

The Greek crisis: a story of self-reinforcing feedback mechanisms

Katarina Juselius and Sophia Dimelis

Abstract

While there seems to be a well-established consensus about the underlying causes to the Greek crisis, less is known about internal and external transmission mechanisms that ultimately caused unemployment to increase rapidly over this period. Motivated by the structural slumps theory in Phelps (*Structural slumps*, 1994), the paper attempts, therefore, to uncover the dynamic mechanisms behind prices, interest rates, and external imbalances that contributed to the severity and the length of the crisis. The authors find that the strongly increasing real bond rate and unemployment rate together with an persistently appreciating real exchange rate and a deterioration of competitiveness in the eurozone have contributed to persistently growing structural imbalances in the Greek economy. As the lack of confidence in the Greek economy grew steadily, the scene was set for a monumental structural slump. Over the crisis period, all variables exhibited self-reinforcing feedback adjustment somewhere in the system except for inflation rate. Unemployment took the burden of adjustment when the bond rate sky rocketed, competitiveness deteriorated, and confidence fell.

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Keywords Greek crisis; unemployment; CVAR analysis; structural slumps; non-constant natural rate; self-reinforcing adjustment

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1 Introduction

From 2008 to 2013, Greece experienced one of the most severe recessions in Europe with a fall in real output of 26% and a rise in unemployment also of 26%. In 2017, for the first time in 10 years of dismal growth, real GDP growth was positive (around 1%). So why was the recovery so slow and which were the mechanisms triggering the Greek crisis?

A number of explanations have been proposed in the literature of which the most popular ones refer to initial macroeconomic imbalances (e.g. fiscal deficits, external deficits), deteriorating competitiveness, current account imbalances, and the strong external dependence combined with sudden lending stop.¹ Apart from these, chronic structural problems in the economic and political system combined with badly designed policies to deal with them - often forced upon Greece by national, supranational and international institutions - have also been proposed.² Some economists have also argued that the contraction was more severe than initially expected because the impact inefficiencies in the Greek institutions was largely overlooked in the many reform programs (see Economidis et al., 2017, Philippopoulos, 2014). In a similar vein, Kollintzas et al. (2017) attribute the dismal growth to the Greek ‘insiders-outsiders’ society and show that the high public sector wage premium and the self-employed taxation gap significantly contributed to the sovereign debt crisis.

But, while the above explanations are clearly relevant for the building up of the Greek crisis, the severeness of the Greek problems cannot be fully understood without fully understanding the forces that were unleashed when Greece became a eurozone member in 2001. Because financial markets incorrectly considered risk to be evenly distributed in the euro area, the Greek bond rate dropped to unprecedented low levels. This led to a strong increase in credit-financed aggregate demand (mostly demand for imports) which caused huge imbalances in the current account and contributed to an accelerating wage and price spiral both in the private and the public sector.

As a consequence, Greece borrowed heavily to pay for unproductive consumption and excessive wages and the resulting deficits hit the country hard when the crisis unfolded. In contrast, foreign lenders were largely rescued in spite of having been badly exposed. For example, Wyplosz (2017) argues that the Great Financial Crisis was rooted primarily in excessive risk-taking by financial intermediaries – a result of the poor regulation and supervision that emerged in connection with financial liberalization. A contributing cause of the external lending problem was, therefore, that financial markets mistakenly assumed that current-account imbalances of the member countries no longer mattered in the eurozone. This may explain why a high external debt country like Greece was able to finance its debt with low interest rate loans up to the crisis - even though the size of the fiscal imbalance must have made severe macroeconomic adjustment seem inevitable. When the financial markets learned their mistakes, Greece experienced the harsh consequences of strongly increasing interest rates and sudden lending stops.

The Greek misfortune was that most of its external borrowing had been used for unproductive spending, much of it closely tied to large and persistent public deficits that, given the rapidly

¹ See, for example, Gibson et al. (2014), Honkapohja (2014), Christodoulakis (2015), Galenianos (2015), Bournakis et al. (2017), Ioannidis and Pissaridis (2015) and Meghir et al. (2017).

² For example, Meghir et al. (2017) provide a detailed analysis of the pathologies that made Greece vulnerable to the crisis with special focus on the product and labor market regulations and the financial system.

increasing interest rates, became extremely harmful. Excessive public spending financed by external borrowing was generally considered the most serious obstacle for getting the Greek economy out of the crisis. See for example Gourinchas et al. (2016). But, rather than a pure sovereign debt crisis, Hyppolite (2016) argues that the Greek crisis is best viewed as an external debt crisis driven by a real estate bubble and unsustainable foreign capital flows.³

But, while there seems to be a well researched narrative about the underlying causes of the crisis, less is known about internal and external transmission mechanisms causing the rapidly increasing unemployment rate over this period. The aim here is, therefore, to uncover the dynamic mechanisms among unemployment, prices, interest rates, and external imbalances that contributed to the severity and the length of the crisis. A similar aim can be found in Juselius and Juselius (2014) that used the Cointegrated VAR (CVAR) model to uncover important relationships among unemployment, prices and interest rates in connection with the Finnish crisis in the beginning of 1990s. In many ways the economic mechanisms leading to the Finnish crisis were similar to the ones of the Greek crisis: the deregulation of the Finnish credit market in 1986 resulted in lower loan rates, a booming housing market and the build-up of a serious house price bubble that finally burst in 1991. House prices dropped by roughly 60 % and unemployment rose from a record low of 2 % to almost 20 %. These are huge fluctuations but of similar magnitudes as in the case of Greece. But, unlike Greece, Finland was able to devalue its currency by 33% and managed to get out of the crisis in approximately three - very hard - years. Even though the Finnish unemployment rate came down reasonably fast, it stabilized at a higher rate than in the pre-crisis period.

One important finding in the Finnish study was an empirically strong Phillips curve relationship with a non-constant Phelpsian natural rate of unemployment as a function of the real bond rate. The results provided support for the structural slumps theory in Phelps (1994), for the theory of balance sheet recessions in Koo (2010) and for the theory of imperfect knowledge expectations in Frydman and Goldberg (2007). The present paper takes a similar approach as in Juselius and Juselius (2014), but recognizes that the Greek crisis, while similar in many respects, differs strongly in others such as in the source of the debt (private/public, internal/external) and in particular in the exchange rate regime. The fact that Finland was able to devalue its currency while Greece was not, is likely to have made all the difference. It is one reason why the comparison with Finland is interesting.

The prolonged period of policy uncertainty following the outbreak of the Greek crisis seem to have aggravated the deepening and the extension of the Greek crisis. Also, the failure in 2012 to restructure the sovereign debt (known as Private Sector Settlement, PSI) further weakened investors' confidence. Unlike the Finnish study we, therefore, additionally include a variable measuring confidence in the Greek economy. Finally, the development of the Greek competitiveness within and outside the eurozone is also likely to have been crucial for the crisis mechanisms, so these are also included in the information set of our model.

Because of the severity of the crisis, we expect the macroeconomic dynamics both during, before and after the Greek crisis to be utterly complex. Our approach differs, therefore, from most papers that have empirically studied the Greek crisis by *not* taking the simple route of assuming *a priori* a few exogenous causes and then forcing these assumptions on the model. We argue that it is seldom possible to know from the outset - and especially not in an utterly complex crisis period -

³ He shows this using a new dataset that evaluates and breaks down national wealth accumulation in Greece since 1997.

which variables are empirically endogenous (purely adjusting) and which are exogenous (purely pushing).

Like Juselius and Juselius (2014), our approach relies on a full system CVAR model in which all systematic aspects of the data have been satisfactorily described. This resonates with the argumentation in Spanos (2009) that a convincing test of the empirical relevance of an economic model has to be carried out in the context of a fully specified statistical model that works as an adequate, though approximate, description of the Data Generating Process given in its entirety. A CVAR model that has passed all basic specification tests, is essentially a summary of the most important empirical facts over the sample period and, thus, qualifies for such a statistical model. A model that has not passed such checks may - and often does - produce totally misleading conclusions. Juselius and Franchi (2007) illustrated this for a real business cycle model. Because data were constrained from the outset in a theoretically pre-specified direction, it was not possible to distinguish between results which were due to the assumptions made and the genuine empirical results. Thus, from the outset data were not allowed to speak about some - potentially true - underlying causes. Scientific objectivity was, hence, undermined.⁴ The main reason for letting the data speak as freely as possible about the mechanisms that caused the crisis is to avoid this pitfall.

The paper is organized as follows: Section 2 discusses broadly the Phillips curve with a Phelpsian natural rate based on Phelps (1994). Section 3 presents a graphical display of the data and Section 4 introduces the empirical model, reports specification tests showing that the model is reasonably well-specified, and finds that it is approximately $I(2)$ over this period based on Maximum Likelihood rank tests. Section 5 reports the estimates of the long-run structure and Section 6 concludes.

2 The structural slumps theory and the non-constant natural rate

The aim of the structural slumps theory, developed by Edmund Phelps in the early nineties, was to explain how open economies connected by the world real interest rate - set in a global capital market - and the real exchange rate - determined in a global customers market for tradables - can be hit by long spells of unemployment. According to this theory, fluctuations in the real interest rates and real exchange rates play an important role in explaining the persistent long swings in the observed unemployment rates. The theoretical implication for a standard Phillips curve is that the natural rate of unemployment becomes a function of the real interest rate and the real exchange rates. While Phelps (1994) assumed that real interest rates and real exchange rates were stationary,⁵ empirical testing often finds that they are indistinguishable from a unit root process. Juselius (2013) argues that the structural slumps theory based on imperfect knowledge expectations would be more adequate to explain the long persistent movements in the data.⁶

In an imperfect knowledge world, the nominal exchange rate is primarily determined by financial speculation whereas prices of tradable goods, being determined in very competitive

⁴ See Hoover et al. (2008) for further discussions.

⁵ This is because the theory was based on model consistent rational expectations

⁶ Frydman and Goldberg (2007, 2011) show that financial behavior under imperfect knowledge can drive asset prices, such as nominal exchange rates and long-term bond rates, persistently away from long-run benchmark values.

customer markets, are not likely to be affected by speculation - energy, precious metals and, recently, grain may be exceptions in this respect. Hence, relative prices would fluctuate much less than nominal exchange rates and real exchange rates would inherit the persistent swings of nominal exchange rates. Figure 1, panel (f), illustrates such persistent swings in the real effective exchange rate of the euro relative to the Greek trading countries outside the eurozone. Relative prices within the eurozone have also exhibited a pronounced upward persistence as shown in panel (e). The nominal bond rate was also strongly affected by financial behavior, in particular after the market became aware of the unsustainability of the Greek debt. Figure 1, panel (c) shows the dramatic increases of the long-term Greek bond rate at the beginning of the crisis. Since the nominal bond rate fluctuated much more than price inflation, the real interest rate inherited the persistent swings of the nominal interest rate. Hence, the strongly increasing real bond rate together with an appreciating real exchange rate and a deteriorating competitiveness with respect to the eurozone are likely to have significantly aggravated the existing structural imbalances in the Greek economy. As the lack of confidence grew steadily, the scene was set for a monumental structural slump a la Phelps (1994).

How would all this affect the Greek unemployment. As Greek enterprises had lost much of their previous competitiveness after a long period of positive shocks to relative costs, a real depreciation would have been the obvious cure. But, being an eurozone member, Greece had given up the possibility to use the exchange rate as a policy tool. Unless Greece left the euro she could not count on exchange rates to restore lost competitiveness. But, unlike Finland in the nineties, the large proportion of external debt would have made such a choice extremely costly. Thus, Greek enterprises, facing domestic wage costs in excess of the foreign ones, may not have had other options than to improve labor productivity. This was achieved by introducing new technology, by lowering domestic wage (though extremely difficult) or by laying off the least productive part of the labor force and producing the same output with less labor. In all those cases unemployment rate took the burden of adjustment.

In line with Phelps (1994), our empirical analysis is centered around a Phillips Curve with a non-constant natural rate:

$$\Delta p = -b_1(u - u^n), \quad (1)$$

where inflation, Δp , is negatively related to unemployment, u , adjusted for the natural rate of unemployment, u^n , the latter potentially a function of the real effective exchange rate, $reer$, relative producer prices with respect to the eurozone, $relc$, market confidence, $conf$, and/or the real bond rate, r .

Figure 1 shows the data over the sample period 2004:5–2017:1. Panel (a) pictures the Greek inflation rate that, in spite of a strong seasonal pattern, looks reasonably stable. Panel (b) shows the decline of unemployment in the period preceding the crisis, result of the increasingly overheated Greek economy. It also shows how it rose to record levels only a few years after the bubble burst, illustrating the force with which the crisis struck the Greek economy. Finland experienced a similar overheated economy with declining unemployment rates prior to the crisis only to be followed by rapidly rising rates. After topping in 2013, the Greek unemployment has slowly started to come down but, at the end of the sample, it is still very high. Panel (c) pictures the bond rate

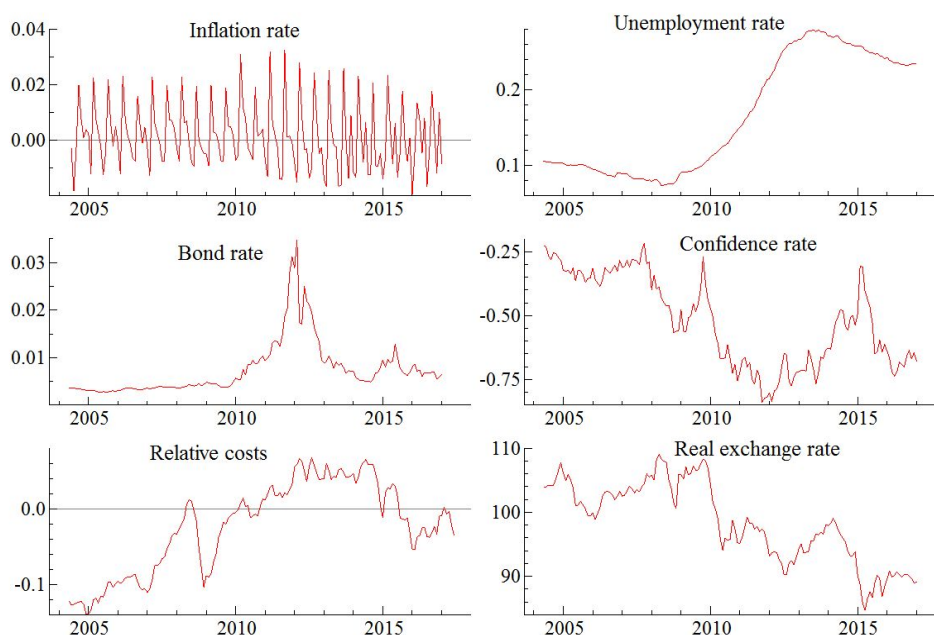


Figure 1: Graphs of the data

and its extreme growth as the crisis unfolded. Panel (d) shows the confidence variable and its decline until approximately 2012 after which it was rising up to 2015, whereafter the election of a new government - hostile to structural adjustment programs - caused market confidence to drop dramatically. As it seemed almost impossible for Greece to honor its external debt, foreign lenders panicked and stopped lending. This almost pushed Greece over the edge and aggravated the very crisis lenders feared. Panel (e) pictures the relative producer price between Greece and Germany and its steady increase up to roughly 2012, its leveling off until 2014, and its steady decline thereafter. Panel (f) pictures the Greek effective real exchange rate and its steady rate of appreciation, mirroring the increase in relative costs in panel (e).

3 The Empirical CVAR

We consider the following VAR model (Johansen, 1995, Juselius, 2006):

$$\Delta x_t = \Pi x_{t-1} + \Gamma_1 \Delta x_{t-1} + \Gamma_2 \Delta x_{t-2} + \mu_0 + \Phi_1 D_t + \Phi_2 S_t + \varepsilon_t, \quad (2)$$

where

$$x_t' = [\Delta p_t, u_t, b_t, conf_t, relC_t, reer_t]$$

- – Δp_t is inflation measured as $\Delta \log(CPI)_t$, source OECD, economic outlook,
- u_t is unemployment rate measured as the number of unemployed relative to the workforce, source OECD, economic outlook,

- $bond_t$ is the long-term government bond rate divided by 1200 to make it comparable with monthly inflation rate measured as $\Delta \log CPI$, source Datastream,
- $conf_t$ is an index between -1.0 and +1.0 measuring the level of confidence in the Greek society, source Datastream,
- $RelC_t = PPI^{Gr} - PPI^{Ge}$ is a measure of the log of Greek producer cost relative to Germany, source Eurostat,
- $reer_t$ = the log of the effective real exchange rate for Greece, source OECD, economic outlook.

D_t is a vector of dummy variables,

S_t is a vector of eleven seasonal dummies.

$\varepsilon_t \sim Niid(0, \Omega)$.

The sample period covers 2004:5–2017:1 and the program Cats in Rats (Dennis et al., 2006) has been used for the empirical calculations.

3.1 Model Specification and extreme events

Figure 1 visualizes the extreme changes in the unemployment rate and the bond rate, but also in the variables measuring confidence and producer costs relative to Germany. Such extreme events can be challenging for a CVAR analysis as it is based on the assumption of multivariate normality. To obtain an empirically well-specified model basically three potential remedies are available: to leave out the crisis years altogether assuming they are not representative for the purpose of the study; to condition on weakly or strongly exogenous variables assuming they are the main cause of the extreme fluctuations in the data; to control for the extreme events using appropriately designed dummy variables. Since the main purpose of this study is to obtain an improved understanding of the crisis mechanisms, the first option is out of question. When testing the second option we found, not surprisingly, that the real exchange rate was both weakly and strongly exogenous independently of the choice of rank. Hence, the subsequent results will be based on a partial VAR conditional on the real effective exchange rate.⁷ But, even though conditioning on the real effective exchange improved the specification, several large outliers remained nonetheless in the model, so the dummy option was also needed. The vector D_t in (2) contain dummy variables that control for the following extraordinary events in this period:

- $D_{p11.09}_t = 1$ in 2011:9, 0 otherwise, controls for the first large increase in the bond rate,
- $D_{p11.11}_t = 1$ in 2011.11 and 2011.12, 0 otherwise, controls for two subsequent large increases in the bond rate,
- $D_{p12.02}_t = 1$ in 2012.2, -2 in 2012.3 and 1 in 2012.5, controls for a large double change in the bond rate,
- $D_{p15.02}_t = 1$ in 2015.2, controls for the effect of the election of a new government on the confidence variable and relative costs between Greece and Germany.

⁷ For the chosen value, $r = 4$, the weak exogeneity test was $\chi^2(4) = 2.00[0.74]$.

Table 1: Dummy variables and misspecification tests

	$D_p11.09$	$D_p11.11$	$D_p12.02$	$D_p15.02$	Jarque – Bera	ARCH(3)
$\Delta\Delta p_t$	0.01 [2.6]	0.00 [0.03]	-0.003 [-1.5]	0.01 [2.4]	0.61[0.74]	1.9[0.60]
Δu_t	-0.002 [-0.9]	-0.002 [-1.1]	0.001 [0.7]	0.001 [0.7]	0.71[0.70]	4.9[0.18]
ΔB_t	0.005 [5.3]	0.007 [10.5]	0.008 [20.7]	-0.001 [-1.4]	15.63[0.00]	7.8[0.05]
$\Delta Conf_t$	-0.067 [-1.7]	0.005 [0.2]	-0.009 [-0.5]	0.23 [5.7]	2.29[0.32]	2.0[0.57]
$\Delta RelC$	0.005 [0.6]	0.001 [0.1]	-0.002 [-0.6]	0.05 [5.3]	5.13[0.08]	0.9[0.83]

The left hand side of Table 1 reports the estimates of the four dummy variables with significant coefficients in bold face. The results show that the first three dummies are needed to control for extreme unanticipated changes in the bond rate as the crisis evolved. Among them $D_p12.02$ controls for the effect on the bond rate when Greece accepted a debt restructuring scheme with its private creditors. It implied that the first adjustment program was rolled over into a second one, causing the previously dramatic increases in the bond rate to reverse. The dummy $D_p15.02_t$ controls for the effect on relative prices and market confidence when a new government - politically opposed to the adjustment programs - was elected, elevating the risk of a Grexit.

The right hand side of Table 1 reports univariate Jarque-Bera normality tests and ARCH tests. The multivariate normality test was $\chi^2(10) = 18.3[0.05]$, the multivariate ARCH was $\chi^2(225) = 204.4[0.83]$ and the multivariate autocorrelation test of second order was $\chi^2(25) = 23.4[0.55]$. Figures 2-6 in the Appendix show actual and estimated changes of the all the variables, standardized residuals, autocorrelograms and residual histograms compared to the normal distribution. With the exception of the bond rate, pictured in Figure 4, the VAR model seems reasonably well specified. But even the bond rate - considering its huge changes over the crisis period - has a surprisingly nice and symmetrical residual distribution, so that the rejection of normality of the bond residuals is due to excess kurtosis rather than skewness. Because the CVAR estimates have been shown to be robust to moderate degrees of excessive kurtosis, we consider the model conditional on the real effective exchange rate and the dummies to be sufficiently well specified.

3.2 Rank determination

Figure 3 in the Appendix illustrates the pronounced persistence in the change of the unemployment rate, suggesting that even the differenced process may contain a unit root. Because such a root cannot be removed by changing the rank of Π , the statistical analysis has to be performed in the $I(2)$ model.

The hypothesis that x_t is $I(2)$ is formulated as a reduced rank hypothesis on $\Pi = \alpha\beta'$ and an additional reduced rank hypothesis on $\alpha'_\perp \Gamma \beta_\perp = \xi \eta'$ where ξ, η are $(p-r) \times s_1$ and $\alpha_\perp, \beta_\perp$ are orthogonal complements of α, β . The total number of stochastic trends, $(p-r)$, are divided into s_1 trends of order $I(1)$ and s_2 trends of order $I(2)$.

Table 2: The trace tests

$p - r$	r	$s_2 = 5$	$s_2 = 4$	$s_2 = 3$	$s_2 = 2$	$s_2 = 1$	$s_2 = 0$
3	2			139.5 [0.00]	86.5 [0.00]	65.5 [0.00]	58.4 [0.01]
2	3				49.7 [0.04]	38.6 [0.02]	31.5 [0.04]
1	4					11.9 [0.47]	9.4 [0.33]
The five largest characteristic roots							
	$r = 5, p - r = 0$	0.98	0.98	0.86	0.77	0.77	
	$r = 4, s_1 = 1, s_2 = 0$	1.0	0.97	0.88	0.76	0.76	
	$r = 4, s_1 = 0, s_2 = 1$	1.0	1.0	0.88	0.75	0.75	

The determination of the reduced rank indices is based on the maximum likelihood trace tests derived in Nielsen and Rahbek (2007) and reported in Table 2. The procedure starts with the most restricted model ($r = 0, s_1 = 0, s_2 = 5$) with s_1 denoting the number of $I(1)$ trends and s_2 the number of $I(2)$ trends, and continues row-wise until the first non-rejection at ($r = 4, s_1 = 0, s_2 = 1$) with a p-value of 0.47.⁸ The column of $s_2 = 0$ contains the trace tests for the $I(1)$ model.

A correct choice of rank indices is crucial for obtaining statistically reliable results. Unfortunately it is also a difficult choice since economic data are often informationally weak about the division into pulling and pushing forces. Therefore, we also use other relevant information as a robustness check of the rank test. The five largest characteristic roots, reported in the lower part of Table 2, are particularly useful in this respect. The unrestricted VAR (conditional on the real exchange rate) contains two large roots almost on the unit circle (0.98, 0.98) plus another large root (0.86) which may or may not correspond to a unit root. The case ($r = 4, s_1 = 1, s_2 = 0$), i.e. the $I(1)$ model with $r = 4$, would leave a large near unit root of 0.97 in the model. Because of this, we conclude that the $I(1)$ model is not an appropriate reduction of the data-generating process. Finally, the case ($r = 4, s_1 = 0, s_2 = 1$) eliminates the two near unit roots but leaves an unrestricted root (0.88) in the model. While large, it is nonetheless small enough to describe to a stationary but slowly adjusting relation. Thus, we continue with this case.

4 Long-Run and Medium-Run Structures

As shown above, the $I(2)$ hypothesis is formulated as a reduced rank condition on a transformed Γ matrix implying that the latter is no longer unrestricted as in the $I(1)$ model. Because of this, Johansen (1997, 2006) suggested a different parameterization more suitable for likelihood based

⁸ The tests for $r = 0$ and 1 were all strongly rejected and the table reports the results only for $r = 2, 3, 4$.

inference (see also Doornik and Juselius, 2017):

$$\begin{aligned} \Delta^2 x_t &= \alpha \left[\begin{pmatrix} \beta \\ \beta_1 \end{pmatrix}' \begin{pmatrix} x_{t-1} \\ t-1 \end{pmatrix} + \begin{pmatrix} d \\ d_0 \end{pmatrix}' \begin{pmatrix} \Delta x_{t-1} \\ 1 \end{pmatrix} \right] \\ &+ \zeta \begin{pmatrix} \beta \\ \beta_0 \end{pmatrix}' \begin{pmatrix} \Delta x_{t-1} \\ 1 \end{pmatrix} + \Gamma_1 \Delta^2 x_{t-1} + \Phi D_t + \varepsilon_t, \end{aligned} \quad (3)$$

$t = 1, \dots, T$

The relations in the hard bracket describe polynomially cointegrated relations, $\tilde{\beta}' \tilde{x}_{t-1} + d' \Delta \tilde{x}_{t-1}$, with $\tilde{x}'_t = [x_t, t]$, capturing a situation where both $d' \Delta \tilde{x}_{t-1}$ and $\tilde{\beta}' \tilde{x}_t$, are very persistent (near) $I(1)$ processes which cointegrate to $I(0)$. A polynomially cointegrated relation can often be interpreted as a dynamic rather than static equilibrium relation in the following sense: When data are $I(2)$, $\beta' x_t$ is generally $I(1)$, i.e. a very persistent long-run equilibrium error. The coefficients α and d describe two levels of equilibrium correction: the α adjustment how the acceleration rates, $\Delta^2 x_t$, adjust to the dynamic equilibrium relation, $\beta' x_t + d' \Delta x_t$, and the d adjustment how the growth rates, Δx_t , adjust to the long-run equilibrium errors, $\beta' x_t$. Finally, the relations among the differenced variables, $\zeta \beta' \Delta \tilde{x}_{t-1}$, describe dynamic adjustment in the medium run.

The long and persistent swings of the data visible in Figure 1 indicate the possibility of self-reinforcing feedback mechanisms in one or more equations of the system. Such behavior is likely to show up as a combination of equilibrium error increasing (positive feedback) and error correcting behavior (negative feedback) either in the adjustment to the five polynomially cointegrating relations, $\alpha(\beta' x_t + d' \Delta x_t)$, or in the adjustment to the changes in the β -relations, $\zeta \beta' \Delta x_t$. The signs and significance of β, d, α , and ζ determine where in the system there is equilibrium error correcting and/or error increasing behavior, i.e. they determine how each variable responds in the medium and/or the long run to imbalances in the system. This will be further discussed below.

Table 3 reports estimates of α, β and d subject to six over-identifying restrictions on β , which are accepted based on $\chi^2(6) = 4.67[0.59]$.⁹ For a given identified β , the d parameters are uniquely determined without further restrictions.¹⁰ The standard errors of β are derived in Johansen (1997) and those of d by the delta method in Doornik and Juselius (2017). Table 4 reports the estimated adjustment coefficients ζ of $\hat{\beta}' \Delta x_t$, where $\hat{\beta}$ is given by the identified structure of Table 3. To facilitate readability, statistically insignificant adjustment coefficients (with a t -ratio $< |1.6|$) are replaced by an asterisk (*).¹¹ Error-increasing coefficients are shown in bold face.

⁹ See Johansen (1997) for the derivation of the LR test.

¹⁰ Mosconi and Paruolo (2014) propose an identification scheme where the d coefficients are identified in their own right.

¹¹ Note that all β coefficients have t ratios that are sufficiently large to be statistically significant also after a near unit root correction.

Table 3: The estimated long-run structure

Test of restricted β structure $\chi^2(6) = 4.67[0.59]$							
	Δp	u	$bond$	$conf$	$relC$	$reer$	t
β_1	1.00	0.02 [12.3]	—	—	—	—	—
d_1	0.002 [3.4]	-0.12 [-3.4]	-0.002 [-3.4]	0.09 [2.8]	-0.17 [-3.3]	-0.04 [-2.1]	0.004 [5.9]
α_1	-1.10 [-7.15]	*	-0.08 [-2.53]	*	0.71 [2.05]	—	—
β_2	—	-0.02 [-4.61]	1.00	—	—	—	—
d_2	0.01 [3.7]	-0.29 [-3.7]	-0.01 [-3.7]	0.36 [5.1]	-0.31 [-2.4]	*	-0.00 [-1.8]
α_2	*	0.13 [3.24]	-0.14 [-7.59]	*	*	—	—
β_3	—	1.00	—	—	-0.87 [-8.31]	0.62 [162.45]	—
d_3	-0.08 [-4.0]	4.32 [4.0]	0.09 [4.0]	-4.71 [-5.3]	5.07 [3.0]	*	-3.04 [-7.4]
α_3	*	-0.01 [-3.57]	-0.01 [-3.85]	0.26 [3.14]	0.04 [1.99]	—	—
β_4	—	—	—	1.00	0.97 [3.29]	-1.83 [-150.0]	—
d_4	-0.23 [-4.4]	12.65 [-4.4]	0.26 [-4.4]	-6.33 [-2.8]	19.53 [4.2]	6.90 [3.9]	8.93 [7.1]
α_4	0.01 [2.57]	-0.01 [-5.58]	*	-0.13 [-5.02]	-0.01 [-1.92]	—	—

* stands for an α and d coefficient with a t-ratio of less than 1.3

Table 4: The estimated coefficients to the medium-run relations

Loadings to	$\beta'_1 \Delta x_t$	$\beta'_2 \Delta x_t$	$\beta'_3 \Delta x_t$	$\beta'_4 \Delta x_t$
	ζ_1	ζ_2	ζ_{31}	ζ_3
$\Delta^2 \Delta p_t$	-1.12 [-5.97]	*	0.36 [2.50]	0.13 [2.50]
$\Delta^2 u_t$	0.13 [1.49]	*	-0.43 [-6.56]	-0.16 [-6.31]
$\Delta^2 bond_t$	0.10 [2.54]	-0.98 [-17.51]	0.05 [1.77]	0.02 [1.96]
$\Delta^2 conf_t$	*	-3.78 [-1.50]	-2.08 [-1.54]	-0.67 [-1.32]
$\Delta^2 relC_t$	-1.19 [-2.80]	*	0.70 [2.16]	*

4.1 Interpreting the long-run β relations and their α adjustment

The estimated structure, $\beta'x_t$, consists of four identified relations describing highly persistent deviations from long-run static equilibrium relations. To improve interpretability, each β relation has been normalized on the economically most relevant variable, y_t , and expressed as a long-run relation, $y_t = b'z_t + z_t$, where z_t cointegrates with y_t from $I(2)$ to $I(1)$ and z_t is an $I(1)$ residual. The four β relations are in turn interpreted as:

1. a Phillips Curve type of relation: $\Delta p_t = -0.02u_t + z_{1,t}$;¹²
2. a positive relationship between unemployment rate and the bond rate: $bond_t = 0.02u_t + z_{2,t}$;
3. a natural rate relation associating the unemployment rate with the relative producer price between Greece and Germany and with the real effective exchange rate: $u_t = 0.87relC_t - 0.62reer_t + z_{3,t}$;
4. a relation associating the confidence variable with the relative producer cost between Greece and Germany and with the real effective exchange rate: $conf_t = -0.97relC_t + 1.83reer_t + z_{4,t}$.

Cointegration is a measure of comovements and as such is silent about causality. However, combined with the α coefficients it is possible to infer where in the system long-run adjustment has taken place. By checking significant values of α_{ij} , one can infer whether variable i is error-correcting or error-increasing in response to an equilibrium error measured by cointegration relation j . If $\alpha_{ij}\beta_j < 0$ (or/and $\alpha_{ij}d_{ij} < 0$), then the acceleration rate, $\Delta^2x_{i,t}$, is equilibrium correcting to $(\beta_i'x_t + d_i'\Delta x_t)$, otherwise it is error-increasing. If only one $\alpha_{ij}\beta_j$ is significant for $j = 1, \dots, r$, then it suggests a causal long-run equilibrium adjustment effect, otherwise joint feed-back effects. Such a check shows that

1. inflation rate, but not unemployment rate, is significantly adjusting to the first relation, the Phillips curve, consistent with the theoretical prior;
2. both unemployment and the bond rate are adjusting to the second relation signifying strong dynamic feed-back effects between the two. The bond rate has increased as the level of unemployment has increased and similarly the unemployment rate has increased as the bond rate has increased;
3. only unemployment is very significantly adjusting to the third relation, suggesting that it is our best candidate for a non-constant natural rate relation; and

¹² The small coefficient of unemployment rate in the first and second relation can be explained by the transformations of the data. The inflation rate is measured as the monthly difference of logCPI (a very small number) and the bond rate is measured as the annual rate divided by 1200 which gives a monthly measure that corresponds in magnitude to the inflation rate. The unemployment rate is measured as percentage unemployment rate divided by 100, a measure which is approximately 30 times as large as that of the inflation and the bond rate. If standardized data had been used the coefficient of 0.02 would instead have been 0.6.

4. only the confidence variable is very significantly adjusting to the fourth relation, suggesting a causal link from fluctuations in relative producer prices and the real exchange rate to market confidence in the Greek economy.

In all cases, except for the bond rate, the α adjustment represents equilibrium-error-correction. The remaining significant α coefficients show that unemployment rate has adjusted very strongly to all relations except to the Phillips curve relation. Thus, unemployment rate in particular is a variable that has taken the burden of adjustment over this period.

4.2 The medium-run adjustment

In the $I(2)$ model, the static long-run equilibrium error, $\beta'x_t$, is a very persistent process. This tells us that there are forces in the system which prevent the variables to equilibrium-correct in the short run. The econometric task is to identify where in the system these forces are at play. The structure of the $I(2)$ model shows that changes in the system variables, $d'\Delta x_t$, are comoving with the persistent equilibrium error, $\beta'x_t$, to produce a dynamic long-run relation, $\beta'x_t + d'\Delta x_t$, that is stationary. This means that the signs and the significance of the d coefficients are informative about the persistent forces that have pushed the system out of equilibrium. If $d_{ij}\beta_{ij} > 0$ (given $\alpha_{ij} \neq 0$), then $\Delta x_{i,t}$, is equilibrium error correcting to $\beta'x_t$, otherwise it is error-increasing. The latter is of particular interest in crisis periods as it is a signal of self-reinforcing adjustment behavior in the system. We shall pay special attention to such evidence in the detailed discussions of the dynamic adjustment behavior below.

The first dynamic relation (the Phillips curve relation) is given by:

$$\begin{aligned} \Delta p_t + 0.02u_t = & 0.002\Delta(\text{bond}_t - \Delta p_t) + 0.12\Delta u_t - 0.09\Delta \text{conf}_t \\ & + 0.17\Delta \text{relC} + 0.04\Delta \text{reer} - 0.004 + v_{1t} \end{aligned}$$

where v_{1t} is a stationary process pictured in Figure 7, panel (a). The results show that the nonstationary equilibrium error in the Phillips curve relation, $z_{1,t} = \Delta p_t + 0.02u_t$, is associated with a positive change in the real bond rate, in the unemployment rate (an error-increasing effect), in relative producer prices (loss of competitiveness), in the real exchange rate, and with a negative change in the market confidence rate. Even though the α coefficients showed that inflation was significantly error-correcting in the long-run, whereas unemployment was not, the d estimates show that the latter has been significantly error-increasing in the medium run. Furthermore, the bond rate has been error-increasing in the long run to the *change* in the bond rate, signifying its almost explosive behavior in the crisis period. Thus, the Phillips curve has moved away from its long-run equilibrium values because of the self-reinforcing adjustment behavior of the unemployment rate partly caused by a strongly increasing bond rate. But the drop in market confidence has also played a significant role in this respect. Finally, the relative producer price has been error-correcting to the *changes* in relative price, but not very significantly so.

The second dynamic relation is given by:

$$\text{bond}_t - 0.02u_t = 0.01\Delta(\Delta \text{bond}_t - \Delta p_t) - 0.36\Delta \text{conf}_t + 0.31\Delta \text{relC} + v_{2,t}$$

where $v_{2,t}$ is a stationary process pictured in Figure 7 panel (b). The results show that the nonstationary equilibrium error in the bond rate/unemployment rate relationship can be explained by an increase in the real bond rate (an error-increasing effect), a drop in the market confidence rate and an increase in relative producer prices. Both unemployment and the bond rate are error-correcting in the long run. This relation can predominantly be interpreted as a crisis relation signifying the observed - almost explosive - behavior of both the bond rate and the unemployment rate, albeit with the bond rate leading the race, as evidenced by its error-increasing behavior.

The third dynamic relation is given by:

$$u_t - 0.87relC_t + 0.62reer_t = -0.09\Delta(\Delta bond_t - \Delta p_t) - 4.3\Delta u_t + 4.7\Delta conf_t - 5.1\Delta relC_t + 3.04 + v_{3,t}$$

where $v_{3,t}$ is a stationary process pictured in Figure 7 panel (c). The results show that the nonstationary deviation from the natural rate of unemployment relation (Phelps, 1994) can be explained by (i) a negative effect of a change in the real interest rate (an increase in the real bond rate is likely to go together with increasing relative prices), (ii) a negative effect of a change in the unemployment rate (an error-correcting effect), (iii) a positive effect of a change in the confidence variable (a positive change in the latter is likely to go together with declining relative producer prices), and (iv) a negative effect of a change in the relative producer prices (an error-increasing effect). The latter shows that in the medium run, the persistent deviations of unemployment from its non-constant natural rate was strongly affected by the error-increasing behavior of relative producer prices, albeit, they were error-correcting ($\alpha_{53} = 0.04$) in the long run. The remaining variables - the unemployment rate, the bond rate and the confidence variable - are all error-correcting.

The fourth dynamic relation is given by:

$$conf_t + 0.97relC_t - 1.83reer_t = -0.23\Delta(\Delta bond_t - \Delta p_t) - 12.7\Delta u_t + 6.3\Delta conf_t - 19.5\Delta relC_t - 6.9\Delta reer_t + 8.9 + v_{4,t}$$

where $v_{4,t}$ is a stationary process pictured in Figure 7 panel (d). The results show that the nonstationary deviation from the long-run confidence relation can be explained by a negative effect from an increase in the real bond rate, the unemployment rate, the relative price (an error-correction effect), and the real exchange rate, and finally from a positive effect of a change in market confidence implying equilibrium increasing behavior in the medium run. However, in the long run, the α coefficient showed that the confidence variable is error-correcting ($\alpha_{44} = -0.13$) and so are the remaining variables - inflation, unemployment and relative producer prices.

Table 4 reports the medium run responses to changes in the static equilibrium errors, $\beta'x_t$. If $\zeta_{ij}\beta_{ij} < 0$ then $\Delta^2x_{i,t}$ is equilibrium correcting to $\beta'_i\Delta x_{t-1}$, otherwise it is error increasing. As before, error-increasing coefficients are reported in bold face. We find error increasing behavior in the unemployment equation as it is responding to the change of the Phillips curve disequilibrium, $\Delta(\Delta p + 0.02u)$, and in the equations for the market confidence and relative producer prices as they respond to the change of the natural rate disequilibrium, $\Delta(u - 0.87relC + 0.62reer)$. These effects

are likely to capture the gradual deterioration of confidence and relative producer prices as a result of the strongly increasing bond rate and unemployment rate.

To summarize: the results provide strong evidence of self-reinforcing feed-back mechanisms during the Greek crisis period. The unemployment rate was found to be error-increasing to the Phillips curve relation in the medium run (both in levels and changes), but error-correcting to the second and third relation; the bond rate was error-increasing in the medium run to the natural rate relation between inflation and the bond rate; the confidence variable was error-increasing to the fourth relation but error-correcting to the third relation; relative producer prices were error-increasing to the third relation but error-correcting to the fourth relation. The only variable that did not show any evidence of error-increasing behavior is the Greek inflation rate. All this gives empirical support to the structural slumps theory combined with imperfect knowledge expectations as discussed in Section 2.

Considering the wild fluctuations over this period, the results seem remarkably good. The signs of the coefficients are as expected, the estimated relations are plausible as a description of dynamic transmission mechanisms in a period of severe crisis. Even though one should consider the medium-run effects with some caution - they may not be completely stable over time - the plausibility of the coefficient estimates gives credibility of the results.

Whether the results will also hold when the crisis is finally over is a more difficult question. We believe that the pronounced persistence of the equilibrium errors is likely to diminish, the corresponding error-increasing adjustment dynamics to become more insignificant, and the data to become approximately $I(1)$. Most of the estimated long-run β relations may very well remain empirically significant, possibly also the α adjustment.

5 Concluding remarks

Motivated by the structural slumps theory in Phelps (1994) we present empirical results relevant for a more elaborate understanding of the deep and prolonged Greek crisis that started around 2008. Based on a cointegrated VAR analysis, the data were found to be approximately $I(2)$ consistent with the prolonged observed imbalances from equilibrium states. The results showed ample evidence of self-reinforcing feed-back mechanisms in the VAR system signifying the very slow adjustment back to long-run equilibrium states.

At the core of the crisis we identified a critical relationship between the bond rate and the unemployment rate. When the crisis erupted, the bond rate increased strongly causing unemployment to increase, the increase in unemployment rate caused the bond rate to increase further and unemployment to follow suite, and so on. This vicious cycle was orchestrated by a continuous fall in market confidence that kept deteriorating until relative producer prices stopped growing around 2012. The results showed that all variables, except CPI inflation, exhibited error-increasing behavior in some equations of the system. This feature is likely to have aggravated the crisis and effectively prevented good policy solutions. Thus, the Greek recession seems to have grown out of many imbalances that were allowed to develop over too long time. But, while accruing imbalances may counterbalance each other to some extent, a balance that is maintained by several imbalances is a very fragile balance. A large shock somewhere in the system, is sufficient for the whole thing

to collapse as demonstrated in 2008 when the financial crisis hit Greece - and the world economy - with unprecedented force.

The results of the paper support the following narrative of the Greek drama: As Greece joined the euro, the level of interest rate dropped to previously unprecedented levels; low interest rates and easy access to foreign capital caused credit financed consumption - public as well as private - to soar. As a result, wages and prices were rising and the Greek competitiveness was consequently deteriorating. As external and internal imbalances grew, the financial market realized that risk was not equally distributed among the eurozone countries and that the Greek external debt was largely unsustainable. The dramatic rise of the Greek bond rate increased the cost of investment and production and made it very costly just to maintain previously accumulated imbalances. The consequence was that unemployment skyrocketed. Since the euro rate was determined by factors mainly outside the control of Greece, she was stuck in a situation with no feasible options: a dramatic lowering of wage costs was politically almost impossible; leaving the euro area would have been extremely costly due to the large proportion of external debt. The prolonged period of policy uncertainty following the outbreak of the crisis contributed to the drop in confidence of the Greek economy, to the worsening of the depressed state of the economy, and to the increase of the already high unemployment rates.

An important lesson to be learnt from the results of this paper is that imbalances in the economy - whether internal or external - can be intolerable costly if they are allowed to accumulate over longer periods. Hence, a reliable monitoring system, that signals the build-up of crucial macroeconomic imbalances well ahead of the outbreak of a crisis, is likely to lower the probability of a similar disastrous drama in the future.

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6 Appendix: Residual analyses

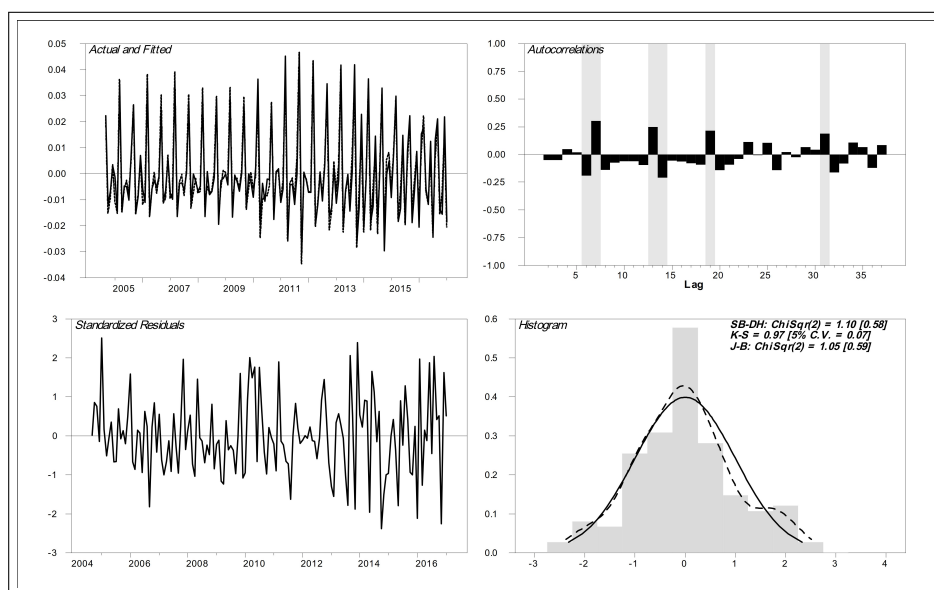


Figure 2: Graphs of actual and fitted change in the Greek inflation rate (upper left hand side panel), the standardized residuals (lower left hand side panel), the residual autocorrelogram (upper right hand side panel), and the residual histogram compared to the normal distribution.

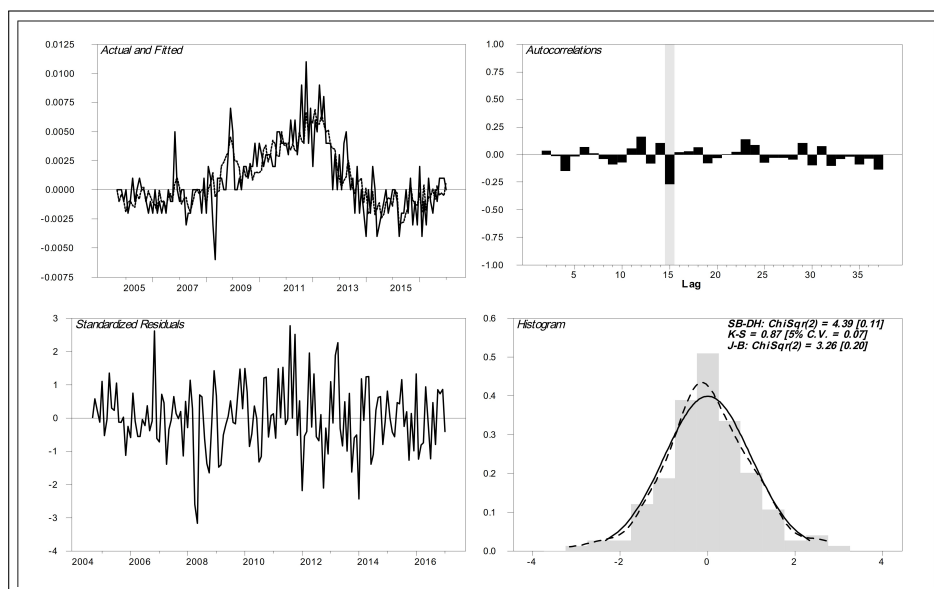


Figure 3: Graphs of actual and fitted change in the Greek unemployment rate (upper left hand side panel), the standardized residuals (lower left hand side panel), the residual autocorrelogram (upper right hand side panel), and the residual histogram compared with the normal distribution.

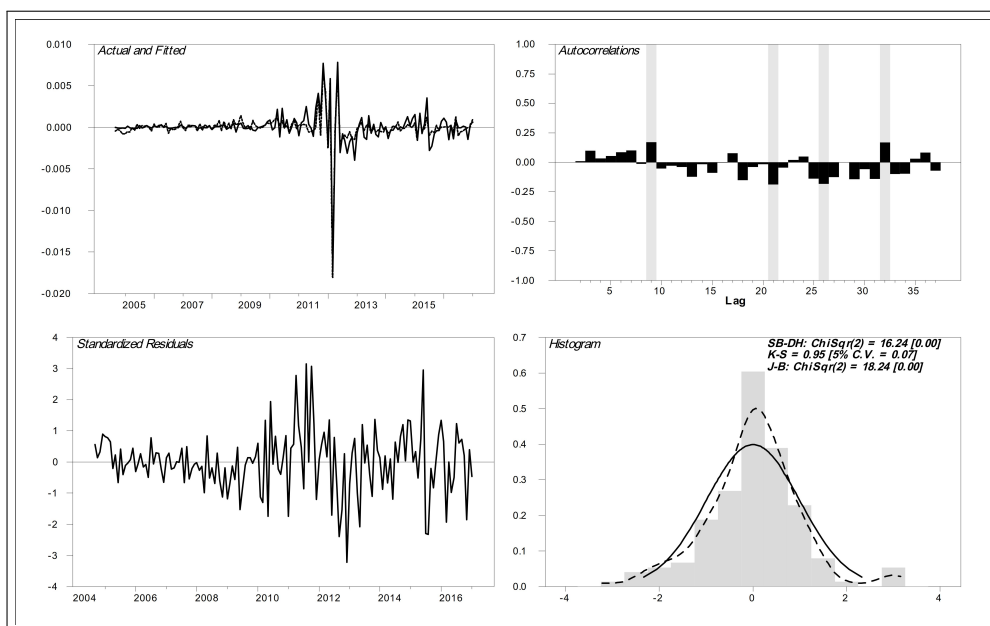


Figure 4: Graphs of actual and fitted change in the Greek bond rate (upper left hand side panel), the standardized residuals (lower left hand side panel), the residual autocorrelogram (upper right hand side panel), and the residual histogram compared to the normal distribution.

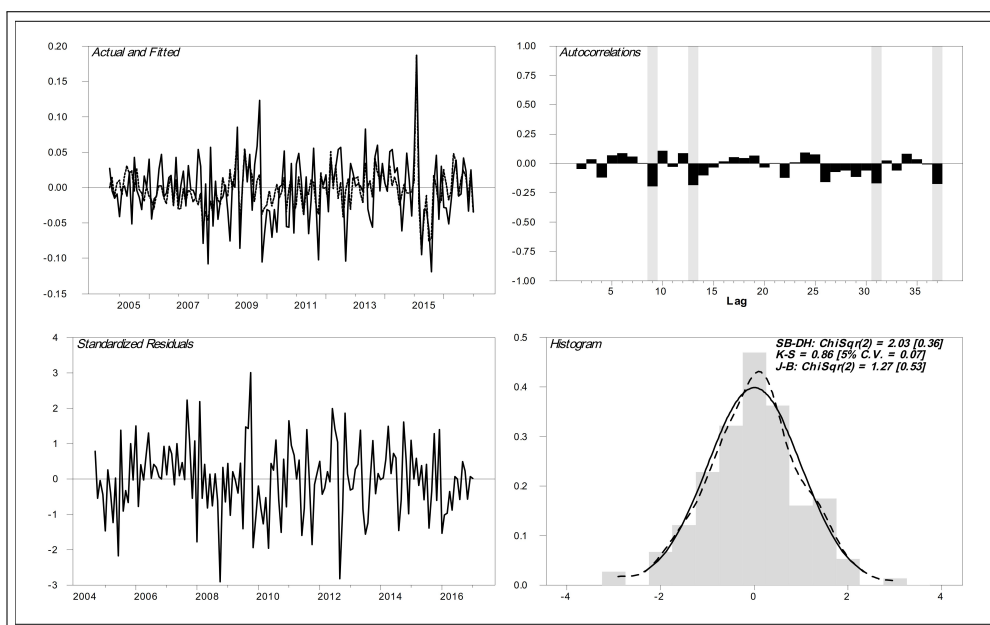


Figure 5: Graphs of actual and fitted change in confidence rate (upper left hand side panel), the standardized residuals (lower left hand side panel), the residual autocorrelogram (upper right hand side panel), and the residual histogram compared to the normal distribution.

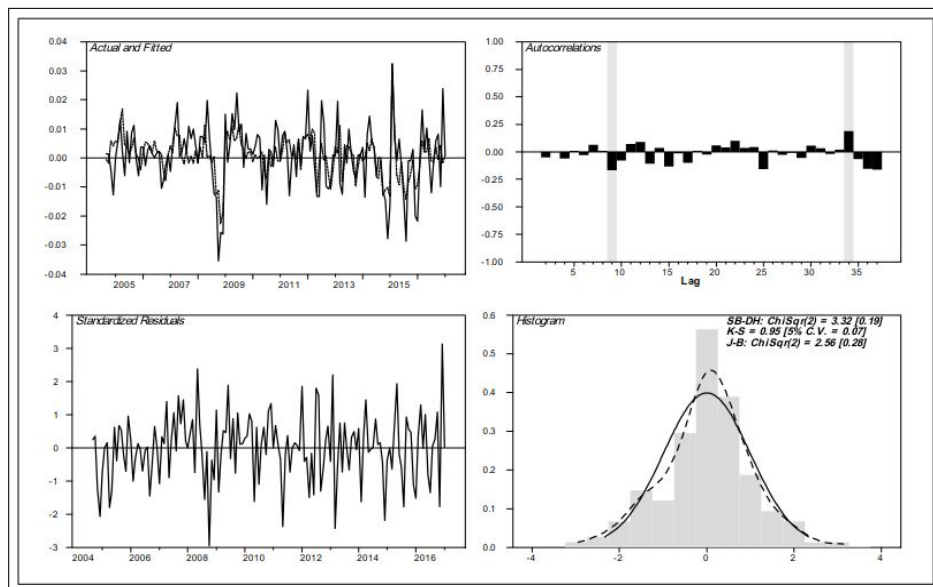


Figure 6: Graphs of actual and fitted change in the relative price between Greece and Germany (upper left hand side panel), the standardized residuals (lower left hand side panel), the residual autocorrelogram (upper right hand side panel), and the residual histogram compared to the normal distribution.

7 Appendix: Graphs of the equilibrium errors v_{it}

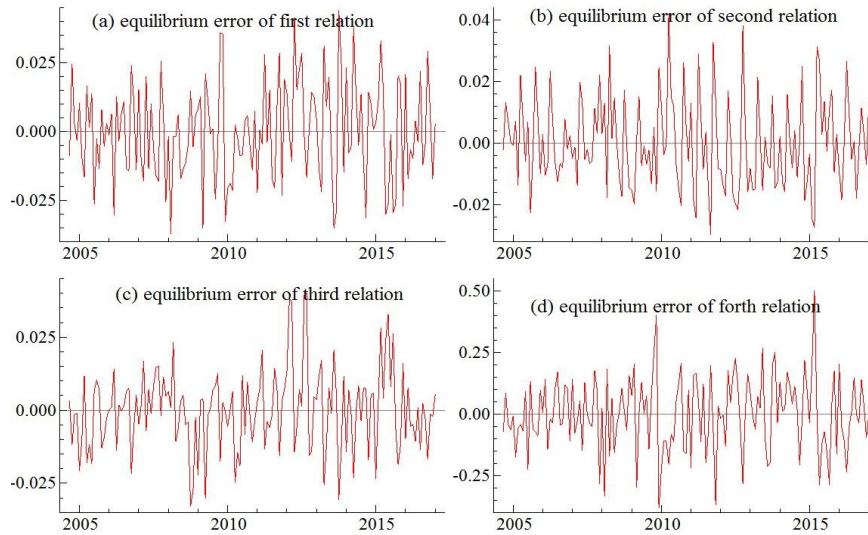


Figure 7: Graphs of the estimated cointegration relations. Panel (a) shows the equilibrium errors of the Phillips curve relation, panel (b) of the bond rate - unemployment rate crisis relationship, panel (c) of the Phelpsian natural rate relation, and panel (d) the confidence rate relation.

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