Investment	X_e	X_s	X_r	DAX
Median contribution	0.56	0.22	0.28	0.14	0.19	0.22	0.17	0.55
Year	10	10	4	10	10	10	10	1

Table 15: GERMANY - Maximum Forecast Error Variance (FEV) - q_{et} news shock; alternative VAR

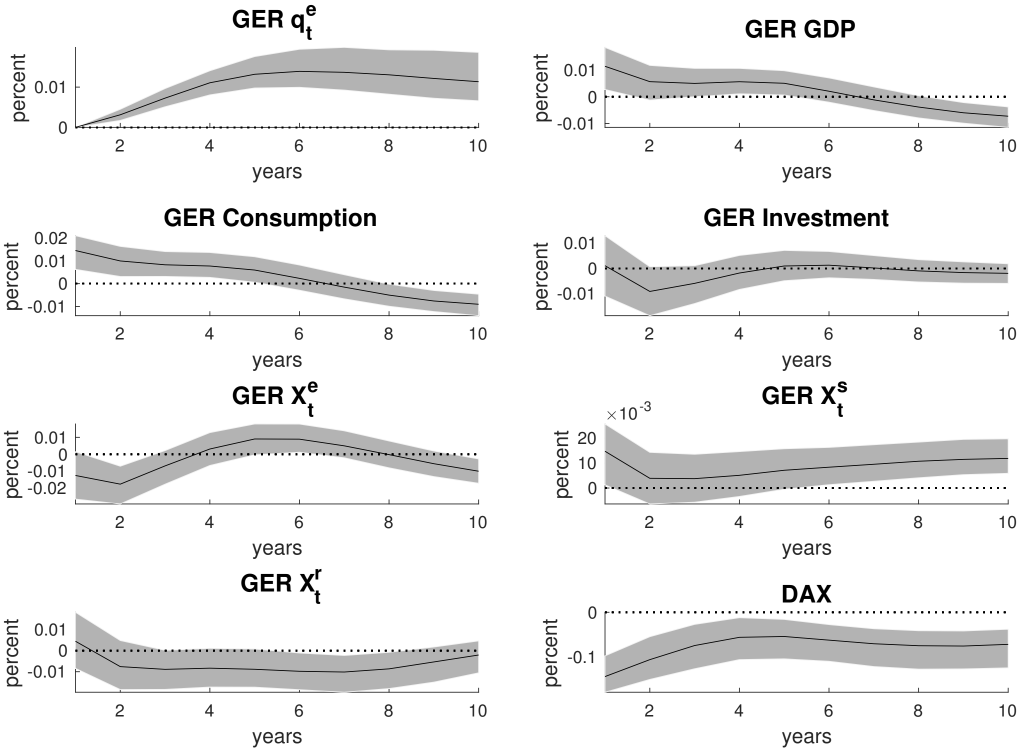


Figure 30: GERMANY - Impulse responses to a 1% innovation in the q_{et} news shock; alternative VAR

11 Appendix C. THEORETICAL MODEL

11.0.1 q_{rt}, News Shock

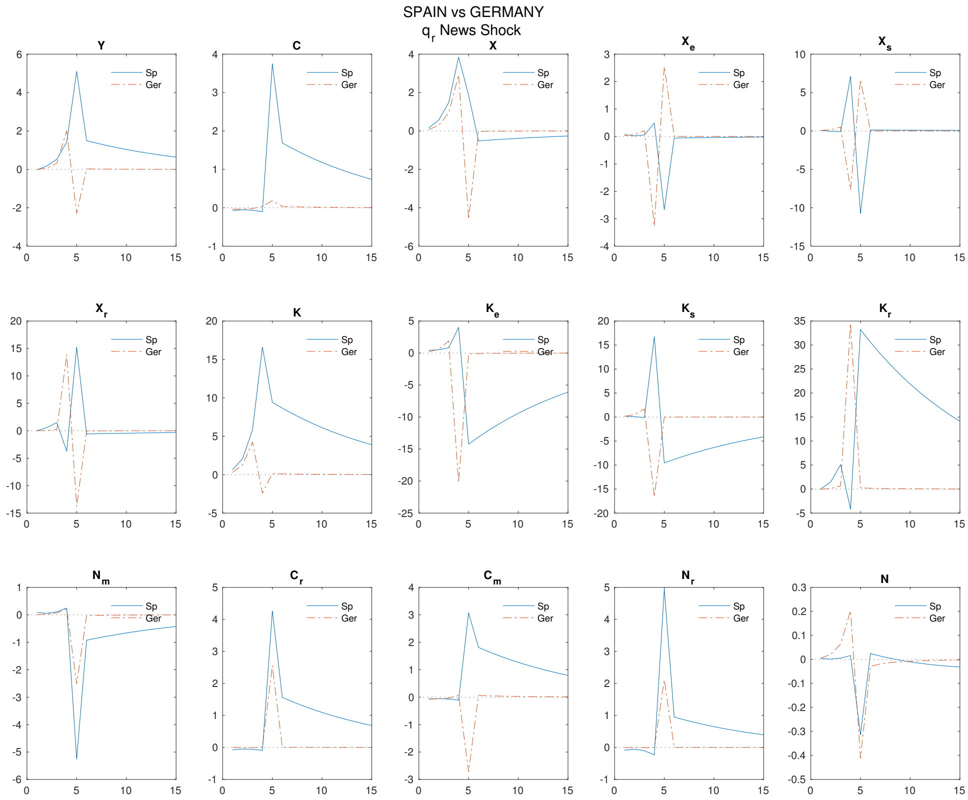


Figure 31: q_{rt} news shock effects on all model's variables

Figure 31 shows the overall IRFs of model's variables following a news shock on the relative prices of residential investment increases of 1%.

11.0.2 q_{st}, News Shock - all var

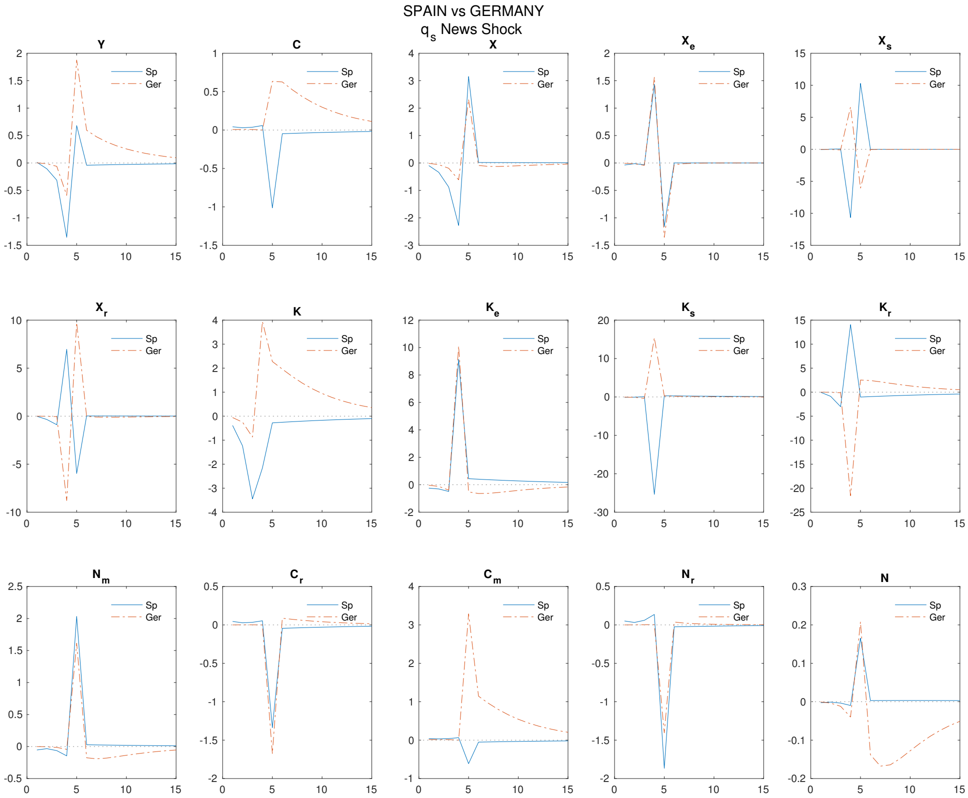


Figure 32: q_{st} news shock effects on all model's variables

Figure 32 shows the overall IRFs of model's variables following a news shock on the relative prices of business structures increases of 1%.

11.0.3 q_{et}, News Shock - all var

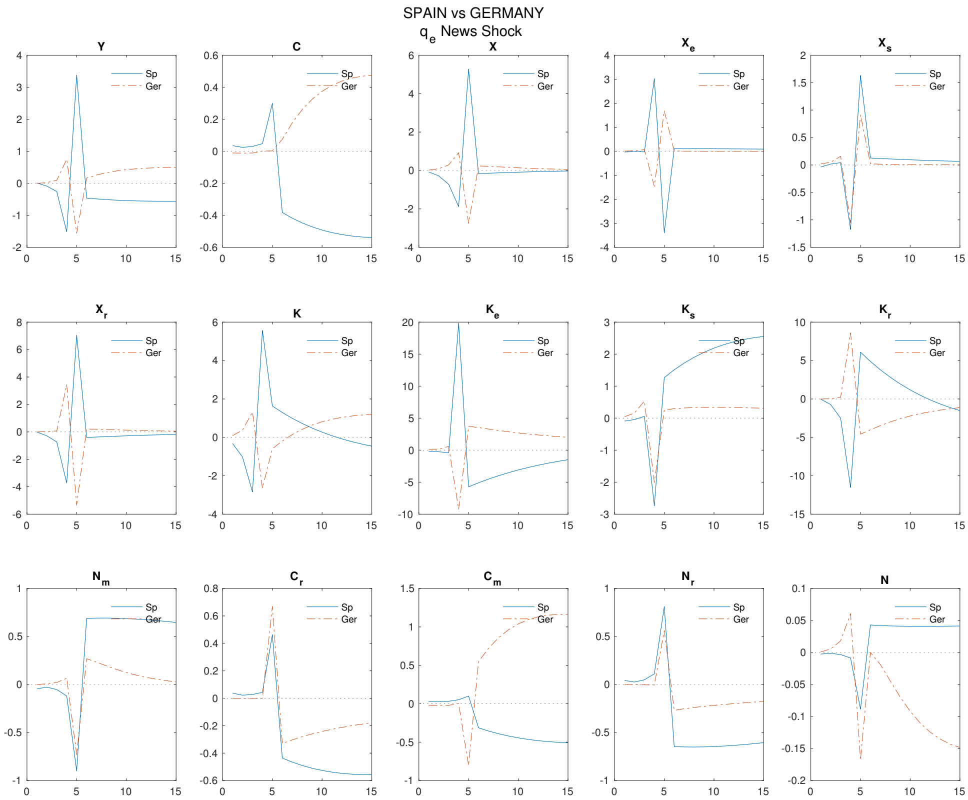


Figure 33: q_{et} news shock effects on all model's variables

Figure 33 shows the overall IRFs of model's variables following a news shock on the relative prices of equipment investment decreases of 1%.

11.0.4 A_t news shock

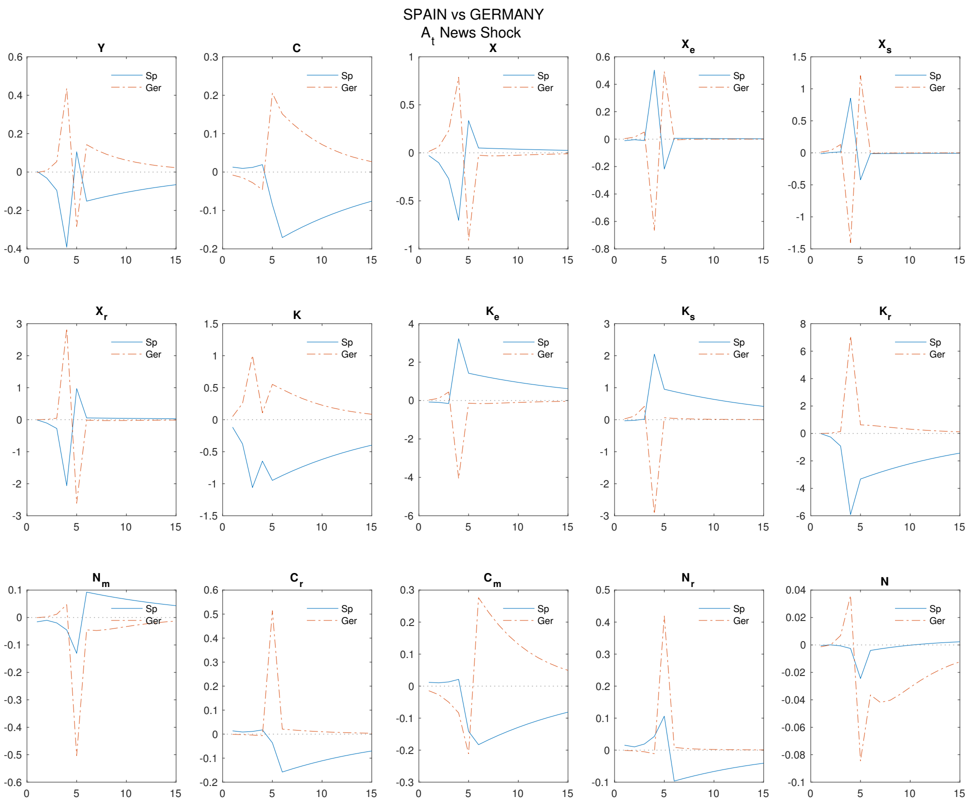


Figure 34: A_t News Shock

Figure 34 shows the IRFs model variables following a news shock on the home production TFP of a magnitude of 1%

12 APPENDIX D

The model uses the class of preferences proposed by Jaimovich and Rebello (AER, 2009) that have the ability to parameterize the strength of the short-run wealth effect on the labor supply. These preferences nest the two classes of utility functions: those characterized in Robert G. King, Charles Plosser, and Sergio Rebelo (1988) - (when parameter $\gamma = 1$) - and in Jeremy Greenwood, Zvi Hercowitz, and Gregory Huffman (1988) ($\gamma = 0$)

Characteristics:

- Introduce a weak short-run wealth effect on the labor supply.
- It helps to generate a rise in hours worked in response to positive news.

$$U(C_t, N_t, \chi_t) = \frac{\left(C_t - \psi N_t^{\theta} \chi_t\right)^{1-\sigma} - 1}{1-\sigma} \tag{26}$$

where

$$\chi_t = C_t^{\gamma} \chi_{t-1}^{1-\gamma} \tag{27}$$

The presence of χ_t makes preferences non-time-separable in consumption and hours worked.

$$N_t = N_{m,t} + N_{r,t} \tag{28}$$

I introduce the home production

$$C_t = (\omega C_{m,t}^{\eta} + (1-\omega) C_{r,t}^{\eta})^{1/\eta} \tag{29}$$

$C_{m,t}$ is market consumption

$$C_{r,t} = A_{r,t} K_{r,t}^{1-\theta_h} N_{r,t}^{\theta_r} \tag{30}$$

is home production.

Utility function:

$$U(C_{m,t}, C_{r,t}, N_{m,t}, N_{r,t}, \chi_t) = \frac{\left(\left(\omega C_{m,t}^{\eta} + (1-\omega) C_{r,t}^{\eta}\right)^{1/\eta} - \psi (N_{m,t} + N_{r,t})^{\theta_n} \chi_t\right)^{1-\sigma} - 1}{1-\sigma} \tag{31}$$

the household budget constraint is

$$\begin{aligned}
& C_{mt} + q_{e,t}K_{e,t+1} + q_{s,t}K_{s,t+1} + q_{r,t}K_{r,t+1} \\
= & W_tN_{m,t} + r_{e,t}K_{e,t} + r_{s,t}K_{s,t} + q_{e,t}(1-\delta_e)K_{e,t} + q_{s,t}(1-\delta_s)K_{s,t} + q_{r,t}(1-\delta_r)K_{r,t}
\end{aligned} \tag{32}$$

$$\max_{C_t,N_t,\chi_t} \sum_{t=0}^{\infty} \beta^t U\Big(U(C_{m,t}, C_{r,t}, N_{m,t}, N_{r,t}, \chi_t)\Big) \tag{33}$$

s. t.

$$\begin{aligned}
& C_{mt} + q_{e,t}K_{e,t+1} + q_{s,t}K_{s,t+1} + q_{r,t}K_{r,t+1} \\
= & W_tN_{m,t} + r_{e,t}K_{e,t} + r_{s,t}K_{s,t} + q_{e,t}(1-\delta_e)K_{e,t} + q_{s,t}(1-\delta_s)K_{s,t} + q_{r,t}(1-\delta_h)K_{r,t}
\end{aligned}$$

$$\begin{aligned}
&\chi_t = C_t^{\gamma}\chi_{t-1}^{1-\gamma}, \\
&C_t = \Big(\omega C_{m,t}^{\eta} + (1-\omega)C_{r,t}^{\eta}\Big)^{1/\eta}, \\
&C_{rt} = A_t K_{r,t}^{1-\theta_r} N_{r,t}^{\theta_r},
\end{aligned}$$

$$\begin{aligned}
&Y_t = Z_t K_{e,t}^{\alpha_e} K_{s,t}^{\alpha_s} N_{m,t}^{1-\alpha_e-\alpha_s}, \\
&Y_t = C_t + q_{e,t}X_{e,t} + q_{s,t}X_{s,t} + q_{r,t}X_{r,t}, \\
&X_t = X_{e,t} + X_{s,t} + X_{r,t},
\end{aligned}$$

$$\begin{aligned}
&K_{e,t+1} = \Theta_{e,t}X_{e,t} + (1-\delta_e)K_{e,t}, \\
&K_{s,t+1} = \Theta_{s,t}X_{s,t} + (1-\delta_s)K_{s,t}, \\
&K_{r,t+1} = \Theta_{r,t}X_{r,t} + (1-\delta_r)K_{r,t},
\end{aligned}$$

$$\begin{aligned}
&q_{e,t} = 1/\Theta_{e,t} \\
&q_{s,t} = 1/\Theta_{s,t} \\
&q_{h,t} = 1/\Theta_{h,t}
\end{aligned}$$

$$\begin{aligned}
&ln\ Z_t = (1-\rho_Z)ln\bar{Z} + \rho_Z ln\ Z_{t-1} + \varepsilon_t^Z, \\
&ln\ A_t = (1-\rho_A)ln\bar{A} + \rho_A ln\ A_{t-1} + \varepsilon_t^A, \\
&ln\ q_{e,t} = (1-\rho_{q_e})ln\bar{q_e} + \rho_{q_e} ln\ q_{e,t-1} + \varepsilon_t^{q_e}, \\
&ln\ q_{s,t} = (1-\rho_{q_s})ln\bar{q_s} + \rho_{q_s} ln\ q_{s,t-1} + \varepsilon_t^{q_s}, \\
&ln\ q_{r,t} = (1-\rho_{q_r})ln\bar{q_r} + \rho_{q_r} ln\ q_{r,t-1} + \varepsilon_t^{q_r} + \varepsilon_{t-1}^{news},
\end{aligned}$$

12.1 The Household's Maximization Problem

12.1.1 Langrangian function

$$\max_{C_t,N_t,K_{r,t+1},K_{e,t+1},K_{s,t+1},\chi_t} \mathcal{L} : \sum_{t=0}^{\infty} \beta^t \Bigg\{ \Bigg[\frac{\Big((\omega C_{m,t}^{\eta} + (1-\omega) C_{h,t}^{\eta})^{1/\eta} - \psi (N_{m,t} + N_{r,t})^{\theta_n} X_t \Big)^{1-\sigma} - 1}{1-\sigma} \Bigg]$$

$$- \lambda_t \Big(C_{m,t} + q_{e,t} K_{e,t+1} + q_{s,t} K_{s,t+1} + q_{r,t} K_{r,t+1}$$

$$- w_t N_{m,t} - (r_{e,t} + q_{e,t}(1-\delta_e)) K_{e,t} - (r_{s,t} + q_{s,t}(1-\delta_s)) K_{s,t} - q_{r,t}(1-\delta_r) K_{r,t} \Big)$$

$$- \mu_t \Big(\chi_t - (\omega C_{m,t}^{\eta} + (1-\omega) C_{r,t}^{\eta})^{\frac{\gamma}{\eta}} \chi_{t-1}^{1-\gamma} \Big) - \xi_t \Big(C_{rt} - A_t K_{r,t}^{1-\theta_r} N_{r,t}^{\theta_r} \Big) \Bigg\} \quad (34)$$

FOC

$$\frac{\partial \mathcal{L}}{\partial C_{m,t}} : \Big((\omega C_{m,t}^{\eta} + (1-\omega) C_{r,t}^{\eta})^{1/\eta} - \psi (N_{m,t} + N_{r,t})^{\theta_n} \chi_t \Big)^{-\sigma} \omega C_{m,t}^{\eta-1} (\omega C_{m,t}^{\eta} + (1-\omega) C_{r,t}^{\eta})^{1/\eta - 1}$$

$$+ \mu_t \Big(\gamma \omega C_{m,t}^{\eta-1} (\omega C_{m,t}^{\eta} + (1-\omega) C_{r,t}^{\eta})^{\gamma/\eta - 1} \chi_{t-1}^{1-\gamma} \Big) = \lambda_t \quad (35)$$

$$\frac{\partial \mathcal{L}}{\partial C_{r,t}} : \Big((\omega C_{m,t}^{\eta} + (1-\omega) C_{r,t}^{\eta})^{1/\eta} - \psi (N_{m,t} + N_{r,t})^{\theta_n} \chi_t \Big)^{-\sigma} (1-\omega) C_{r,t}^{\eta-1} (\omega C_{m,t}^{\eta} + (1-\omega) C_{r,t}^{\eta})^{1/\eta - 1}$$

$$+ \mu_t \Big(\gamma (1-\omega) C_{r,t}^{\eta-1} (\omega C_{m,t}^{\eta} + (1-\omega) C_{r,t}^{\eta})^{\gamma/\eta - 1} \chi_{t-1}^{1-\gamma} \Big) = \xi_t \quad (36)$$

$$\frac{\partial \mathcal{L}}{\partial N_{m,t}} : \Big((\omega C_{m,t}^{\eta} + (1-\omega) C_{r,t}^{\eta})^{1/\eta} - \psi (N_{m,t} + N_{r,t})^{\theta_n} \chi_t \Big)^{-\sigma} \psi \theta_n (N_{m,t} + N_{r,t})^{\theta_n - 1} \chi_t = \lambda_t w_t \quad (37)$$

$$\frac{\partial \mathcal{L}}{\partial N_{r,t}} : \Big((\omega C_{m,t}^{\eta} + (1-\omega) C_{r,t}^{\eta})^{1/\eta} - \psi (N_{m,t} + N_{r,t})^{\theta_n} \chi_t \Big)^{-\sigma} \psi \theta_n (N_{m,t} + N_{r,t})^{\theta_n - 1} \chi_t$$

$$= \xi_t (\theta_r A_t K_{r,t}^{1-\theta_r} N_{r.t}^{\theta_r - 1}) \quad (38)$$

$$\frac{\partial \mathcal{L}}{\partial \chi_t} : \Big((\omega C_{m,t}^{\eta} + (1-\omega) C_{r,t}^{\eta})^{1/\eta} - \psi (N_{m,t} + N_{r,t})^{\theta_n} \chi_t \Big)^{-\sigma} \psi (N_{m,t} + N_{r,t})^{\theta_n} + \mu_t =$$

$$E_t \Big[\mu_{t+1} \beta \Big((1-\gamma) (\omega C_{m,t+1}^{\eta} + (1-\omega) C_{r,t+1}^{\eta})^{\gamma/\eta} \chi_t^{-\gamma} \Big) \Big] \quad (39)$$

$$\frac{\partial \mathcal{L}}{\partial \lambda_t} : C_{m,t} + q_{e,t}K_{e,t+1} + q_{s,t}K_{s,t+1} + q_{r,t}K_{r,t+1}$$
$$= w_t N_{m,t} + r_{e,t}K_{e,t} + r_{s,t}K_{s,t} + q_{e,t}(1-\delta_e)K_{e,t} + q_{s,t}(1-\delta_s)K_{s,t} + q_{r,t}(1-\delta_r)K_{r,t} \tag{40}$$

$$\frac{\partial \mathcal{L}}{\partial \mu_t} : \chi_t = (\omega C_{m,t}^{\eta} + (1-\omega)C_{r,t}^{\eta})^{\frac{\gamma}{\eta}} \chi_{t-1}^{1-\gamma} \tag{41}$$

$$\frac{\partial \mathcal{L}}{\partial \xi_t} : C_{rt} = A_t K_{r,t}^{1-\theta_h} N_{r,t}^{\theta_r} \tag{42}$$

$$\frac{\partial \mathcal{L}}{\partial K_{e,t+1}} : \lambda_t = \beta E_t \left[\lambda_{t+1} \frac{r_{e,t+1} + q_{e,t+1}(1-\delta_e)}{q_{e,t}} \right] \tag{43}$$

$$\frac{\partial \mathcal{L}}{\partial K_{s,t+1}} : \lambda_t = \beta E_t \left[\lambda_{t+1} \frac{r_{s,t+1} + q_{s,t+1}(1-\delta_s)}{q_{s,t}} \right] \tag{44}$$

$$\frac{\partial \mathcal{L}}{\partial K_{r,t+1}} : \lambda_t = \beta E_t \left[\lambda_{t+1} \frac{q_{r,t+1}(1-\delta_r)}{q_{r,t}} + \xi_{t+1} \frac{(1-\theta_r)A_{t+1}K_{r,t+1}^{-\theta_r}N_{r,t+1}^{\theta_r}}{q_{r,t}} \right] \tag{45}$$

$$ln\ Z_t = (1-\rho_Z)ln\bar{Z} + \rho_Z ln\ Z_{t-1} + \varepsilon_t^Z \tag{46}$$

$$ln\ A_t = (1-\rho_A)ln\bar{A} + \rho_A ln\ A_{t-1} + \varepsilon_t^A \tag{47}$$

$$ln\ q_{e,t} = \rho_{q_e} ln\ q_{e,t-1} + \varepsilon_t^{q_e} \tag{48}$$

$$ln\ q_{s,t} = \rho_{q_s} ln\ q_{s,t-1} + \varepsilon_t^{q_s} \tag{49}$$

$$ln\ q_{r,t} = \rho_{q_r} ln\ q_{r,t-1} + \varepsilon_t^{q_r} + \varepsilon_{t-4}^{news} \tag{50}$$

12.2 The Firms problem:

Firm producing final good

$$\max_{K_{e,t},K_{s,t},N_t} \Pi_t = Z_t K_{e,t}^{\alpha_e} K_{s,t}^{\alpha_s} N_t^{1-\alpha_e-\alpha_s} - r_{e,t}K_{e,t} - r_{s,t}K_{s,t} - w_t N_{m,t}. \tag{51}$$

FOC

$$\frac{\partial \Pi_t}{\partial K_{e,t}} : \alpha_e Z_t K_{e,t}^{\alpha_e-1} K_{s,t}^{\alpha_s} N_{m,t}^{1-\alpha_e-\alpha_s} = r_{e,t} \tag{52}$$

$$\frac{\partial \Pi_t}{\partial K_{s,t}} : \alpha_s Z_t K_{e,t}^{\alpha_e} K_{s,t}^{\alpha_s-1} N_{m,t}^{1-\alpha_e-\alpha_s} = r_{s,t} \tag{53}$$

$$\frac{\partial \Pi_t}{\partial N_t} : (1-\alpha_e-\alpha_s) Z_t K_{e,t}^{\alpha_e-1} K_{s,t}^{\alpha_s} N_{m,t}^{-\alpha_e-\alpha_s} = w_t \tag{54}$$