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Business Cycle Synchronisation in the Euro Area: a Sectoral and National Study

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Abstract
This thesis examines how business cycle synchronisation within the euro area changes after the onset of the 2007/2008 financial crisis, looking both at the sectoral and the national level. Three measures are used to study the change in synchronisation: correlation, relative volatility, and elasticity. The results show that synchronisation decreases post-crisis in terms of correlation and relative volatility, while there is no trend for elasticity. These results are consistent both at the sectoral and the national level, but, depending on the measure of synchronisation, not across all filters. In terms of correlation, industry and wholesale are the predominant sectors for national synchronisation, but it is not possible to observe any predominant sectors for relative volatility and elasticity. Greece appears to be the least synchronised EA-12 country; the level of correlation falls and the relative volatility increases, while the elasticity does not significantly change. Other countries show similar trends, but since Greece started out in a position of low synchronisation, while other countries did not, the case of Greece is especially problematic from an optimal currency area perspective.

Keywords: business cycles, currency area, euro area, financial crisis, synchronisation

JEL: E32, F15, F44, F45, G01

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1 Introduction

The establishment of the euro on 1 January 1999 was a monumental step towards achieving the European dream of an integrated economy. However, for the advantages of the single currency to outweigh its disadvantages, the currency area must satisfy the core requirements of an optimal currency area (OCA) (Mundell, 1961). One such requirement is business cycle synchronisation (Frankel and Rose, 1998).

In the case of the euro area, early studies show that business cycles to a considerable degree are synchronised and that synchronisation has increased after the introduction of the euro (Haan, Inklaar, and Jong-A-Pin, 2008). At first glance, these results would seem to suggest that the euro area has moved closer to OCA status. However, most of these studies look at a period of continuous economic growth, which according to Massmann and Mitchell (2004) is less of a challenge than a crisis for business cycle synchronisation. In the case of the euro area, countries are vulnerable to asymmetrical shocks because they have surrendered their independent monetary policies to the European Central Bank's (ECB) "one-size-fits-all" policy rate. Therefore, to understand the functioning of the currency area it is essential to evaluate how it withstands a crisis.

This thesis studies business cycle synchronisation within the euro area before and after the onset of the 2007/2008 financial crisis, looking both at the sectoral and the national level. The aim is to answer the following research question: how has business cycle synchronisation changed after the onset of the financial crisis and how have changes varied across sectors and countries? By studying sectoral business cycles, this thesis attempts to give an insight into the heterogeneous importance of sectors for national business cycle synchronisation.

Using quarterly data for seasonally adjusted real gross value added by an A*10 sector breakdown[1], the cyclical component is estimated by the BK filter and the HP filter for the EA-12 countries and five non-euro countries over the period 1999Q1–2017Q4. The BK filter is used as the primary filtering method, since the spectral density functions suggest that it is closer to an ideal filter, while the HP filter is used for robustness testing.

[1] Agriculture, industry, construction, wholesale, information, financial, real estate, professional, public, entertainment, and total

Business cycle synchronisation is calculated vis-à-vis a common cycle, estimated by a euro area average, to understand the functioning of the currency area as a whole. In contrast to the business cycle synchronisation literature at large, several measures of synchronisation are used: the Pearson correlation, a time variant correlation measure, the volatility, and the elasticity of the cyclical component.

The Pearson correlation shows that at the national level, all of the EA-12 countries, except Greece, are statistically correlated with the common cycle before and after the onset of the financial crisis. Periphery countries are generally less correlated than core countries. Furthermore, countries with a higher number of synchronised sectors have a tendency to be more synchronised at the national level. The two sectors (industry and wholesale) with the largest sectoral contributions to national business cycles synchronisation, as defined by Afonso and Furceri (2009), are also the most synchronised pre-crisis and post-crisis.

Using a time-variant correlation measure developed by Cerqueira (2013) as the dependent variable while controlling for *country_sector* fixed effects, the study finds that synchronisation decreases post-crisis at the national and the sectoral level. At the national level, Austria, France, Greece, and Spain experience the largest decreases. At the sectoral level, industry and wholesale experience a large number of structural shifts and are the predominant sectors for national synchronisation. Generally, the total sectoral contribution and the magnitude of the change affect synchronisation at the national level.

The relative volatility of country i to the euro area average moves further from one for most countries, suggesting that synchronisation decreases after the onset of the financial crisis at the national level. Ireland and Greece experience the largest changes in magnitude. At the sectoral level, most changes tend to co-move with changes at the national level, with the strong exception of public.

For elasticity, no well-defined trend can be observed, since there are few significant changes and these are in opposite directions. This is true both at the sectoral and the national level.

The results for Pearson correlation, relative volatility and elasticity are robust across filters. However, this is not the case in terms of time-variant correlation, but omitting the end points from the HP filter removes most of the inconsistences.

Based on the above results, we, in line with previous research (see e.g. Gächter and Riedl, 2014), find that Greece has the lowest level of synchronisation among the EA-12 countries; Greece's synchronisation decreases in terms of correlation and volatility, while its elasticity does not significantly change. These patterns suggest that synchronisation is more problematic at peaks and troughs when the need for unity among the EA-12 countries is especially important due to ECB's "one-size-fits-all" monetary policy. Spain experiences a similar decrease in synchronisation but the case of Greece is particularly problematic from an OCA perspective since the country did not start out from a position of strong synchronisation.

The relationship between volatility and elasticity suggests that, post-crisis, less of the variation in the former can be explained by the variation in the latter. Besides a general dispersion, the main driver of this phenomenon appears to be Greece becoming a noticeable outlier since the country shifts from being structurally different to having a divergent business cycle compared to the rest of the euro area. In other words, post-crisis, Greece's high volatility cannot be explained by its elasticity but rather by country-specific factors.

The rest of this thesis is structured as follows. Section 2 reviews the relevant literature, emphasising previous empirical work. Section 3 presents the data. Section 4 describes the methods used. Section 5 presents the results. Section 6 presents the robustness tests. Finally, Section 7 concludes.

2 Literature review

The theory of optimal currency areas (OCA) was pioneered by Mundell (1961) and was later built on by McKinnon (1963) and Kenen (1969). In brief, the theory states that for a certain geographical region, the advantages of a common currency outweigh the disadvantages of said currency. Advantages frequently mentioned include lower transaction costs, lower exchange rate risk, and increased trade, while the disadvantages primarily revolve around the loss of independent monetary policy. Research has mainly focused on four major criteria for the existence of an OCA (Frankel and Rose, 1998): trade, labour mobility, fiscal risk-sharing, and business cycle synchronisation (henceforth, synchronisation). The final criterion is the interest of this study.

It is theoretically ambiguous how synchronisation changes over time in the euro area.

On the one hand, there are theories which suggest that the euro area would lead to less synchronisation. Krugman (1991) and Krugman and Venables (1996) predict a decrease in synchronisation owing to an increase in inter-sector trade deriving from geographical specialisation due to low barriers to trade. Specialisation would then lead to lower synchronisation because of asymmetric shocks pertaining to certain, but not all, sectors.

On the other hand, there are theories which suggest that the euro area would lead to more synchronisation. Frankel and Rose (1998) and Rose (2000) suggest that synchronisation is endogenous. Countries with a large amount of trade are more likely to connect their currencies and linked currencies lead to increased synchronisation. A common currency leads to increased trade between countries, which in turn leads to a higher degree of synchronisation. Therefore, the euro area should achieve higher synchronisation, and thereby become an OCA, with time.

Empirical studies have produced a large output of results using an almost equally large number of different methods. The lack of homogeneity has often yielded conflicting results, which is why it is suitable to outline some of the more frequently used methods (data, business cycles, filtering techniques, and measures of synchronisation) before reviewing a subset of the empirical research.

The preferred measure of output is GDP followed by industrial production (Haan, Inklaar, and Jong-A-Pin, 2008). Using these measures, most studies examine the original euro area countries including Greece (EA-12) over varying time periods and focus on different clusters of countries, e.g. core and periphery[2] (see e.g. Beine, Candelon, and Sekkat, 2003; Belke, Domnick, and Gros, 2017b).

The standard definition of business cycles originates from Burns and Mitchell (1946) and refers to oscillations in business data with recurring periods between six and thirty-two quarters. According to the literature, there are two types of business cycles: classical cycles and growth cycles. Classical cycles are defined by Burns and Mitchell (1946) as the absolute expansion and contraction of economic activity, while growth cycles evaluate deviations from a long-term trend (Lucas, 1977). Modern research focuses mainly on growth cycles because growth recessions are more common and most empirical methods used to study synchronisation require stationary points (Haan, Inklaar, and Jong-A-Pin, 2008).

To evaluate business cycles, the two most commonly used filtering methods[3] are the BK filter (Baxter and King, 1999) and the HP filter (Hodrick and Prescott, 1997) (Haan, Inklaar, and Jong-A-Pin, 2008). The choice of filter may affect the results[4] because of their different de-trending techniques. This can be seen by, for example, the fact that the BK filter omits end points and has a tendency to underestimate the cyclical component, while the HP filter tends to estimate end points poorly and contain spurious effects (Harvey and Jaeger, 1993; Rand and Tarp, 2002; Darvas and Szapáry, 2004). Despite these facts, most studies do not perform robustness tests across filtering methods (Haan, Inklaar, and Jong-A-Pin, 2008).

The two most popular measures used to evaluate synchronisation are the Pearson correlation and the rolling window correlation (Haan, Inklaar, and Jong-A-Pin, 2008). However, in recent years, a correlation measure developed by Cerqueira (2013) has gained attention (see e.g. Gächter and Riedl, 2014; Belke, Domnick, and Gros, 2017b) as it does not suffer from the econometric issues normally associated with time-variant correlation measures. It is noteworthy that most empirical studies do not evaluate measures of synchronisation besides correlation.

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[2] Traditionally, the following countries are considered periphery: Greece, Ireland, Italy, Portugal, and Spain.

[3] The filter separates the output, Y_t, into a trend, T_t, and a cyclical component, C_t, so that $Y_t = T_t + C_t$. The trend, T_t, can be interpreted as the potential output and the cyclical component, C_t, as the output gap (Haan, Inklaar, and Jong-A-Pin, 2008).

[4] For a further discussion of whether different filtering techniques affect the results of business cycle synchronisation, see e.g. Artis and Zhang (1997), Frankel and Rose (1998), Canova (1998), Darvas and Szapáry (2004), Massman and Mitchell (2005), Haan, Inklaar, and Jong-A-Pin, (2008), and Degiannakis, Duffy, and Filis, (2014).

Moving to the empirical results, the consensus is largely positive towards the conclusion that business cycle synchronisation has increased within the euro area. Most studies find that synchronisation increases over time, some claim it originates from the introduction of the EMS (European Monetary System), others claim the early 1990s, while a third group claims the late 1990s with the introduction of the euro (Fatas, 1997; Altavilla, 2004). However, these studies have received strong criticism from those who have looked at the same time period but have used different methods (Inklaar and Haan, 2001; Harding and Pagan, 2002). Moreover, studies using more recent data find a decline in synchronisation (see e.g. Belke, Domnick, and Gros, 2017b).

Most studies reach the conclusion that synchronisation is not homogenous across countries. Both periphery countries (Beine, Candelon, and Sekkat, 2003) and new members of the EU (Eickmeier and Breitung, 2006) have been identified by a large number of studies to be less synchronised vis-à-vis the currency area as a whole.

The number of studies investigating synchronisation after the financial crisis has been limited, which is not surprising given the crisis' relative recency. So far, the literature finds that synchronisation has declined, especially highlighting differences between core and periphery countries. Examples of recent studies include Gächter, Riedl, and Ritzberger-Grünwald (2012) and Belke, Domnick, and Gros (2017b), who find that dispersion increases and correlation decreases after the 2007/2008 financial crisis. Nevertheless, Rosati (2017) finds evidence that synchronisation in the euro area reached its trough in 2011 with the sovereign debt crisis.

While the above mentioned results refer to synchronisation at the national level, the interest in sectoral synchronisation has been limited. The most notable exemption is Afonso and Furceri (2009), who study sectoral synchronisation by comparing a broad selection of European countries. Using annual data of gross value added and a coarse division of sectors, the authors examine which sectors drive synchronisation within the euro area. The study finds that the three main drivers of national synchronisation are industry, building and construction, and agriculture, fishery, and forestry.

3 Data

This study uses quarterly data for seasonally adjusted real gross value added by an A*10 sector breakdown from Eurostat.[5] Gross value added is defined as the difference between output and intermediate consumption.

The dataset covers the period from 1999Q1 to 2017Q4 and is divided into two time periods: pre-crisis (1999Q1–2007Q4) and post-crisis (2008Q1–2017Q4). The first period runs from the introduction of the euro until the beginning of the financial crisis[6], while the second period covers the phase following the onset of the financial crisis until 2017Q4.

NACE Rev.2 Code	Short sector name	Full sector name
A	Agriculture	Agriculture, forestry, and fishing
BE	Industry	Industry (except construction)
F	Construction	Construction
GI	Wholesale	Wholesale and retail trade, transport, accommodation, and food service activities
J	Information	Information and communication
K	Financial	Financial and insurance activities
L	Real estate	Real estate activities
MN	Professional	Professional, scientific and technical activities; administrative and support service activities
OQ	Public	Public administration, defence, education, human health, and social work activities
RU	Entertainment	Arts, entertainment and recreation; other service activities; activities of household and extra-territorial organizations and bodies
TO	Total	Total gross value added

Table 1. A*10 sectors as classified by Eurostat and total gross value added.

The dataset includes the EA-12 countries[7] to cover the full period following the establishment of the euro. Five non-euro countries (Denmark, Norway, Sweden, Switzerland, and the United Kingdom)[8] are included to observe whether the results are euro area specific or not.

[5] Giannone et al. (2010) argue against the general usage of quarterly data for business cycle studies. Their criticism is not relevant to this study because we use readily available and modern data for developed countries.
[6] The date for the onset of the financial crisis reflects previous work by Bekiros, Nguyen, Uddin, and Sjö (2015) and Bekiros, Belke, Domnick, and Gros (2017a)
[7] The eleven countries that adopted the Euro in 1999 (Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, The Netherlands, Portugal, and Spain) and Greece that joined in 2001. See Table A.1 for ISO codes
[8] See Table A.1 for ISO codes.

4 Method

4.1 Sectoral contribution

To evaluate the heterogenous importance of sectors for national synchronisation, this study uses a method for non-linear filters developed by Afonso and Furceri (2009) to estimate the sectoral contribution to national synchronisation (henceforth, sectoral contribution):[9]

$$w_{i\,s} = \frac{y_{i\,s}}{y_{i\,TO}} \times \frac{\sigma_{C_{i\,s}}}{\sigma_{C_{i\,TO}}} \tag{1}$$

$w_{i\,s}$ = sectoral contribution of country *i* in sector *s*

y_{is} = gross value added of country *i* in sector *s*

$y_{i\,TO}$ = total gross value added of country *i*

$\sigma_{C_{i\,s}}$ = standard deviation of the cyclical component of country *i* in sector *s*

$\sigma_{C_{i\,TO}}$ = standard deviation of the total cyclical component of country *i*

The total sector is used as a proxy for national business cycles.

4.2 Business cycles and filtering methods

In accordance with the literature, this study examines growth cycles and uses the natural logarithm of gross value added. Following the recommendation of several studies (see e.g. Haan, Inklaar, and Jong-A-Pin, 2008), the cyclical component is estimated by the BK filter and the HP filter. To examine which filter is ideal for this study, the spectral density functions are plotted on periodograms.

The HP filter uses the standard smoothing parameter of $\lambda = 1600$ for quarterly data and a cut-off frequency of 32 quarters (Ravn and Uhling, 2002). The BK filter admits frequencies between six and thirty-two quarters with a lead-lag length equal to 12 quarters, which are the standard parameters suggested by Baxter and King (1999). Consequently, the cyclical

[9] Given that the filters are non-linear, the sectoral contributions will not sum to 100%. To compare $w_{i\,s}$ between countries, the following two steps are used to rescale the variables:
(1) $w_{i\,s}^{Total} = \sum_{j=i}^{n} w_{i\,s}$ (2) $w_{i\,s}^{scaled} = \frac{w_{i\,s}}{w_{i\,s}^{Total}}$

component for the BK filter is limited to the period 2002Q1–2014Q4, while the cyclical component for the HP filter contains the full period of 1999Q1– 2017Q4.

4.3 Correlation

Correlation is measured between *country_sector* (country *i* and sector *s*) and a common cycle EA (estimated by the simple average of the EA-12 countries). The common cycle is used to illustrate the functioning of the currency union as a whole. The 5% significance level is used.

4.3.1 Pearson correlation

The Pearson correlation is calculated pre-crisis and post-crisis to observe the level of synchronisation in both time periods. A *country_sector* is believed to be synchronised with the common cycle if they are positively and significantly correlated with each other. The Pearson correlation coefficient ($\rho_{i\,s\,p}$) is defined as follows:

$$\rho_{i\,s\,p} = \frac{cov\left(C_{i\,s\,p}, C_{EA\,s\,p}\right)}{\sigma_{C_{i\,s\,p}}\sigma_{C_{EA\,s\,p}}} \tag{2}$$

$C_{i\,s\,p}$ = cyclical component of country *i* and sector *s* in period p

$C_{EA\,s\,p}$ = cyclical component of *EA* and sector *s* in period p

$\sigma_{C_{i\,s\,p}}$ = standard deviation of the cyclical component of country *i* and sector *s* in period p

$\sigma_{C_{EA\,s\,p}}$ = standard deviation of the cyclical component of EA and sector *s* in period p

p = Period (pre-crisis or post-crisis)

4.3.2 Time-variant correlation measure

To account for time variability, a correlation measure first developed by Cerqueira and Martins (2009) and later refined by Cerqueira (2013) is used. The model (henceforth, CM) is used with cyclical data by, among others, Gächter and Riedl (2014) and Belke, Domnick, and Gros (2017b).

$$\rho_{i\,s\,t}^{tv} = 1 - \frac{1}{2}\left(\frac{C_{i\,s\,t} - \overline{C_{\iota\,s}}}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(C_{i\,s\,t} - \overline{C_{\iota\,s}})^2}} - \frac{C_{EA\,s\,t} - \overline{C_{EA\,s}}}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(C_{EA\,s\,t} - \overline{C_{EA\,s}})^2}}\right)^2 \tag{3}$$

$$\rho_{i\,s\,t}^{CM} = \frac{1}{2}\ln\left(\frac{1 + \frac{\rho_{i\,s\,t}^{tv}}{2T-3}}{1 - \rho_{i\,s\,t}^{tv}}\right) \tag{4}$$

$\rho_{i\,s\,t}^{CM}$ = CM

$\rho_{i\,s\,t}^{tv}$ = the correlation measured developed by Cerqueira and Martins (2009)

$C_{i\,s\,t}$ = cyclical component of country *i* and sector *s* at quarter t

$C_{EA\,s\,t}$ = cyclical component of *EA* and sector *s* at quarter *t*

$\overline{C_{\iota\,s}}$ = average cyclical component of country *i* and sector *s*

$\overline{C_{EA\,s}}$ = average cyclical component of *EA* and sector *s*

T = total number of quarters

There are four benefits of the CM compared to the commonly used method of rolling windows. Firstly, it removes the need to select an arbitrary window span; secondly, no observations are lost; thirdly, the problem of ghost features[10] is reduced; lastly, the econometric problem of heavily autocorrelated variables is eliminated (Degiannakis, Duffy, and Filis, 2014; Gächter and Riedl 2014).

To test how synchronisation changes post-crisis, the study adopts the following *country_sector* fixed effect OLS regression model[11]:

$$\rho_{i\,s\,t}^{CM} = \beta_1 country\_sector_{i\,s} \times crisis_t + \delta_{i\,s} + \epsilon_{i\,s\,t} \tag{5}$$

The dependent variable $\rho_{i\,s\,t}^{CM}$ is the CM measure calculated in equation (4). The interaction term consists of a dummy variable for each *country_sector* and a crisis dummy equal to 1 for the post-crisis period and 0 otherwise.

[10] A temporary shock that is immediately reversed will affect the moving-average for n/2 periods before and after the shock occurred, where n equals the length of the rolling window. For more details, see Penza and Bansai (2001).

[11] Time fixed effects are not included because it would exhaust the degrees of freedom.

If β_1 is significant, country *i* experiences a structural shift in synchronisation vis-á-vis *EA* for sector *s*. For example, if β_1 is significantly negative ($\beta_1 < 0$), synchronisation decreases post-crisis.

4.4 Amplitude

Altavilla (2004) argues that using correlation as a measure of synchronisation is misleading if business cycles have different amplitudes. For example, two countries can have perfectly correlated business cycles, but if their amplitudes differ they will have different optimal policy rates (see Figure 1). These differences are more pronounced at the peaks and the troughs of cycles, which emphasises the importance of studying a crisis period to understand the functioning of a currency area.

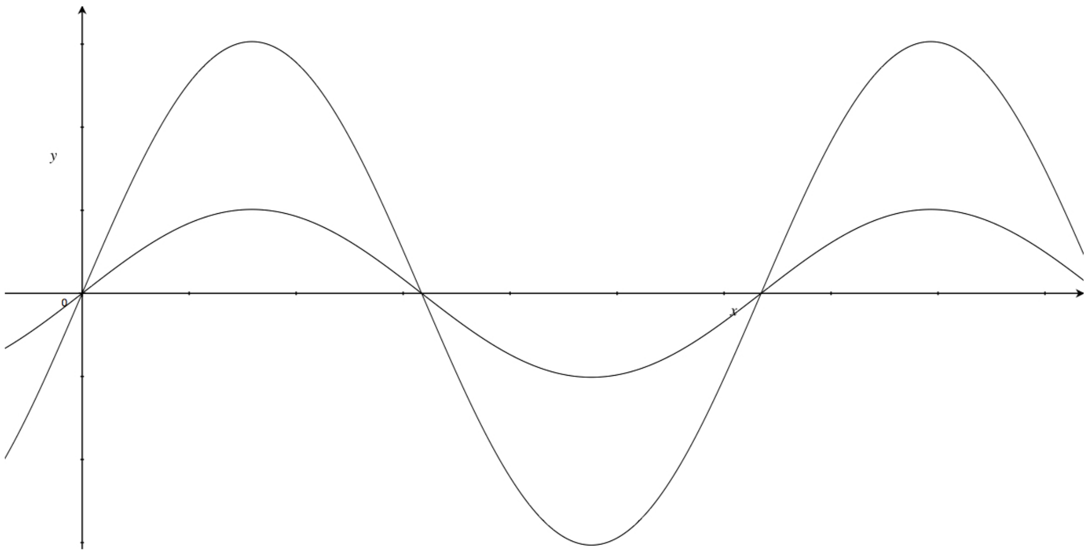

Figure 1: Illustration of differences in amplitude for two perfectly correlated cycles

Two explanations for differences in amplitude are volatility and elasticity.

4.4.1 Relative volatility

The volatility is defined as the standard deviation of the cyclical component and is estimated for each *country_sector*. To examine the change in synchronisation, the relative volatility is calculated pre-crisis and post-crisis. The relative volatility is defined as the ratio of the standard deviation of each *country_sector* to the standard deviation of the corresponding common cycle.

$$\sigma_{C_{i\,s\,p}}^{Relative} = \frac{\sigma_{C_{i\,s\,p}}}{\sigma_{C_{EA\,s\,p}}} \tag{6}$$

A relative volatility equal to one suggests that the cycles are perfectly synchronised in terms of volatility. Therefore, to study how synchronisation changes, it is observed whether the relative volatility moves closer to or further from one using the following equation:

$$\alpha_{i\,s} = \left| \frac{\sigma_{C_{i\,s\,pre-crisis}}}{\sigma_{C_{EA\,s\,pre-crisis}}} - 1 \right| - \left| \frac{\sigma_{C_{i\,s\,post-crisis}}}{\sigma_{C_{EA\,s\,post-crisis}}} - 1 \right| \tag{7}$$

A positive (negative) value of $\alpha_{i\,s}$ suggests that the synchronisation increases (decreases). The size of the coefficient shows how much closer to (further from) one the relative volatility is post-crisis.

4.4.2 Elasticity

For the functioning of the euro area, it is important to understand which sectors and countries are sensitive to changes in the common cycle (Belke, Domnick, and Gros, 2017a). A measure of this is elasticity, which is estimated by the following regression:

$$c_{i\,s\,t} = \beta_0 + \beta_1 c_{EA\,s\,t} + u_{i\,s\,t} \tag{8}$$

The dependent variable $c_{i\,s\,t}$ is the cyclical component of *country_sector* at time *t* and $c_{EA\,s\,t}$ is the cyclical component of *EA* and sector *s* at time *t*. The regression is run for the pre-crisis and the post-crisis period, respectively.

To understand how the elasticity changes post-crisis, the following regression is run using robust standard errors (Belke, Domnick, and Gros, 2017a) for each *country_sector*:

$$c_{i\,s\,t} = \beta_0 + \beta_1 c_{EA\,i\,s} + \beta_2 crisis_t + \beta_3 c_{EA\,i\,s} crisis_t + u_{i\,s\,t} \tag{9}$$

The dependent variable $c_{i\,s\,t}$ is the cyclical component of *country_sector* at time *t*, $crisis_t$ is a dummy variable equal to 1 if post-crisis and 0 otherwise, and $c_{EA\,i\,s}$ is the cyclical component of *EA* and sector *s* at time *t*. A *country_sector* is believed to be more (less) synchronised with the common cycle if the sum of β_1 and β_3 is closer to (further from) unit elasticity than β_1. This relationship is examined for each *country_sector* with the following equation:

$$\delta_{i\,s} = |\beta_{1i\,s} - 1| - |\beta_{1\,i\,s} + \beta_{3\,i\,s} - 1| \tag{10}$$

The above nonlinear combination of the estimators β_1 and β_3 is used to test for significant change in elasticity.[12] The 5% significance level is used. A positive (negative) value of $\delta_{i\,s}$ suggests that the synchronisation increases (decreases). This way of interpreting the elasticity is in sharp contrast with Belke, Domnick, and Gros (2017a), who only look at the direction of the change and whether the change is significant. This fails to take into consideration that both an increase and a decrease in elasticity could imply an increase in synchronisation depending on the pre-crisis elasticity.

4.4.3 The relationship between volatility and elasticity

Since elasticity effects volatility, the relationship is examined by plotting the two measures on scatter diagrams pre-crisis and post-crisis. A high R-squared suggests that much of the variation in volatility can be explained by the variation in elasticity for countries that lie on the fitted line.

Countries that cluster on the fitted line but still outside the main cluster are defined as structurally different from the euro area average, i.e. their economic structures make them more sensitive to the common cycle. Countries that lie outside the trend line are defined as having divergent business cycles since their volatilities to a larger extent are explained by country-specific factors (Belke, Domnick, and Gros, 2017a).

[12] The following null hypothesis is tested against a one-sided alternative:

$$H_0: |\beta_1 - 1| - |\beta_1 + \beta_3 - 1| = 0$$

5 Results

5.1 Sectoral contribution

According to Table 2, the sectoral contribution is relatively homogenous across the EA-12 countries with industry and wholesale having the largest sectoral contributions. Two notable exemptions are Greece and Luxembourg, where industry has a relatively small sectoral contribution. Moreover, the sectoral contribution of financial is large in Luxembourg, while the sectoral contribution of real estate is large in Greece.

Country	A	BE	F	GI	J	K	L	MN	OQ	RU	To
AUT	3%	44%	9%	16%	4%	5%	4%	9%	4%	1%	100%
BEL	2%	26%	7%	19%	4%	14%	4%	17%	5%	2%	100%
DEU	3%	45%	4%	14%	6%	8%	4%	11%	4%	1%	100%
ESP	5%	25%	18%	18%	3%	6%	4%	10%	9%	2%	100%
FIN	2%	44%	8%	19%	5%	4%	6%	7%	3%	1%	100%
FRA	7%	19%	8%	19%	8%	6%	8%	19%	4%	2%	100%
GRC	4%	9%	13%	25%	4%	6%	14%	7%	10%	6%	100%
IRL	2%	46%	4%	11%	8%	8%	5%	9%	4%	1%	100%
ITA	2%	40%	6%	21%	4%	6%	5%	9%	4%	3%	100%
LUX	1%	17%	6%	16%	10%	28%	4%	11%	5%	1%	100%
NLD	2%	21%	12%	24%	5%	6%	3%	18%	8%	2%	100%
PRT	3%	24%	13%	17%	4%	9%	7%	9%	12%	2%	100%
CHE	1%	35%	4%	15%	4%	22%	4%	9%	4%	2%	100%
DNK	5%	23%	8%	27%	5%	8%	6%	9%	8%	2%	100%
GBR	1%	15%	12%	20%	5%	9%	5%	20%	9%	4%	100%
NOR	3%	30%	12%	17%	3%	7%	5%	14%	7%	2%	100%
SWE	2%	43%	9%	13%	8%	3%	8%	11%	4%	1%	100%
Average	3%	30%	9%	18%	5%	9%	5%	11%	6%	2%	100%

Table 2. The weights of sectoral contribution, as defined by Afonso and Furceri (2009), for the BK filter.[13]

5.2 Business cycles and filtering methods

The periodograms show that both the BK filter and the HP filter remove unwanted oscillations longer than 32 quarters from the cyclical component. However, the BK filter removes all unwanted oscillations shorter than six quarters, while the HP filter does not remove frequencies below its cut-off frequency. As a result, the BK filter is closer to an ideal filter in this case. However, there are other aspects to consider (see Section 2) when evaluating filters, so it is not appropriate to completely discard the HP filter. Therefore, the analysis will focus on the BK filter, while using the HP filter for robustness testing.

[13] The results are robust for the HP-filter.

5.3 Correlation

5.3.1 Pearson correlation

At the national level, as seen in Table 3 and 4, all countries, except Greece, are statistically correlated with the common cycle both pre-crisis and post-crisis. Among the significantly correlated countries, there are differences across core and periphery countries; Portugal is the least synchronised EA-12 country pre-crisis, while Spain, Ireland, and Portugal are the least synchronised countries post-crisis.

Country	A	BE	F	GI	J	K	L	MN	OQ	RU	TO
AUT	0.77*	0.99*	0.54	0.91*	0.55	0.66	-0.19	0.91*	0.17	0.73*	0.99*
BEL	0.39	0.80*	0.72*	0.35	0.58	0.59	-0.44	0.68*	-0.29	0.68*	0.91*
DEU	0.85*	1.00*	0.71*	0.93*	0.99*	0.88*	0.66	0.97*	0.90*	0.97*	0.97*
ESP	0.25	0.97*	0.81*	0.96*	0.65	0.86*	0.76*	0.96*	-0.39	0.73*	0.98*
FIN	-0.30	0.98*	0.46	0.54	0.59	0.58	0.41	0.83*	0.07	0.49	0.95*
FRA	0.79*	0.98*	0.98*	0.91*	0.81*	-0.11	0.20	0.89*	-0.40	-0.16	0.95*
GRC	-0.05	0.63	0.52	0.08	0.80*	-0.04	0.41	0.64	-0.50	0.62	0.57
IRL	0.87*	0.61	0.76*	0.95*	0.69*	0.80*	0.36	0.40	-0.20	0.74*	0.94*
ITA	0.78*	0.99*	0.89*	0.89*	0.72*	0.67	-0.36	0.59	0.79*	0.95*	0.99*
LUX	0.57	0.57	0.85*	0.51	0.66	0.79*	0.75*	0.52	0.64	0.63	0.96*
NLD	0.64	0.82*	0.83*	0.97*	0.88*	0.77*	0.51	0.90*	0.69*	0.44	0.99*
PRT	0.71*	0.81*	0.60	0.68*	0.97*	0.54	0.59	0.78*	0.45	-0.25	0.85*
CHE	0.86*	0.91*	-0.77*	0.86*	0.58	0.40	0.00	0.47	0.81*	-0.01	0.95*
DNK	0.13	0.64	0.73*	0.91*	0.18	0.53	-0.22	-0.03	0.77*	-0.23	0.83*
GBR	-0.22	0.95*	0.44	0.93*	0.29	0.38	-0.30	0.83*	-0.25	-0.03	0.73*
NOR	0.69*	-0.52	0.81*	0.94*	0.05	0.34	0.82*	0.88*	-0.29	0.03	0.74*
SWE	0.34	0.92*	0.97*	0.84*	0.01	0.42	0.33	0.83*	0.56	0.52	0.94*

Table 3. Pearson correlation coefficients for the BK filter. Pre-crisis (2002Q1–2007Q4). * indicates significance at the 5% level.

Country	A	BE	F	GI	J	K	L	MN	OQ	RU	TO
AUT	0.50	0.94*	0.53	0.85*	0.85*	-0.17	0.32	0.96*	0.86*	0.66*	0.96*
BEL	-0.14	0.94*	0.38	0.92*	-0.21	0.67*	-0.32	0.80*	-0.40	0.08	0.99*
DEU	0.58	0.99*	0.11	0.85*	0.89*	0.62	0.85*	0.96*	0.87*	0.84*	0.95*
ESP	0.45	0.85*	0.75*	0.82*	0.28	0.60	0.36	0.78*	0.94*	0.82*	0.75*
FIN	0.19	0.93*	0.47	0.97*	0.78*	0.05	0.61	0.83*	0.40	0.64*	0.98*
FRA	0.66*	0.89*	0.76*	0.96*	0.85*	-0.25	-0.35	0.95*	-0.81*	0.65*	0.95*
GRC	-0.55	-0.62	-0.29	0.32	-0.24	-0.05	-0.14	0.13	0.70*	0.07	-0.04
IRL	0.74*	0.45	0.55	0.87*	0.06	0.44	0.29	0.78*	0.51	0.77*	0.77*
ITA	0.29	0.99*	0.90*	0.92*	0.30	0.55	0.47	0.82*	0.47	0.46	0.97*
LUX	-0.41	0.46	0.55	0.75*	0.25	0.24	0.48	0.88*	-0.58	-0.26	0.82*
NLD	0.60	0.95*	0.83*	0.96*	0.89*	0.50	0.31	0.80*	0.68*	0.84*	0.97*
PRT	0.27	0.95*	0.87*	0.42	0.63*	0.56	-0.22	0.41	0.76*	0.91*	0.70*
CHE	0.41	0.93*	-0.40	0.43	-0.13	0.41	0.72*	0.47	-0.16	0.02	0.92*
DNK	-0.65*	0.86*	0.47	0.74*	0.28	0.39	-0.40	0.71*	0.55	0.23	0.96*
GBR	0.52	0.97*	0.53	0.86*	0.55	0.01	-0.60	0.86*	-0.41	0.28	0.89*
NOR	-0.35	-0.06	0.44	0.74*	0.17	-0.25	0.61	0.43	0.45	0.43	0.52
SWE	0.55	0.96*	0.71*	0.87*	0.48	0.23	0.55	0.79*	0.54	0.61	0.95*

Table 4. Pearson correlation coefficients for the BK filter. Post-crisis (2008Q1–2014Q4). * indicates significance at the 5% level.

Countries with a higher number of synchronised sectors have a tendency to be more synchronised at the national level. Furthermore, sectors with a high sectoral contribution tend be more synchronised as seen by industry, wholesale, and professional which are the most synchronised sectors.

Non-euro countries are less correlated with the common cycle both at the sectoral and the national level compared to the EA-12 countries. This is not surprising since the non-euro countries are not included in the euro area average (EA).

5.3.2 Time-variant correlation measure

The results from regression (5), presented in Table 5, show that national synchronisation decreases post-crisis, as seven EA-12 countries experience a negative national structural shift. Similarly, a large majority of all sectoral structural shifts are negative, which shows that sectoral synchronisation also decreases post-crisis.

The results show that sectors with a high relative share of total gross value added (see Table A.4) change more frequently compared to smaller sectors; industry, wholesale, and public account for nearly two-thirds of all negative sectoral structural shifts among the EA-12 countries. Moreover, at least one of these sectors change significantly for all countries that experience a structural shift at the national level.

However, as Afonso and Furceri (2009) find, large sectors are not necessarily the main drivers of national synchronisation. Table 5 shows that both the magnitude of the sectoral change and the sectoral contribution have an impact on national synchronisation. This is most clearly illustrated by Belgium and France, where wholesale and industry have a considerable impact on national synchronisation. Two other examples are Austria and Spain where large sectoral changes in industry and wholesale contribute to the largest negative national structural shifts among the EA-12. In contrast, public appears to have a limited impact on national synchronisation as seen by the fact that Finland, Ireland, or Italy do not change at the national level.

Non-euro countries do not experience any structural shifts at the national level, but change more frequently at the sectoral level. Thus, the sectoral contribution does not have explanatory power for the non-euro countries. This suggests that sectoral desynchronisation is not a euro area specific phenomenon, while it is for national desynchronisation. This provides ample opportunity for further research.

Country	A	BE	F	GI	J	K	L	MN	OQ	RU	To
AUT	-0.08	-0.51*	-0.23	-0.97*	0.33	-0.14	-0.08	0.15	0.28	-0.41	-1.11*
BEL	-0.21	0.31	-0.24	0.87*	0.21	0.03	-0.39	-0.15	-0.56*	-0.63	0.87*
DEU	-0.39	-0.56	-1.02*	-0.78*	-0.12	-0.36	0.67*	-0.44	0.16	-0.93*	-0.37*
ESP	0.27	-1.15*	-0.40	-0.89*	-0.29	0.04	0.21	-0.39	0.36	-0.23	-1.33*
FIN	0.11	-0.63	-0.07	0.17	0.61	0.19	-0.41	-0.33	-0.58*	-0.08	0.18
FRA	0.38	-0.60*	-0.17	-0.01	0.54	0.54	0.43	0.08	-0.35	0.69	-0.70*
GRC	0.20	-0.88*	-0.10	-0.09	-0.70*	0.97*	0.01	-0.70	-0.23	-0.71*	-0.69*
IRL	0.13	-0.41	-0.39	-0.23	0.00	-0.15	0.01	0.09	-0.62*	0.55	-0.18
ITA	0.39	0.03	0.42	-0.41	0.01	0.14	0.38	0.44	-0.50*	-0.58	-0.42
LUX	-0.22	-0.35	-0.32	-0.09	-1.23*	-0.41	-0.27	0.51	-0.84*	-0.58	-0.63*
NLD	0.08	0.07	0.34	-0.21	0.40	-0.13	-0.79*	-0.21	-0.17	1.18*	0.38
PRT	0.06	0.00	0.32	-0.60*	-0.42	0.47	-0.61*	-0.63*	-0.11	0.90*	-0.62*
CHE	-0.47	-0.04	-0.18	-0.92*	0.04	0.63	0.57*	-0.39	0.04	-0.09	-0.45
DNK	-0.10	0.19	-0.84*	-1.07*	-0.24	0.48	-0.57*	0.75*	-0.31	0.22	0.01
GBR	0.60	-0.19	0.10	-0.45	-0.01	-0.18	0.18	-0.22	-0.74*	0.28	0.32
NOR	-0.80*	0.52	-1.04*	-0.84*	1.02	0.33	0.08	-0.94*	0.51	0.19	-0.30
SWE	0.73*	-0.22	-1.20*	-0.09	0.37	-0.13	0.05	0.30	-0.33	0.36	0.46

Table 5. Changes in correlation as seen in regression (5) for the BK filter. * indicates significance at the 5% level.

5.4 Amplitude

5.4.1 Relative volatility

At the national level, as seen in Table 6, the relative volatility moves further from one for most EA-12 countries, including a substantial number of the core countries, making them less synchronised. All periphery countries, except Portugal, become less synchronised, but the level of desynchronisation is generally not greater than for the core countries. Three exceptions are Greece and Ireland, which experience the largest decreases in synchronisation, and Luxembourg, which experiences the largest increase in synchronisation.

At the sectoral level, the relative volatility moves further from one for most *country_sectors*, with the strong exception of public. Additionally, the magnitude of sectoral change varies across sectors; industry and professional experience the smallest absolute changes in synchronisation, while public and real estate experience the largest changes in magnitude. Based on the reasoning in Section 5.1, changes in professional, public, and real estate should have a limited impact on national synchronisation, while industry's impact should be large. However, it is difficult to evaluate sectoral contribution given that the method of choice does not take significance into consideration.

Country	A	BE	F	GI	J	K	L	MN	OQ	RU	TO
AUT	-0.97	0.29	0.09	-0.04	-0.32	-0.69	-2.08	0.10	0.39	-0.33	0.01
BEL	-1.58	-0.10	0.48	-0.09	-0.18	-1.69	-1.55	0.33	0.55	-0.46	0.06
DEU	-1.46	-0.15	-0.49	0.31	0.20	-0.90	-0.88	-0.11	2.08	-0.21	-0.06
ESP	-0.65	0.24	-1.70	0.19	0.57	-1.10	1.74	0.43	-1.47	-0.46	-0.13
FIN	0.43	0.43	-0.59	-0.59	0.02	-1.16	-3.91	-0.33	0.52	-0.53	-0.21
FRA	-0.51	-0.14	0.19	0.27	-0.64	-0.23	1.93	-0.02	0.51	0.13	-0.04
GRC	-0.51	0.04	4.00	-1.31	-3.83	-1.93	2.74	-0.39	0.88	-7.22	-0.72
IRL	-2.23	-1.05	-1.90	0.99	-0.71	-3.02	3.28	1.40	2.80	0.53	-0.52
ITA	-0.31	0.05	-0.05	-0.02	-0.01	-0.58	-0.60	-0.18	0.99	0.71	-0.03
LUX	-0.47	0.74	0.63	-0.99	-3.05	-1.36	0.71	-0.03	2.74	-0.98	0.54
NLD	0.48	0.02	-1.14	0.19	-0.17	-0.04	-3.09	0.17	3.08	0.37	-0.02
PRT	-0.03	-0.02	-0.57	-0.26	-0.19	-1.46	-1.28	0.02	0.96	-1.24	0.14
CHE	-0.28	-0.05	0.03	-0.10	-0.04	-0.81	-0.78	-0.17	2.45	-1.53	-0.25
DNK	-3.37	0.04	-0.93	0.63	-0.97	-2.35	-3.81	0.81	3.21	-0.52	-0.04
GBR	-0.74	0.04	-1.43	-0.02	0.05	-1.16	0.72	0.37	5.09	0.02	0.01
NOR	-0.68	-0.19	-0.37	0.36	-0.06	-1.13	2.16	0.72	2.44	1.04	-0.07
SWE	-0.01	-0.49	0.47	-0.19	-2.05	-0.27	-5.19	0.93	2.24	-0.05	-0.26

Table 6. Changes in relative volatility as seen in equation (7) for the BK filter.

There are no considerable differences across the EA-12 countries and the non-euro countries. This suggests that the increase in relative volatility is not a euro area specific phenomenon.

5.4.2 Elasticity

As seen in Table 7, the level of synchronisation does not change in a specific direction neither at the national nor the sectoral level. At the national level, three EA-12 countries move closer to unit elasticity, while two countries move further away. At the sectoral level, less than half of all *country_sectors* change significantly, with an even distribution between positive and negative changes.

Agriculture and construction experience the highest number of negative changes, while wholesale experiences the highest number of positive changes. However, it is ambiguous how sectoral changes affect national synchronisation. This is not surprising since a *country_sector* may have a pre-crisis elasticity either below or above one, which means that a move towards unit elasticity can either be caused by an increase or decrease in elasticity. Thus, increases and decreases in sectoral synchronisation might work in opposite directions when affecting the national synchronisation.

Non-euro countries display a similar pattern to the EA-12 countries with frequent sectoral changes but few national changes.

Country	A	BE	F	GI	J	K	L	MN	OQ	RU	TO
AUT	0.30	0.27*	-0.07	-0.08	0.09	-1.04*	1.11	0.22*	0.59*	0.25	0.05
BEL	-0.73*	0.02	-0.56*	0.48*	-0.74*	-1.11*	-0.35	-0.20	0.02	-0.80*	0.11
DEU	0.08	-0.13*	-0.53*	0.44*	0.38*	-0.06	-1.22*	-0.09	1.91*	0.02	-0.03
ESP	0.52	0.13*	-0.82*	0.03	0.02	-0.28	0.91	0.59*	-0.57	0.06	-0.09
FIN	0.35	0.49*	0.06	-0.78*	0.05	-0.73	-2.24*	0.10	0.39	0.51*	-0.26*
FRA	-0.10	-0.18*	-0.16	0.30*	-0.20	-0.23	-1.33*	0.14	0.35	0.96*	-0.05
GRC	-1.10*	-1.10*	1.22	0.79	-2.21*	-0.13	2.14	0.09	0.98	1.31	-0.78
IRL	-1.34*	0.25	-0.35	1.06*	-0.27	-0.84	1.76	-0.02	1.45	0.50	-0.09
ITA	-0.53*	0.05	0.16	-0.05	-0.41*	0.19	1.51*	0.05	0.36	0.99*	0.02
LUX	-1.46	0.12	1.13*	-0.64*	0.26	0.29	2.04*	-0.76	0.00	-1.48*	0.72*
NLD	0.27*	0.11	-0.97*	0.18	0.14	0.22	-0.02	0.11	2.12*	-0.05	-0.03
PRT	-0.30*	0.05	-0.95*	-0.36*	0.41*	-0.09	-1.20	0.09	-0.52	0.16	-0.02
CHE	-0.40	-0.05	0.33*	-0.43*	-0.71*	0.08	-0.60	-0.47*	0.70*	0.08	-0.30*
DNK	-3.22*	0.21*	0.01	0.85*	0.38	-0.26	-1.99*	0.76*	2.93*	0.57	0.07
GBR	1.17*	0.05*	-0.03	0.05	0.61*	-0.27	-0.47	0.26	0.98	0.74	0.16
NOR	-1.23*	0.24*	0.43	0.04	0.09	-0.05*	2.26*	0.46*	1.58*	0.37	-0.18
SWE	0.22	-0.51*	0.97*	0.12	0.46	0.02	-3.78*	0.39	0.54	0.37*	-0.25*

Table 7. Changes in elasticity as seen in equation (10) for the BK filter. * indicates significance at the 5% level.

5.4.3 The relationship between volatility and elasticity

At the sectoral and the national level, the volatility and the elasticity are positively correlated, both pre-crisis and post-crisis. According to Figure A.1–11, Ireland, Luxembourg, and Greece tend to lie outside the general cluster of the EA-12 countries.

Ireland and Luxembourg's high elasticities and high volatilities, both pre-crisis and post-crisis, suggest that much of the variation in their volatilities can be explained by structural differences, i.e. they are more sensitive to the common cycle than the other EA-12 countries.

In contrast to Ireland and Luxembourg, Greece's position changes post-crisis. Pre-crisis, Greece is defined as being structurally different, given its high volatility and high elasticity. Post-crisis, the country instead lies outside of the fitted line, suggesting that the country has a divergent business cycle compared with the rest of the euro area. This suggests that less of Greece's volatility can now be explained by its elasticity and that instead other factors drives its volatility.

Across most sectors, R-squared is high pre-crisis, but falls considerably post-crisis. The main reasons are a general dispersion and Greece becoming a noticeable outlier in almost all sectors. Two notable exemptions of the fall in R-squared are public (R-squared increases) and wholesale (R-squared remains constant).

A lower R-squared suggests that less of the variation in volatility can be explained by the variation in elasticity. However, R-squared might not accurately describe the relationship since, ceteris paribus, a negative and a positive elasticity of the same magnitude is expected to yield the same volatility. In the case of Greece, the elasticity might still have an explanatory power in three of the sectors where Greece's elasticity is negative (industry, agriculture, and real estate). For the remaining sectors, the scatter diagrams' suggest that the variation in Greece's volatility seems to be driven by other factors than elasticity.

6 Robustness tests

6.1 Pearson correlation – HP filter

According to Table A.2 and A.3, the overall results are consistent across the HP filter and the BK filter, but the level of correlation tends to be higher for the BK filter. Furthermore, Ireland is not synchronised post-crisis at the national level.

6.2 Time-varying correlation – HP filter

The results are not consistent across the two filters. Table A.5 shows that only three EA-12 countries experience a negative structural shift at the national level for the HP filter. There is no negative trend at the sectoral level, except for industry and construction. Similarly, sectoral structural shifts have an ambiguous impact on national synchronisation.

To test whether the results are sensitive to poorly estimated (HP filter) or excluded (BK filter) end points, the first and the last 12 quarters are omitted from the cyclical component estimated by the HP filter.[14] Accordingly, the cyclical component for each filter now covers the same time period (2002Q1–2014Q4) when regression (5) is run.

As seen in Table A.6, the inconsistences are not fully removed, but both filters now show that synchronisation decreases at the sectoral and the national level. This suggests that the inconsistent results between the HP filter and the BK filter are mainly caused by the end points and not by the different cut-off frequencies. The problem with end points might be especially pronounced in this study because it considers a relatively short time period and the six years excluded by the BK filter might have a considerable impact on the result. For example, if synchronisation increases after 2014Q4, it could explain why the results show less signs of desynchronisation for the HP filter. This study cannot conclude whether synchronisation has started to increase after 2014Q4, but it encourages future studies to approach this question.

6.3 Time-varying correlation – the euro area without Germany

Germany is the largest European economy (Eurostat, 2018) and could be regarded as an "outlier" among the EA-12 countries. This is examined by excluding Germany from the euro area average (*EA*).

[14] Omitting end points is a simple method to deal with the potential bias and is suggested by several studies, see e.g. Bruchez (2003) and Dabla-Norris et al. (2010).

According to Table A.7, the overall results are consistent for the BK filter, as synchronisation decreases post-crisis both the sectoral and the national level. However, Greece and Portugal do not change significantly at the national level, which suggests that the euro area might be more homogenous if Germany were not a member.

6.4 Relative volatility – HP filter

The general trend is consistent across both filters, i.e. synchronisation decreases both at the sectoral and the national level (see Table A.10).

6.5 Elasticity – HP filter

As seen in Table A.11, the results are consistent across both filters, i.e. synchronisation does not change in a specific direction.

6.6 Relationship between correlation and elasticity – HP filter

The results are robust for the choice of filter (see Figure A.12–22).

7 Conclusion

This thesis examines how business cycle synchronisation within the euro area changes after the onset of the financial crisis, looking both at the sectoral and the national level. Our findings add to the lacking literature on sectoral business cycle synchronisation by identifying sectoral patterns and potential drivers of national synchronisation.

It is inconclusive how synchronisation changes post-crisis across our three measures; synchronisation decreases in terms of correlation and relative volatility, while there are few changes in elasticity and these changes show no well-defined trend. In terms of correlation, industry and wholesale are the predominant sectors for national synchronisation, but it is not possible to observe any predominant sectors for relative volatility and elasticity. These results are consistent both at the sectoral and the national level, but, depending on the measure of synchronisation, not across all filters. However, an attentive reader will reflect upon the validity of these results given that our chosen method for studying the change in relative volatility does not consider significance.

In line with previous research, Greece has the lowest level of synchronisation among the EA-12 countries; Greece's synchronisation decreases in terms of correlation and relative volatility, while its elasticity does not significantly change. These patterns suggest that synchronisation might be more problematic at peaks and troughs when the need for unity among the EA-12 countries is more important due to ECB's "one-size-fits-all" monetary policy. Spain experiences a similar decrease in synchronisation but the case of Greece is especially problematic from an OCA perspective since the country did not start out from a position of strong synchronisation.

The relationship between volatility and elasticity suggests that, post-crisis, less of the variation in the former can be explained by the variation in the latter. Besides a general dispersion, the main driver of this phenomenon appears to be Greece becoming a noticeable outlier since the country shifts from being structurally different to having a divergent business cycle compared to the rest of the euro area. In other words, post-crisis, its high volatility cannot be explained by its elasticity but rather by country-specific factors. The underlying cause of this finding is outside the scope of this study, but we encourage future studies to examine the drivers of this phenomenon.

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9 Appendix

9.1 ISO codes

ISO CODES	Country
AUT	Austria
BEL	Belgium
DEU	Germany
ESP	Spain
FIN	Finland
FRA	France
GRC	Greece
IRL	Ireland
ITA	Italy
LUX	Luxembourg
NLD	The Netherlands
PRT	Portugal
CHE	Switzerland
DNK	Denmark
GBR	United Kingdom
NOR	Norway
SWE	Sweden

Table A.1 Country codes

9.2 Pearson correlation

Country	A	BE	F	GI	J	K	L	MN	OQ	RU	TO
AUT	0.53	0.95*	0.37	0.77*	0.47	0.41	-0.34	0.76*	0.17	0.64*	0.96*
BEL	0.38	0.84*	0.74*	-0.03	0.69*	0.49	0.31	0.71*	-0.09	0.64*	0.88*
DEU	0.83*	1.00*	0.66*	0.85*	0.96*	0.87*	0.70*	0.95*	0.79*	0.91*	0.97*
ESP	0.22	0.94*	0.76*	0.89*	0.62*	0.79*	0.04	0.93*	0.30	0.66*	0.97*
FIN	-0.11	0.93*	0.18	0.51	0.66*	0.56	0.48	0.80*	-0.07	0.45	0.93*
FRA	0.77*	0.94*	0.87*	0.96*	0.67*	-0.08	0.57*	0.86*	-0.20	0.04	0.95*
GRC	0.01	0.43	0.28	0.09	0.67*	0.03	0.27	0.14	-0.16	0.38	0.38
IRL	0.73*	0.52	0.65*	0.76*	0.52	0.60*	0.03	0.46	-0.16	0.32	0.84*
ITA	0.74*	0.96*	0.68*	0.89*	0.72*	0.62*	-0.43	0.65*	0.69*	0.88*	0.96*
LUX	0.41	0.55	0.52	0.42	0.55	0.58*	0.79*	0.54	0.41	0.30	0.89*
NLD	0.48	0.84*	0.82*	0.93*	0.74*	0.55	0.55	0.87*	0.49	0.45	0.95*
PRT	0.55	0.73*	0.60*	0.77*	0.94*	0.38	0.70*	0.68*	0.51	0.38	0.83*
CHE	0.74*	0.76*	-0.70*	0.85*	0.61*	0.29	0.34	0.50	0.68*	-0.38	0.94*
DNK	0.06	0.68*	0.48	0.86*	0.21	0.23	0.28	0.26	0.47	0.01	0.82*
GBR	-0.17	0.94*	0.10	0.45	0.37	0.21	-0.22	0.79*	-0.32	0.00	0.65*
NOR	0.35	-0.04	0.53	0.84*	0.17	0.31	0.59*	0.82*	-0.09	0.20	0.62*
SWE	0.28	0.86*	0.84*	0.67*	0.22	0.30	0.42	0.83*	0.08	-0.05	0.87*

Table A.2 Pearson correlation coefficient for the HP filter. Pre-crisis (1999Q1—2007Q4). * indicates significance at the 5% level.

Country	A	BE	F	GI	J	K	L	MN	OQ	RU	To
AUT	0.39	0.85*	0.57*	0.81*	0.80*	-0.07	0.40	0.88*	0.76*	0.54	0.92*
BEL	0.05	0.88*	0.28	0.85*	-0.21	0.58*	-0.15	0.79*	0.12	0.09	0.97*
DEU	0.64*	0.98*	0.27	0.79*	0.85*	0.65*	0.87*	0.94*	0.88*	0.88*	0.94*
ESP	0.22	0.82*	0.75*	0.73*	0.30	0.68*	0.47	0.73*	0.85*	0.79*	0.72*
FIN	-0.11	0.87*	0.47	0.87*	0.61*	0.18	0.53	0.76*	0.39	0.49	0.94*
FRA	0.77*	0.87*	0.76*	0.95*	0.78*	-0.22	-0.22	0.93*	-0.42	0.58*	0.93*
GRC	0.01	-0.45	0.12	0.33	-0.12	0.05	-0.04	0.18	0.58*	0.11	0.05
IRL	0.73*	0.30	0.60*	0.75*	0.24	0.33	0.30	0.61*	0.38	0.52	0.51
ITA	0.74*	0.97*	0.89*	0.92*	0.17	0.50	0.38	0.75*	0.43	0.47	0.97*
LUX	0.41	0.45	0.40	0.62*	0.15	0.14	0.47	0.62*	-0.46	-0.25	0.71*
NLD	0.48	0.83*	0.77*	0.95*	0.77*	0.40	0.20	0.77*	0.68*	0.83*	0.94*
PRT	0.55	0.84*	0.79*	0.44	0.57*	0.51	-0.14	0.34	0.66*	0.86*	0.67*
CHE	0.32	0.86*	-0.30	0.24	-0.06	0.27	0.50	0.38	-0.29	0.11	0.83*
DNK	-0.40	0.72*	0.43	0.72*	0.10	0.24	-0.32	0.37	0.38	0.11	0.84*
GBR	-0.17	0.95*	0.44	0.73*	0.40	0.07	-0.45	0.79*	-0.51	0.04	0.84*
NOR	0.35	0.01	0.42	0.59*	0.04	-0.32	0.24	0.35	0.34	0.43	0.34
SWE	0.28	0.88*	0.69*	0.75*	0.17	0.06	0.47	0.75*	0.37	0.53	0.89*

Table A.3 Pearson correlation coefficient for the HP filter. Post-crisis (2008Q1—2017Q4). * indicates significance at the 5% level.

9.3 Relative share of gross value added

Country	A	BE	F	GI	J	K	L	MN	OQ	RU	TO
AUT	2%	23%	7%	23%	3%	4%	9%	8%	18%	3%	100%
BEL	1%	18%	5%	20%	4%	6%	9%	12%	22%	2%	100%
DEU	1%	26%	5%	16%	4%	5%	11%	11%	17%	4%	100%
ESP	3%	18%	10%	23%	4%	4%	10%	7%	18%	4%	100%
FIN	3%	23%	6%	16%	5%	3%	11%	8%	22%	3%	100%
FRA	2%	14%	6%	18%	5%	4%	13%	13%	22%	3%	100%
GRC	4%	13%	5%	24%	4%	4%	15%	6%	21%	4%	100%
IRL	1%	28%	2%	16%	8%	10%	7%	9%	17%	2%	100%
ITA	2%	19%	6%	20%	4%	5%	13%	9%	17%	4%	100%
LUX	0%	9%	5%	16%	6%	26%	8%	10%	15%	2%	100%
NLD	2%	17%	6%	20%	5%	8%	6%	14%	21%	3%	100%
PRT	2%	18%	7%	23%	3%	5%	11%	7%	22%	3%	100%
CHE	1%	22%	5%	21%	4%	11%	7%	9%	18%	2%	100%
DNK	1%	20%	5%	20%	4%	5%	10%	8%	23%	4%	100%
GBR	1%	15%	6%	19%	6%	8%	12%	11%	19%	4%	100%
NOR	2%	36%	5%	15%	4%	4%	7%	6%	20%	2%	100%
SWE	2%	22%	6%	18%	5%	4%	9%	10%	21%	3%	100%

Table A.4 Relative share of total gross value added.

9.4 Time-variant correlation measure

Country	A	BE	F	GI	J	K	L	MN	OQ	RU	TO
AUT	0.46	0.15*	-0.47	-0.46	0.33	0.52	0.55	-0.41	0.05	-0.04	0.78*
BEL	0.00	-0.13*	-0.09	-0.43*	-0.29	0.89	0.09	0.27	-0.84	0.09*	0.30*
DEU	0.00	0.75*	-0.31*	-0.37*	-0.19	0.02	0.41	-0.05	0.57	0.08	0.81
ESP	-0.53	-0.77*	-0.22	1.14*	-0.16	0.33	-0.27*	0.05	-0.07	-0.47*	0.97*
FIN	-0.14	0.10	0.44	-1.28*	0.38	0.64	0.31	0.12	-0.61	0.29	-0.52
FRA	0.00	-0.87	-0.90	-0.50	-0.08	0.33*	0.45	-0.37	0.18	-0.25	-0.30
GRC	0.40	-1.03*	-0.02	-0.74	0.04	0.07*	0.66	-0.04	0.10	0.51	-1.38
IRL	0.27	-0.43*	0.32	0.63	0.40	0.41	-0.32	-0.27	0.36	-0.10	0.03*
ITA	-0.05	-0.39	-0.04	0.25	0.48	0.82*	0.11*	0.39*	0.10*	0.20	-0.27
LUX	0.43	0.13	0.13*	0.13	0.56	0.28	0.24	0.00	-0.33	0.27	0.49
NLD	0.36	-0.68*	-0.04*	0.14	0.11	0.79*	0.12	0.31	-0.19	-0.35*	0.28
PRT	-0.04	-0.06	0.33	0.04	0.57	0.58*	0.48*	0.55	-0.48	-0.24*	0.07
CHE	0.00	0.45	-0.28	0.32*	0.29	0.00*	0.64	-0.80	-0.33*	-0.24	1.06*
DNK	0.10	-0.84	0.09	0.01	0.85	0.20*	0.04	-0.12*	0.50	-0.17	-0.58
GBR	-0.14*	-0.38	-0.29	-0.46	0.22	0.48	0.07	0.56	-0.20	0.09	-0.14
NOR	-0.38	-0.72	-0.32	0.03	0.15	0.17	0.24	0.06*	-0.24	0.40	-0.79
SWE	0.32*	-0.39	-0.51	-0.47	-0.42	-0.01	-0.32	-0.09*	-0.36	-0.35*	-0.41

Table A.5 Changes in correlation as seen in regression (5) for the HP filter. * indicates significance at the 5% level.

Country	A	BE	F	GI	J	K	L	MN	OQ	RU	TO
AUT	0.09	-0.94*	-0.31	-0.75*	0.77	0.12	0.14	-0.12	0.23	-0.60	-1.00*
BEL	-0.34	-0.24	-0.16	0.78*	0.22	0.04	-0.19	0.15	-0.45*	-0.53*	0.86*
DEU	-0.23	-0.67*	-1.02*	-0.72*	-0.21	0.13	0.64*	-0.58*	-0.02	-0.50	-0.32
ESP	0.52	-1.14*	-0.08	-0.94*	-0.43	-0.13	-0.06	-0.50	0.31	0.09	-1.49*
FIN	-0.02	-0.16	-0.04	0.57	0.54	0.38	-0.27	-0.27	0.15	-0.12	0.23
FRA	0.63*	-0.88*	-0.14	0.23	0.52	0.67*	0.23	0.30	-0.18	0.35	-0.62*
GRC	0.29	-0.83*	0.00	0.04	-0.67	0.71*	-0.38	-0.42	0.06	-0.70*	-0.54*
IRL	-0.56	-0.52	-0.38	-0.10	-0.20	0.08	-0.13	0.18	-0.67	0.02	-0.30
ITA	0.13	-0.30	0.25	-0.41	0.17	0.26	0.18	0.58*	-0.63*	-0.34	0.02
LUX	-0.13	-0.51*	-0.91*	0.25	-0.91	0.06	-0.17	0.15	-0.86*	-0.24	-0.70*
NLD	0.36	-0.23	-0.07	0.24	0.79	0.17	-0.74*	-0.50	-0.07	1.00*	-0.07
PRT	0.41	-0.06	0.08	0.04	0.21	0.27	-0.84*	-0.49	0.04	0.99*	-0.64*
CHE	-0.52*	-0.08	0.39	-0.85*	-0.22	0.53*	0.36	-0.44	-0.39	0.40	-0.68*
DNK	0.06	-0.04	-0.59	-0.53	-0.06	0.02	-0.37	0.58*	-0.03	-0.39	-0.14
GBR	0.72*	-0.45	0.09	-0.10	0.33	-0.01	0.30	-0.39	-0.52	0.23	0.43
NOR	-0.39	-0.05	-0.64	-0.34	0.78	0.24	0.60	-0.95*	-0.12	0.64*	-0.62*
SWE	0.82*	-0.04	-0.62	-0.17	0.27	0.19	0.12	0.79*	0.10	0.76	0.26

Table A.6 Changes in correlation as seen in regression (5) for the HP filter without end points. * indicates significance at the 5% level.

Country		BE	F	GI	J	K	L	MN	OQ	RU	TO
AUT	-0.22	-0.44	-0.38	-0.07	-0.10	0.53	0.01	-0.77*	0.07	-0.65*	-0.91*
BEL	-0.16	-0.05	-0.59*	1.03*	-0.24	-0.13	0.57	0.04	-1.01*	-0.68*	0.10
DEU	-0.42	-0.57	-0.96*	-0.65*	-0.41	-0.27	0.11	-0.54*	0.29	-0.86*	-0.41*
ESP	0.44	-1.04*	-0.36	-1.03*	-0.52*	-0.48	0.30	-0.22	0.11	0.52	-1.42*
FIN	0.23	-0.92*	-0.36	-0.50	0.34	0.31	0.29	-0.18	-0.61*	-0.10	-0.61
FRA	-0.22	-0.99*	-0.39	-0.02	-0.23	0.79*	0.49	-0.14	-1.12*	0.68*	-1.64*
GRC	0.45	-0.95*	0.01	-0.26	-0.71*	0.03	1.08*	-0.45	-0.23	-0.64*	-0.44
IRL	0.17	-0.35	-0.29	-0.24	-0.05	-0.13	0.07	0.40	-0.53	0.47	-0.23
ITA	-0.04	-0.23	-0.46*	1.13*	0.38	-0.36	0.36	0.67*	-0.23	-0.93*	-0.62*
LUX	-0.46	-0.29	-0.61*	0.13	-1.20*	0.03	0.34	0.55	-0.53*	-0.71*	-0.35
NLD	0.18	-0.32	-0.08	0.20	-0.22	0.14	-0.06	-0.59	-0.11	1.13*	0.10
PRT	0.03	-0.18	0.27	-0.32	-0.35	0.57	0.04	-0.96*	0.01	0.87*	-0.17
CHE	-0.38	-0.10	-0.46	-0.55	0.12	-0.40	0.69*	-0.30	0.21	-0.07	-0.09
DNK	0.25	0.12	-0.80*	-0.52	-0.14	-0.03	0.58	0.73*	0.00	-0.27	-0.46
GBR	0.55	-0.33	-0.51	-0.45	0.20	-0.07	0.78*	-0.48	-0.64*	0.49	-0.51
NOR	-1.23*	0.36	-1.17*	-0.36	0.65*	-0.11	0.29	-0.92*	0.03	0.08	-0.59*
SWE	0.11	-0.39	-0.81*	-0.85*	0.60	0.74*	0.46	0.07	-0.40	-0.21	-0.55*

Table A.7 Changes in correlation as seen in regression (5) for the BK filter omitting Germany from the euro area average. * indicates significance at the 5% level.

9.5 Relative volatility

Country	A	BE	F	GI	J	K	L	MN	OQ	RU	TO
AUT	0.82	1.32	1.40	0.80	1.22	1.12	1.57	0.81	1.70	0.92	1.10
BEL	0.84	0.80	1.54	1.00	0.99	1.59	1.18	1.39	1.82	1.52	0.70
DEU	3.40	1.27	0.98	1.58	1.97	1.99	2.47	1.22	3.63	0.99	1.35
ESP	1.14	0.61	0.82	0.78	0.41	1.49	3.16	1.69	2.14	0.73	0.98
FIN	0.49	1.88	1.77	1.55	1.43	1.95	1.85	1.00	1.83	0.80	1.55
FRA	1.80	0.62	1.20	0.73	0.85	0.87	3.62	0.94	1.97	0.54	0.73
GRC	1.61	0.86	8.98	1.97	1.26	2.75	13.94	2.65	8.42	3.99	1.24
IRL	2.36	1.19	3.49	2.57	2.27	1.24	11.44	2.96	6.40	3.30	1.92
ITA	0.89	1.22	0.94	1.18	0.98	1.14	1.87	1.02	2.25	2.37	0.92
LUX	4.64	2.39	3.02	1.50	2.42	1.89	6.38	2.06	6.42	1.38	2.05
NLD	0.44	0.71	1.65	1.53	0.86	0.64	1.30	1.33	4.81	1.85	0.96
PRT	0.65	0.72	1.68	0.96	0.61	1.17	2.90	0.65	4.14	1.09	0.80
CHE	1.17	1.02	0.92	0.88	1.00	1.97	2.84	1.41	3.51	0.99	1.02
DNK	1.34	0.81	1.75	2.28	1.09	1.44	2.67	1.81	5.33	0.83	1.01
GBR	0.81	0.55	1.31	1.14	0.55	0.80	2.99	1.96	6.84	2.41	0.92
NOR	0.88	0.50	1.80	1.45	0.86	1.28	4.52	2.12	3.63	2.06	0.66
SWE	0.99	1.20	2.46	1.00	1.12	0.76	4.33	1.95	3.40	0.78	1.29

Table A.8. Relative volatility for the BK filter. Pre-crisis period (2002Q1–2007Q4).

Country	A	BE	F	GI	J	K	L	MN	OQ	RU	TO
AUT	2.16	1.03	1.31	0.76	1.54	1.82	3.65	1.09	1.31	1.40	1.08
BEL	2.74	0.70	0.95	0.91	0.81	3.27	2.73	0.94	1.27	1.98	0.75
DEU	4.85	1.42	1.51	1.27	1.78	2.89	3.36	1.32	1.55	1.21	1.41
ESP	1.79	0.85	2.88	0.98	1.02	2.59	1.42	1.26	3.61	1.73	1.16
FIN	1.08	1.46	2.36	2.14	1.42	3.10	5.76	1.33	1.31	1.73	1.76
FRA	2.31	0.48	0.99	1.00	1.78	1.36	1.70	1.08	0.54	1.33	0.68
GRC	2.12	0.90	4.99	3.28	5.09	4.68	11.19	3.04	7.54	11.21	1.96
IRL	4.59	2.24	5.39	1.58	2.98	4.26	8.17	1.56	3.60	2.77	2.43
ITA	0.58	1.17	1.11	1.21	0.97	1.72	2.46	0.80	1.26	1.66	1.11
LUX	5.11	1.65	2.38	2.49	5.47	3.25	5.67	2.09	3.67	2.35	1.52
NLD	0.92	0.73	2.79	1.34	1.31	1.40	4.39	1.16	1.73	1.49	0.94
PRT	0.62	0.70	2.24	0.70	1.58	2.63	4.19	1.33	3.18	2.33	0.94
CHE	1.45	0.93	0.96	0.78	1.04	2.78	3.63	0.42	0.94	2.54	0.73
DNK	4.72	0.85	2.67	1.65	2.06	3.79	6.49	1.00	2.12	1.69	0.96
GBR	1.92	0.59	2.74	1.16	1.40	2.36	2.27	1.59	1.76	2.39	0.94
NOR	1.80	0.31	2.18	0.92	0.79	2.40	2.37	1.40	1.19	0.98	0.59
SWE	1.01	1.69	1.99	1.19	3.17	1.50	9.52	0.99	1.16	1.27	1.55

Table A.9. Relative volatility for the BK filter. Post-crisis period (2008Q1–2014Q4).

Country	A	BE	F	GI	J	K	L	MN	OQ	RU	TO
AUT	-1.41	0.19	0.27	-0.07	-0.42	-0.87	-1.93	0.04	0.40	-5.63	-0.10
BEL	-2.27	-0.08	0.55	-0.01	-0.09	-2.26	-1.03	0.26	0.71	-0.94	0.04
DEU	-1.23	-0.13	-0.09	0.16	0.02	-0.53	-0.87	-0.16	1.28	-0.89	-0.11
ESP	-0.51	0.22	-1.53	0.15	0.31	-1.15	1.35	0.33	0.18	-0.46	-0.14
FIN	-0.16	0.42	0.08	-0.84	0.16	-2.65	-2.68	-0.37	1.54	-0.04	-0.21
FRA	-0.68	-0.15	0.29	0.15	-0.45	-0.33	2.36	-0.02	0.27	-0.55	-0.07
GRC	-0.30	-0.06	3.46	-1.74	-3.68	-2.58	0.22	-0.70	1.34	1.85	-0.87
IRL	-1.78	-1.32	-1.32	0.66	-1.61	-3.65	0.90	0.62	2.16	1.20	-1.33
ITA	0.06	-0.04	-0.07	0.18	0.22	-0.59	-0.51	0.11	1.02	0.03	-0.12
LUX	-0.04	0.74	0.29	-0.08	-4.21	-2.28	1.48	-0.09	2.31	0.31	0.34
NLD	0.06	-0.05	-0.73	0.28	-0.09	-0.20	-2.56	0.32	2.09	0.57	0.11
PRT	0.18	0.06	0.00	-0.09	-0.19	-1.76	-1.14	-0.32	0.59	0.22	0.04
CHE	-0.07	-0.01	-0.01	-0.02	0.29	-0.90	-0.16	0.01	1.71	0.12	-0.13
DNK	-3.66	-0.07	-0.06	0.44	-1.14	-2.85	-0.33	-0.09	1.71	-0.05	0.16
GBR	-0.89	0.00	-0.77	-0.08	-0.15	-1.05	-0.31	0.07	3.06	0.72	0.08
NOR	-0.66	-0.09	0.16	0.42	0.04	-1.28	1.61	0.57	2.57	-0.04	-0.15
SWE	0.16	-0.49	0.53	-0.27	-4.10	-1.14	-3.47	0.73	1.60	-0.78	-0.25

Table A.10 Changes in relative volatility as seen in equation (7) for the HP-filter.

9.6 Elasticity

Country	A	BE	F	GI	J	K	L	MN	OQ	RU	TO
AUT	0.40	0.21*	0.16	-0.03	0.14	-0.80*	1.17*	0.38*	0.56*	0.17	-0.04
BEL	-0.25	-0.04	-0.58*	0.85*	-0.94*	-0.69	-0.76*	-0.11	0.44	-0.76*	0.10*
DEU	-0.12	-0.11*	-0.43	0.22	0.23	0.14	-1.14*	-0.13	0.85*	0.10	-0.07
ESP	0.27	0.12*	-0.66*	-0.02	-0.07	-0.46	0.71	0.52*	-1.73*	0.02	-0.07
FIN	0.22	0.48*	0.61*	-0.64*	0.05	-0.02	-1.18*	0.10	0.72	0.40	-0.24
FRA	-0.18	-0.18*	-0.10	0.17*	0.16	-0.23	-0.18	0.18*	0.12	0.81*	-0.09*
GRC	-0.84*	-0.91*	1.46	0.72	-1.41*	0.16	0.17	0.22	-0.51	0.32	-0.34
IRL	-0.88	0.09	-0.59	0.52	0.38	-0.74	-0.59	-0.02	1.58	-1.03	0.02
ITA	-0.49*	-0.05	0.26	0.13	-0.72*	0.14	1.36*	-0.17	-0.01	0.56*	-0.04
LUX	-0.91	0.40	0.48	-0.60	0.20	-0.38	2.76*	-0.24	-1.19	-1.56*	0.61*
NLD	0.12	-0.03	-0.47	0.23*	-0.02	0.19	0.06	0.28	0.63	-0.03	0.00
PRT	-0.12	0.14	-0.43	-0.59*	0.39*	-0.08	-0.87	0.04	0.04	-0.82*	-0.12
CHE	-0.51*	0.08	0.56*	-0.61*	-0.91*	0.20	-0.56	-0.54*	-0.40	0.96	-0.33*
DNK	-2.42*	-0.01	0.10	0.64*	-0.04	0.53	-2.30*	0.26	0.84	0.22	-0.11
GBR	1.13*	0.02	0.83*	0.40	0.11	-0.01	-0.71	0.06	0.62	0.13	0.24*
NOR	-1.10*	0.03	-0.17	-0.19	-0.12	-1.32*	1.26*	0.34	1.18	0.29	-0.31*
SWE	0.20	-0.52*	0.70*	0.28*	0.63	-0.18	-1.82	0.19	0.27	0.81*	-0.24

Table A.11 Changes in elasticity as seen in equation (10) for the HP filter. * indicates significance at the 5% level.

9.7 The relationship between volatility and elasticity – BK filter

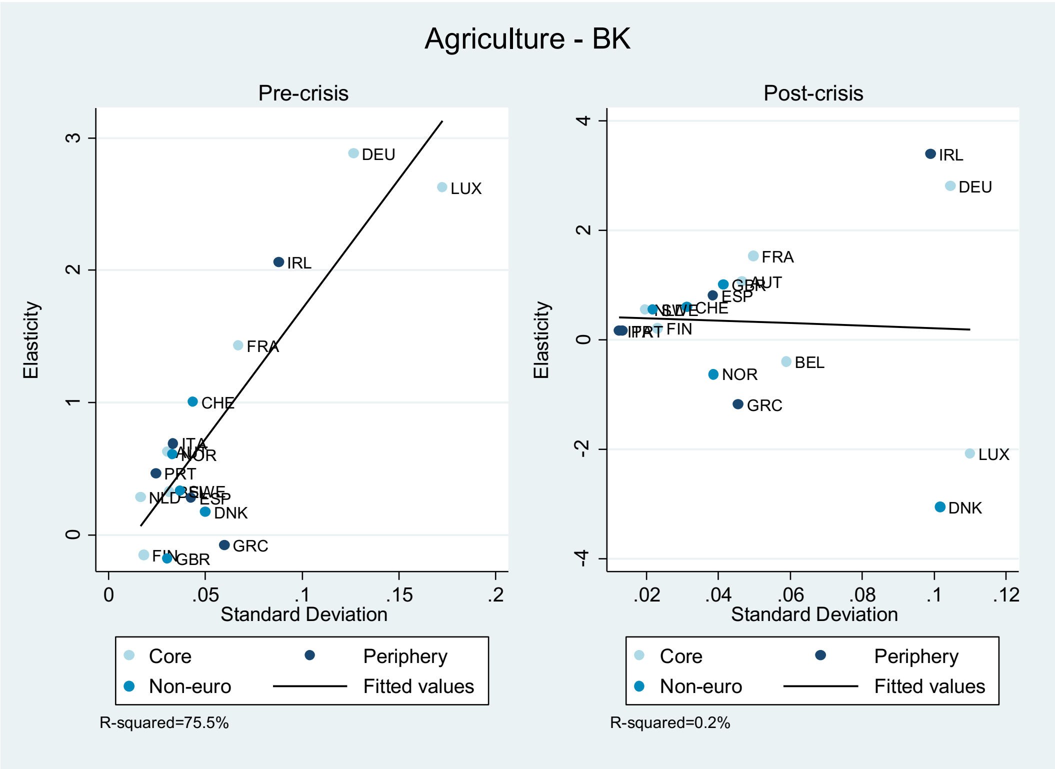

Figure A.1

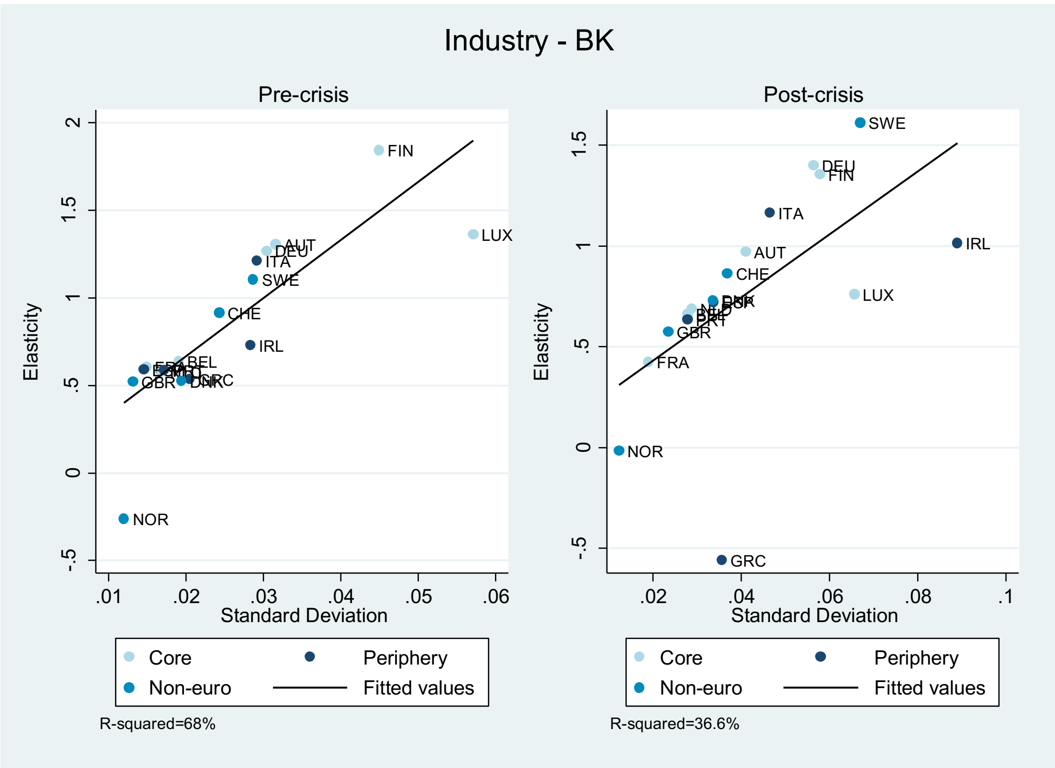

Figure A.2

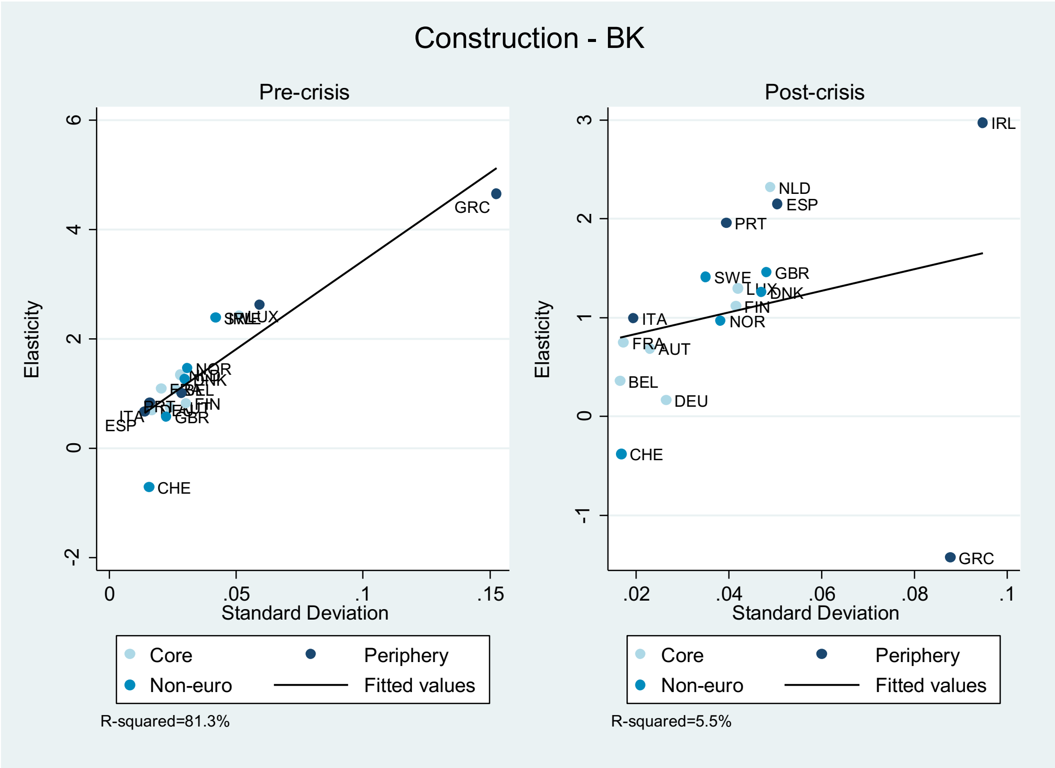

Figure A.3

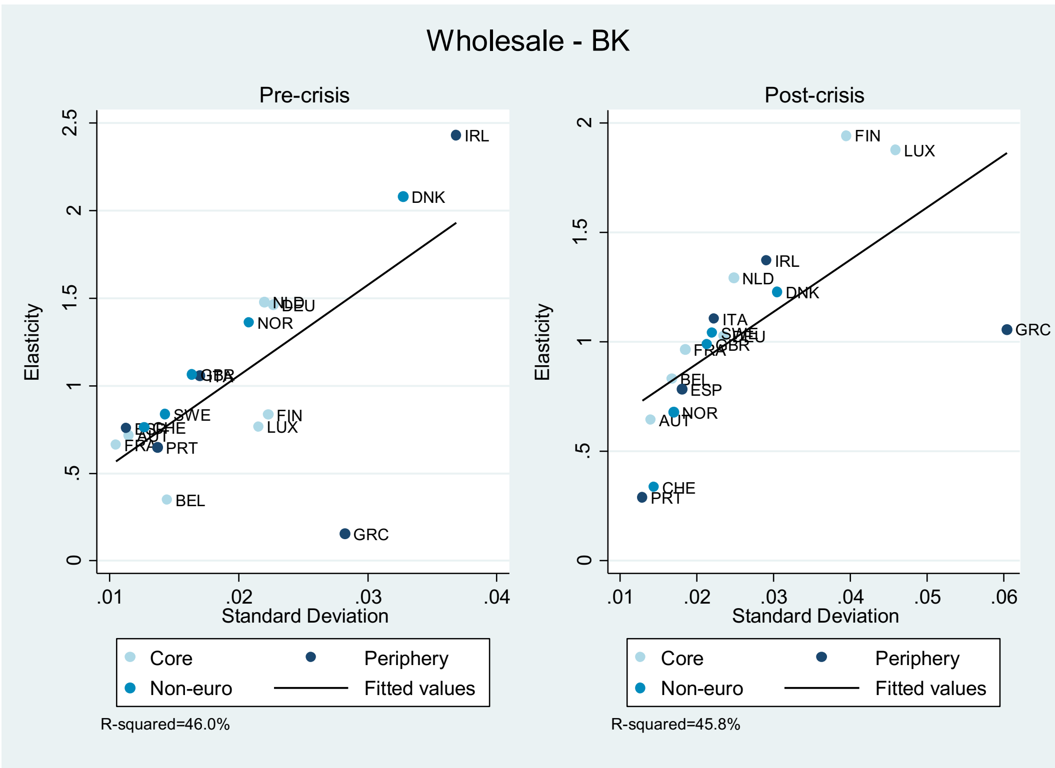

Figure A.4

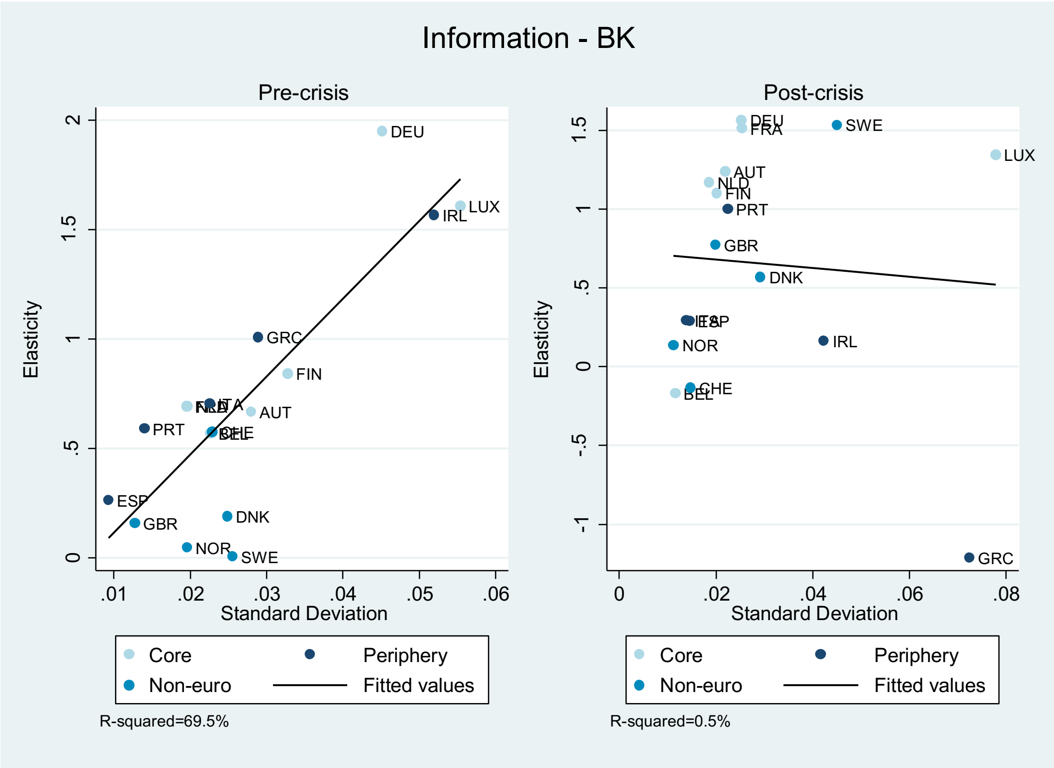

Figure A.5

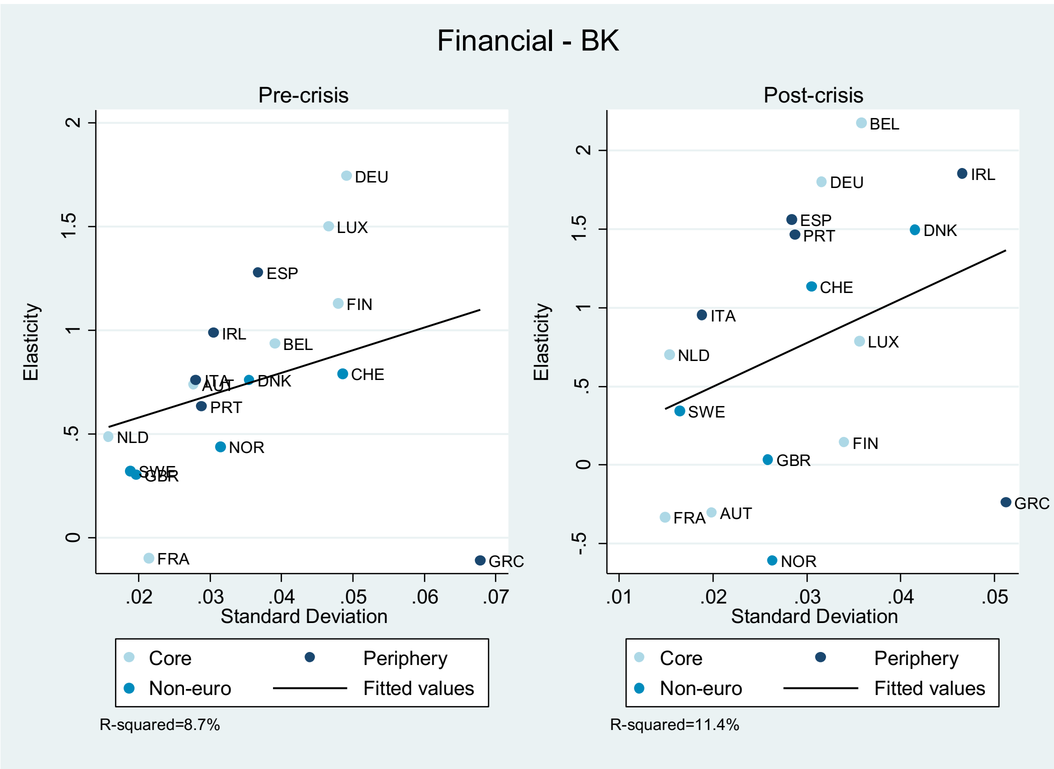

Figure A.6

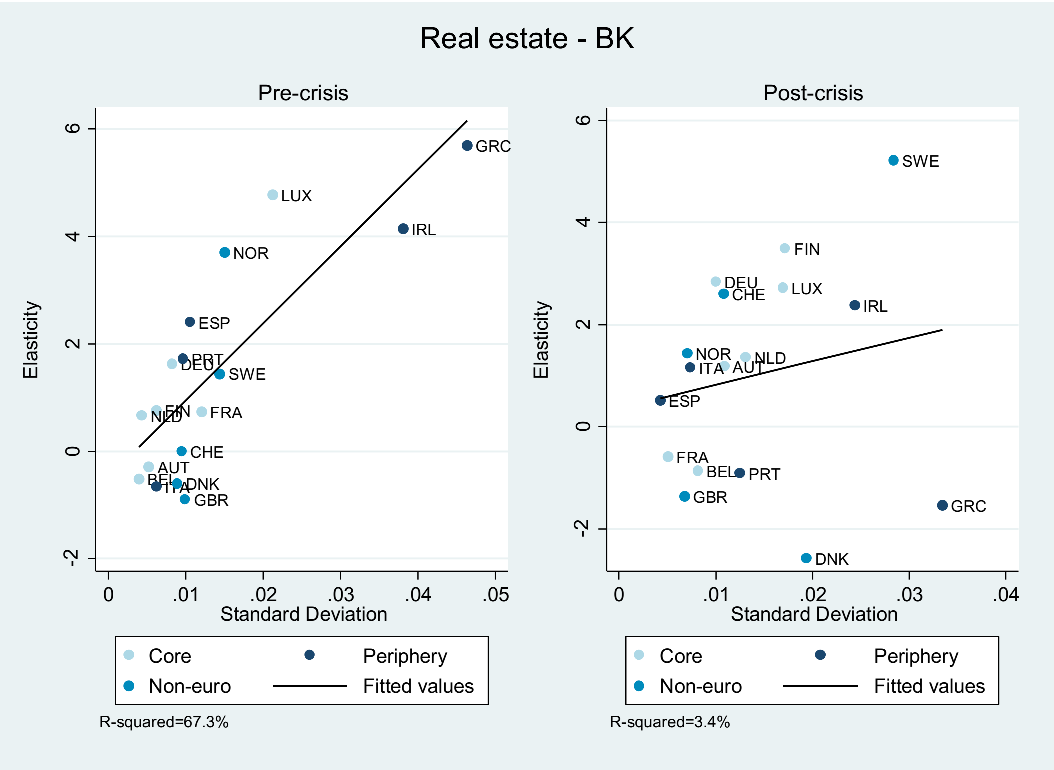

Figure A.7

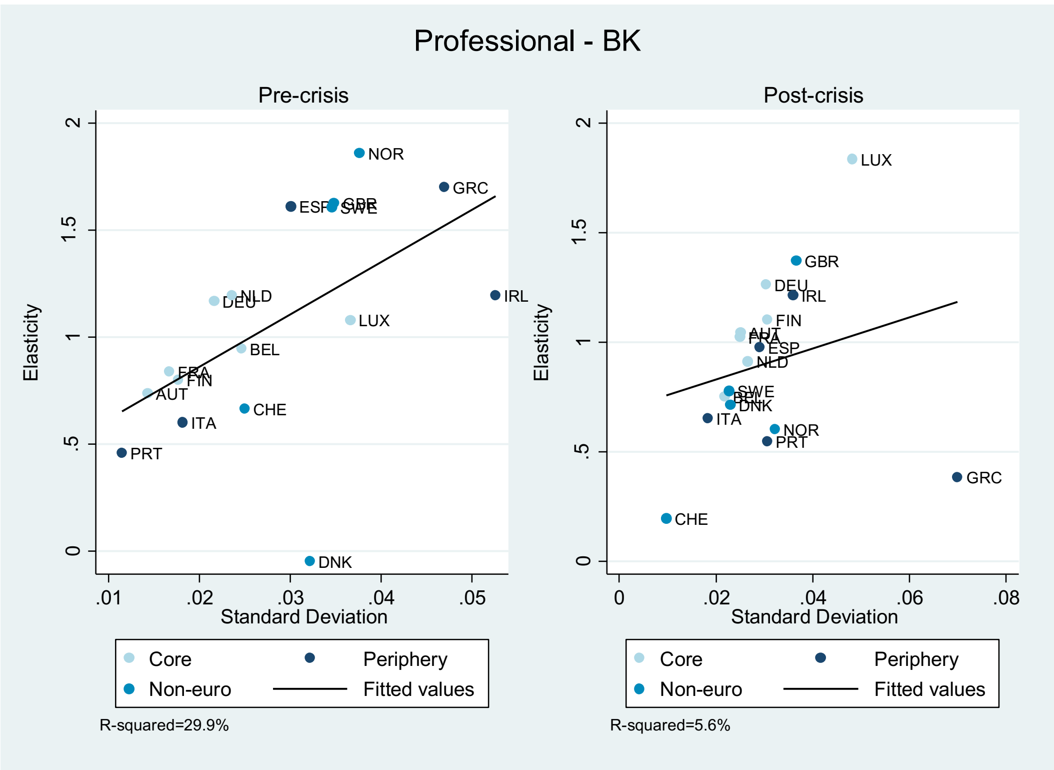

Figure A.8

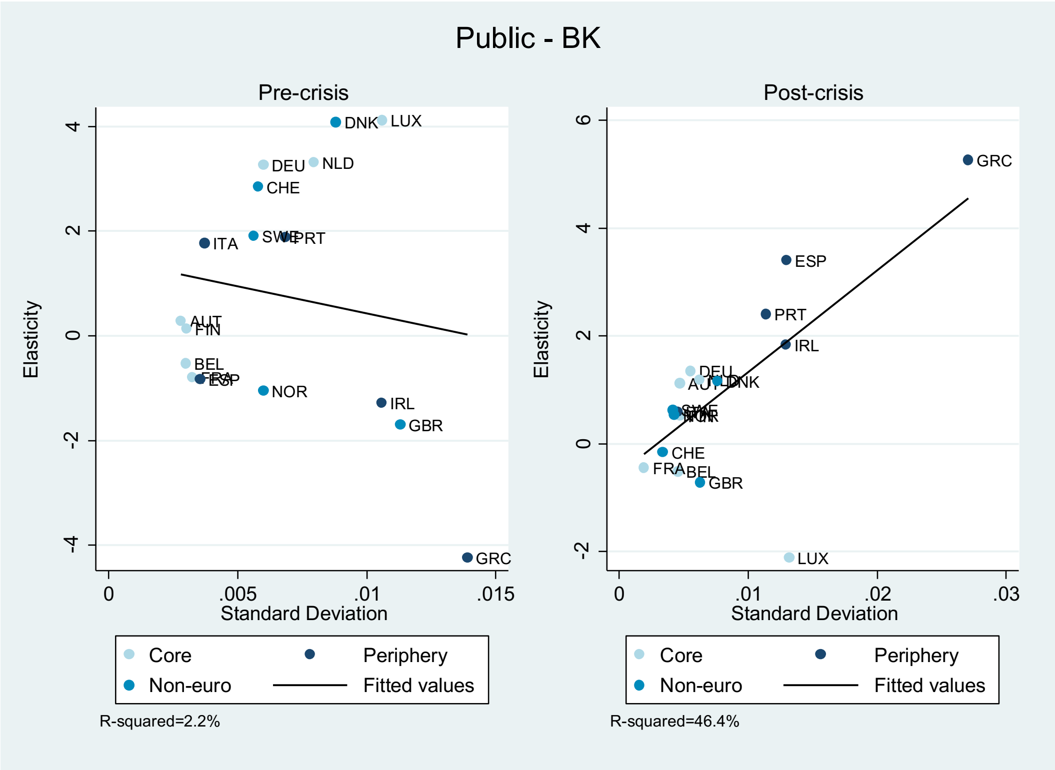

Figure A.9

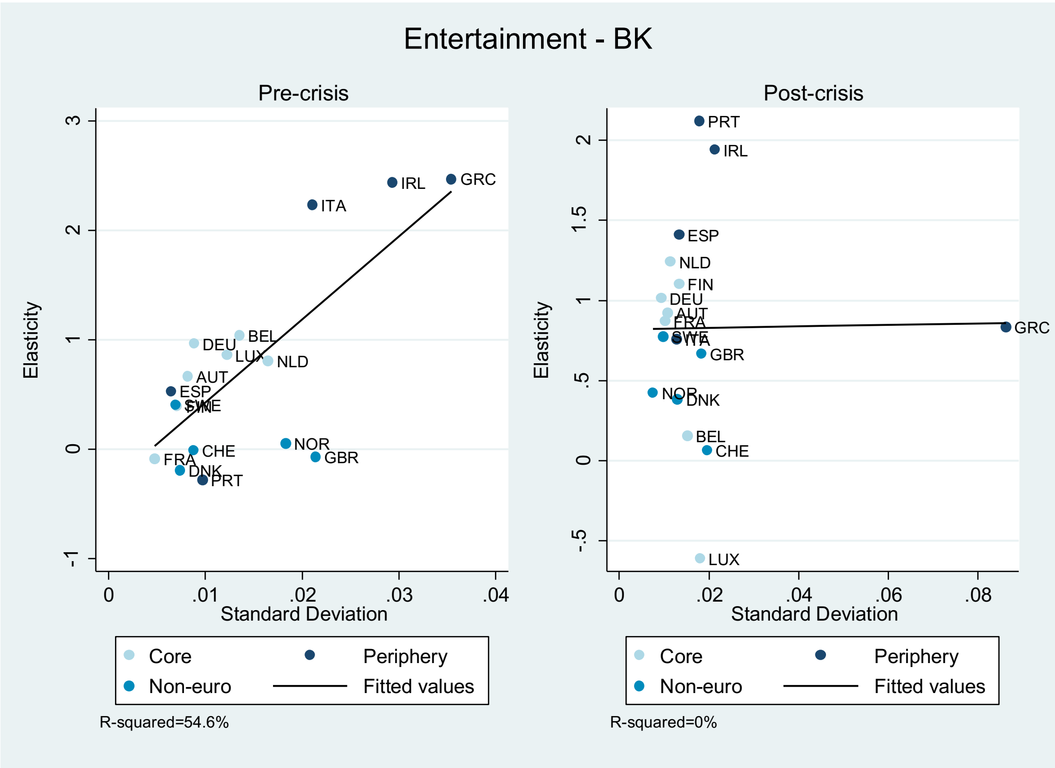

Figure A.10

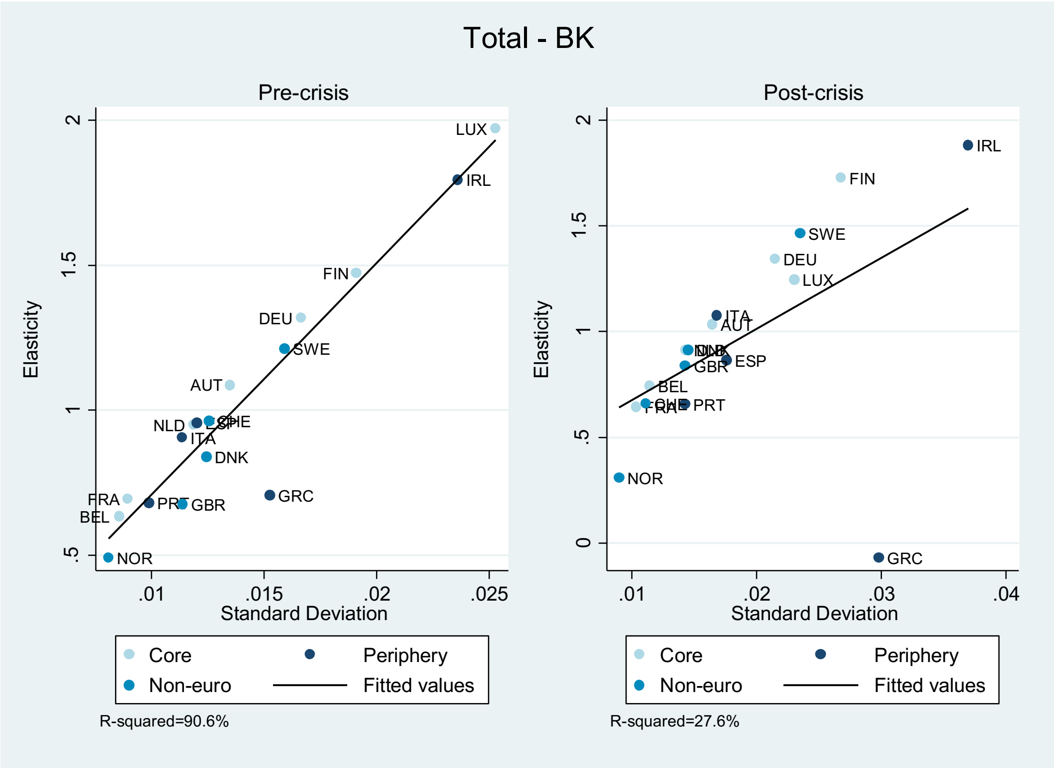
Total - BK
Pre-crisis
Post-crisis
Elasticity
Standard Deviation
Core
Periphery
Non-euro
Fitted values
R-squared=90.6%
R-squared=27.6%
LUX
IRL
FIN
DEU
SWE
AUT
NLD
ITA
DNK
GRC
FRA
BEL
PRT
GBR
NOR
ESP

Figure A.11

9.8 The relationship between volatility and elasticity – HP filter

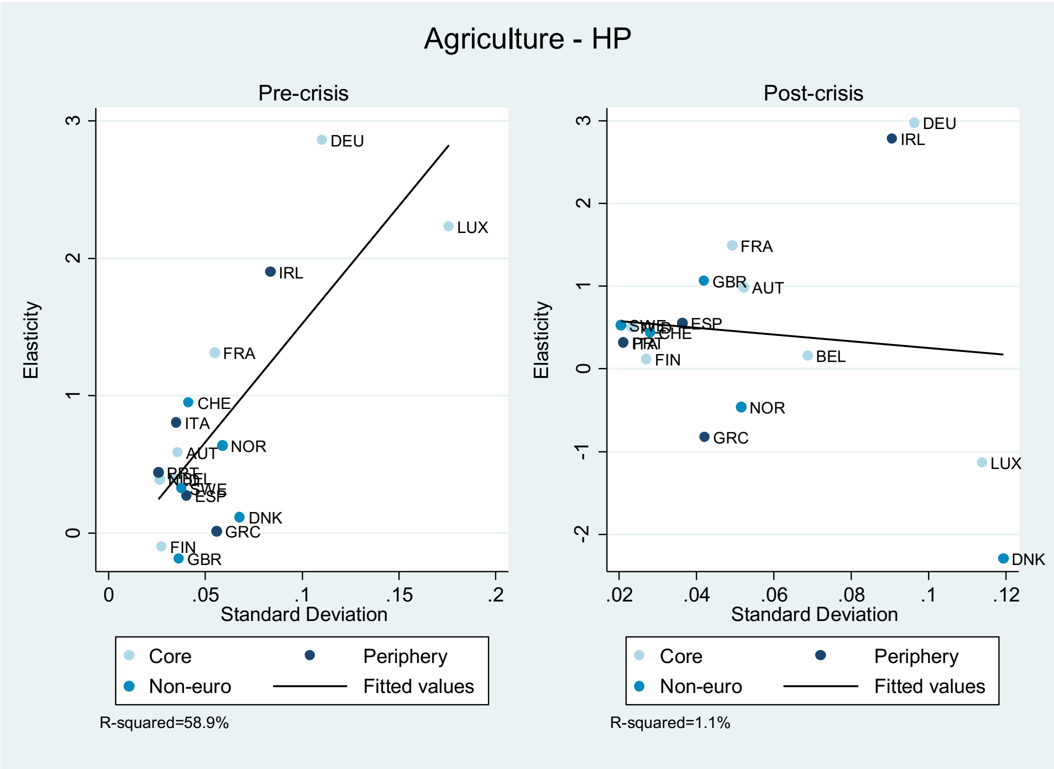

Figure A.12

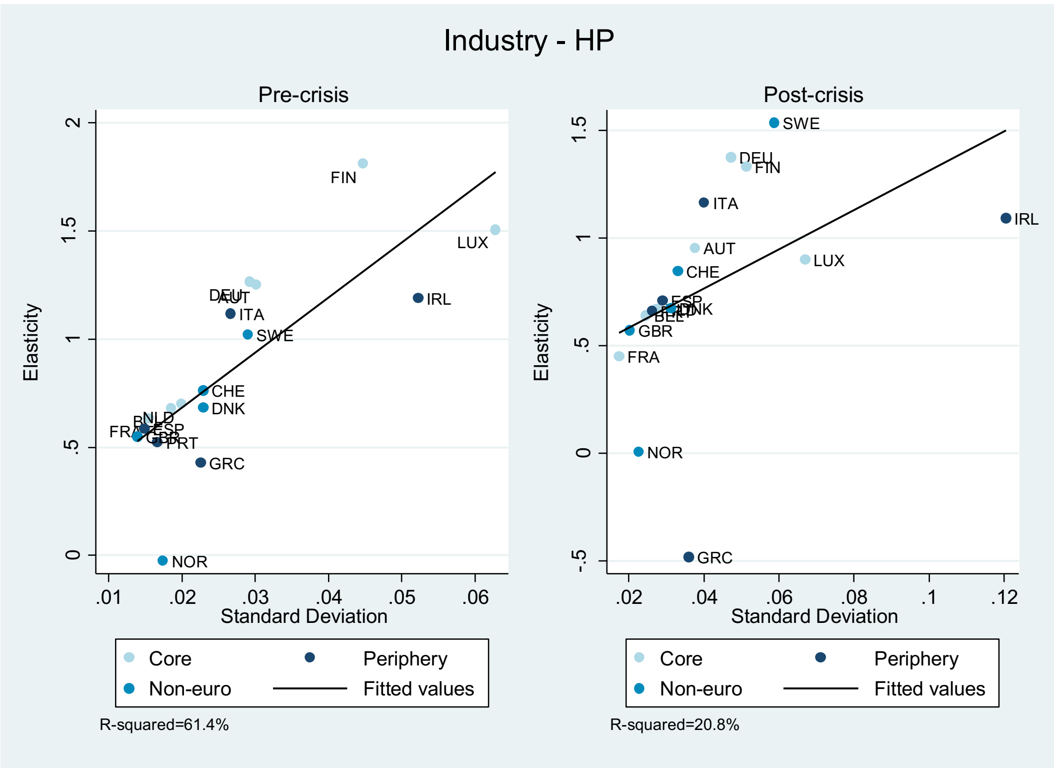

Figure A.13

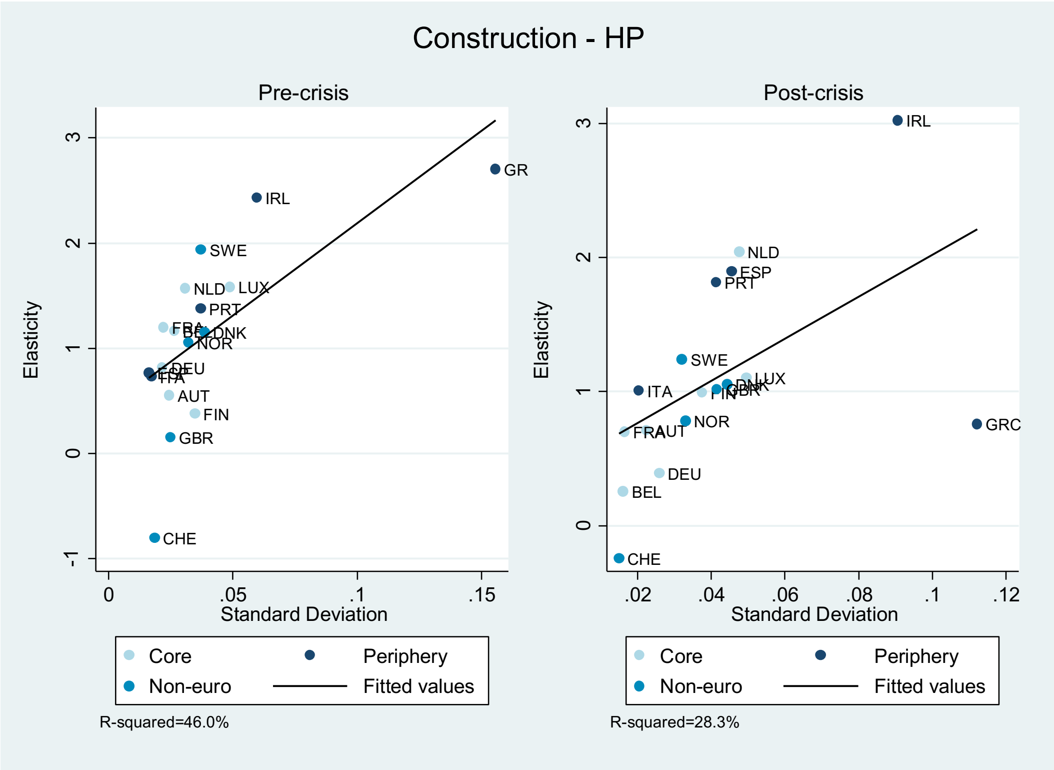

Figure A.14

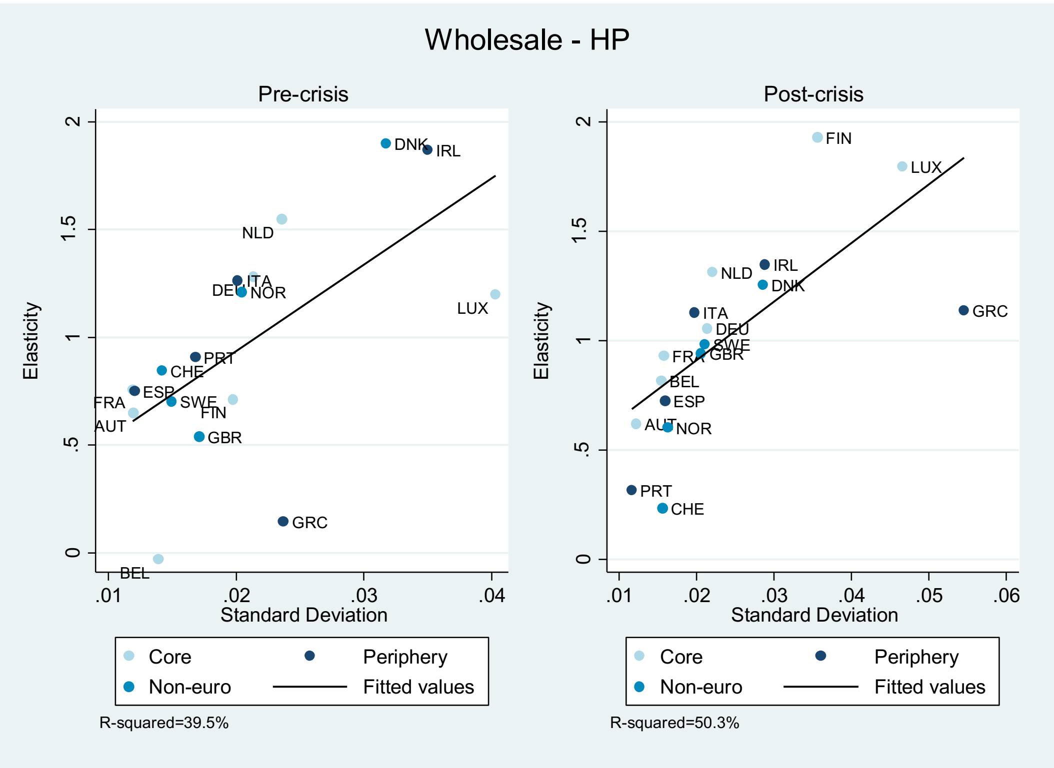

Figure A.15

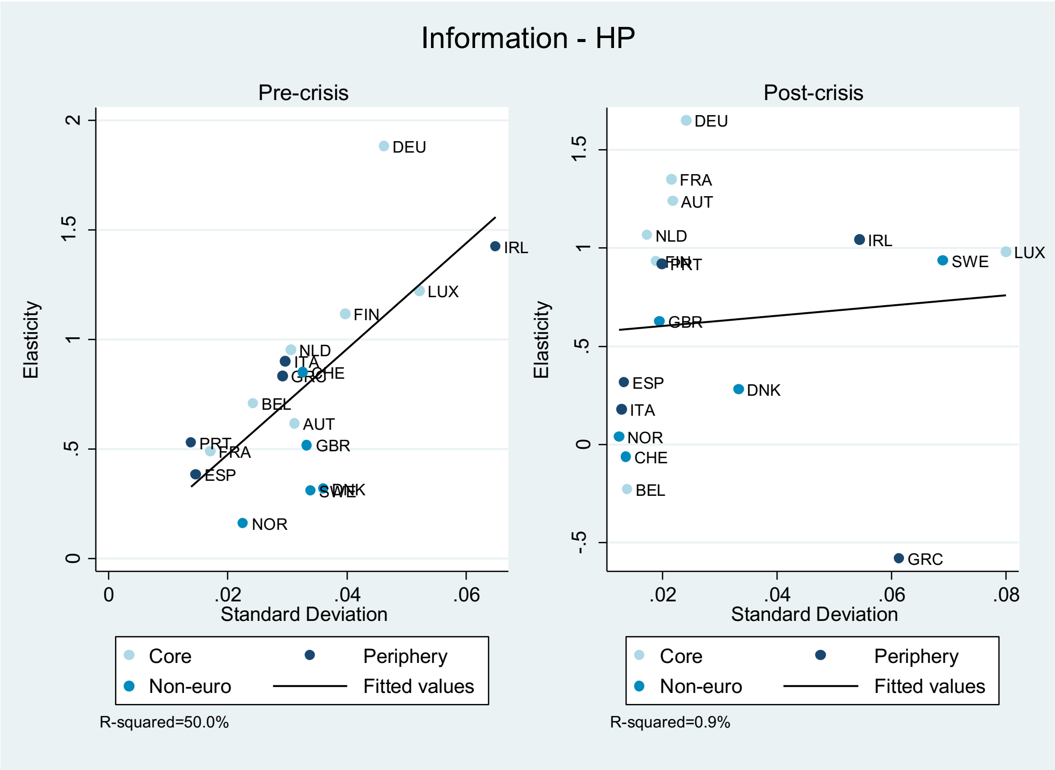

Figure A.16

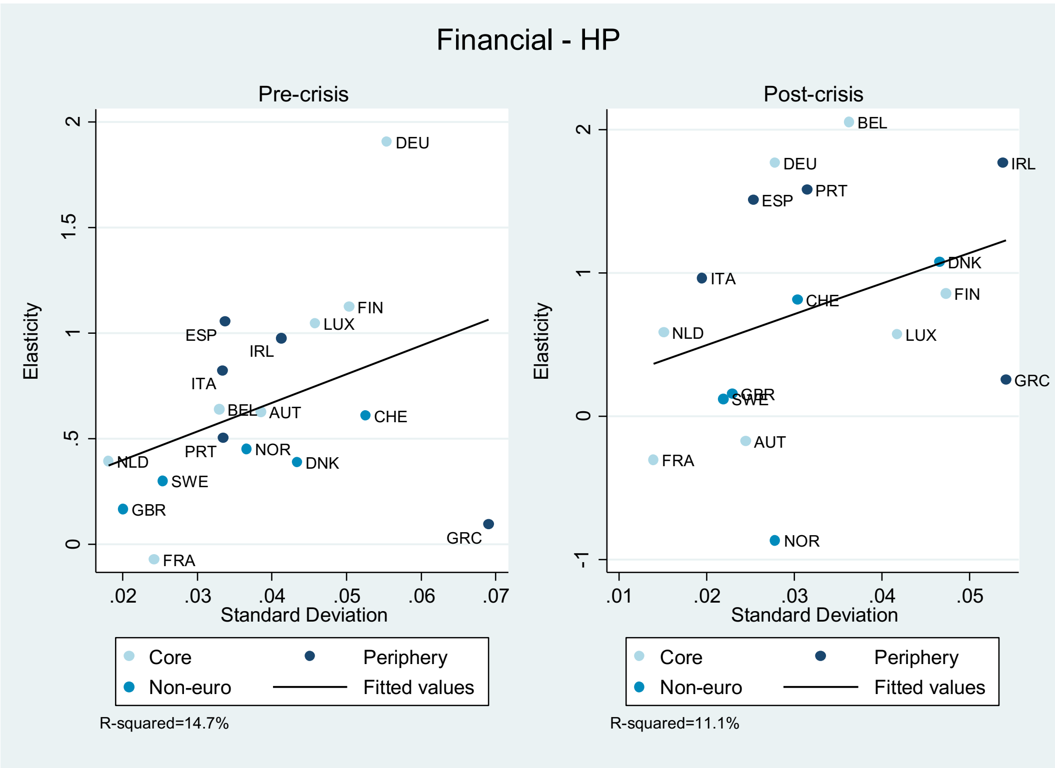

Figure A.17

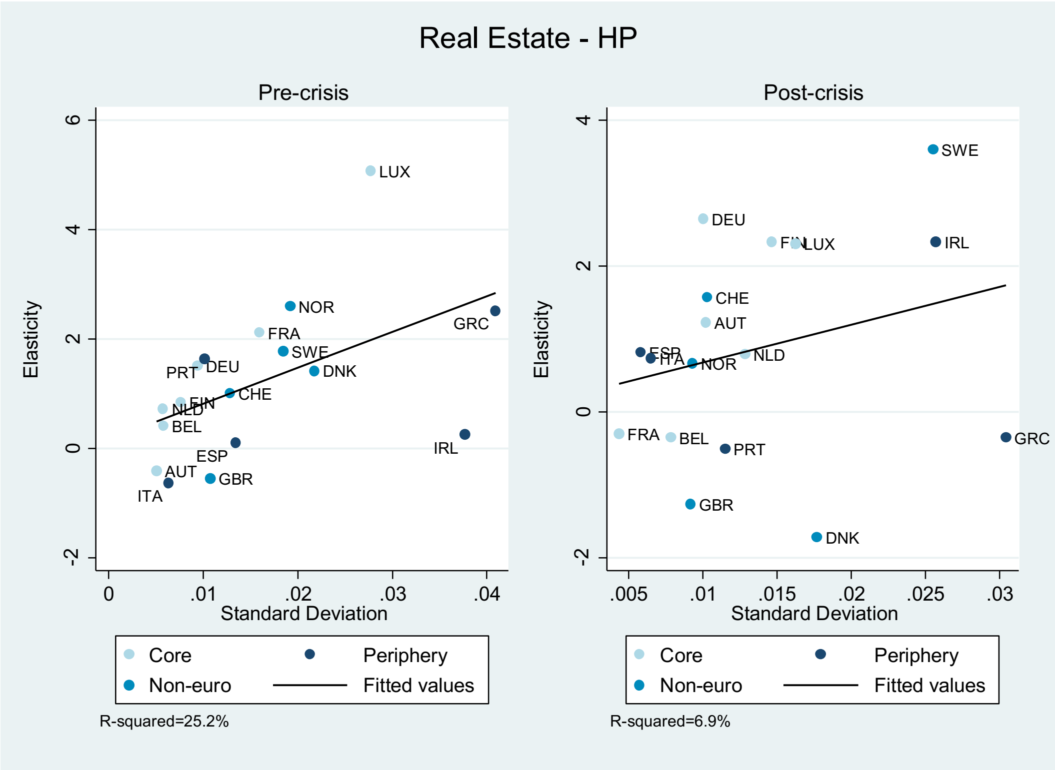

Figure A.18

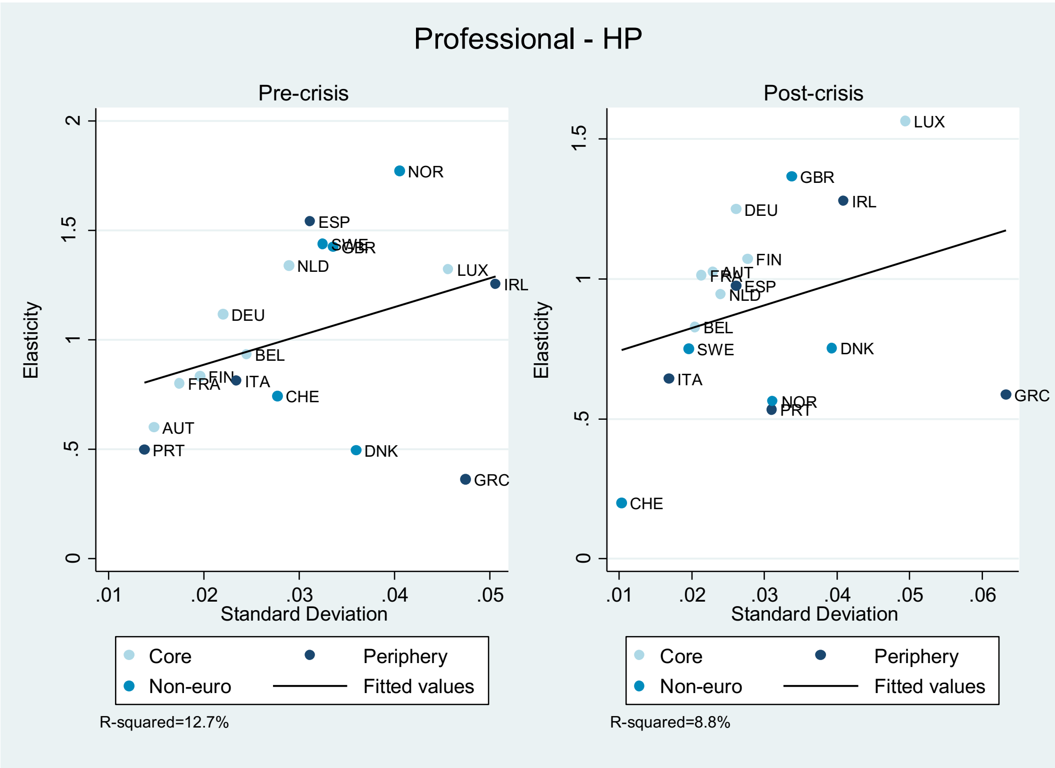

Figure A.19

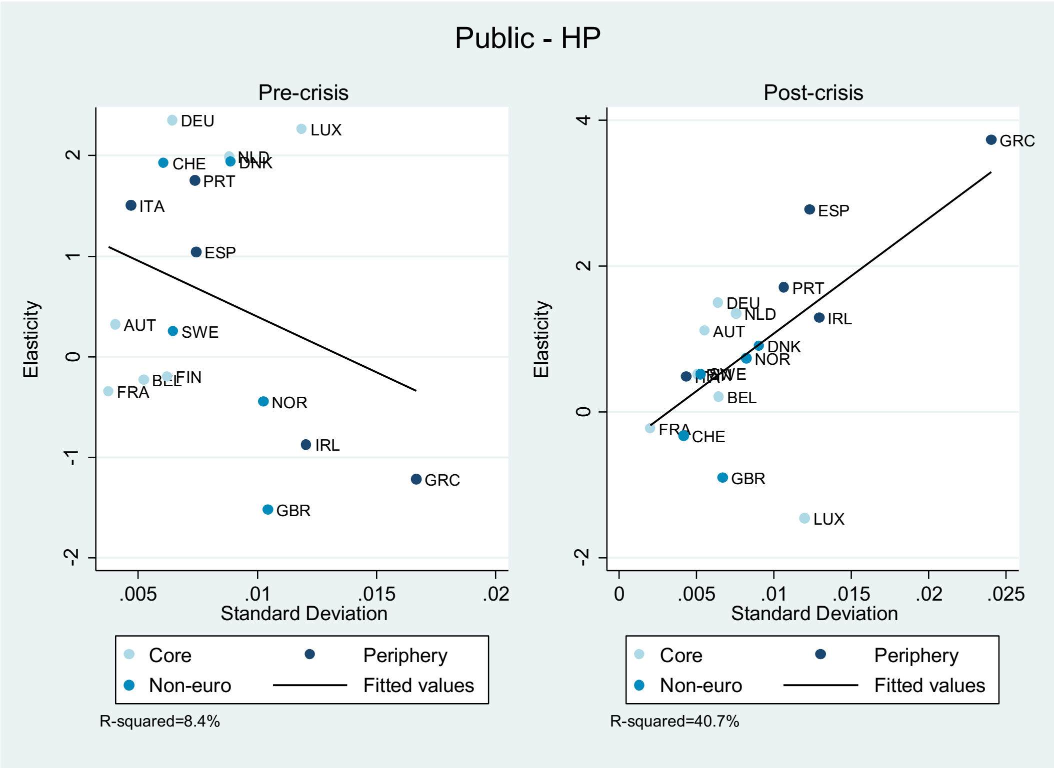

Figure A.20

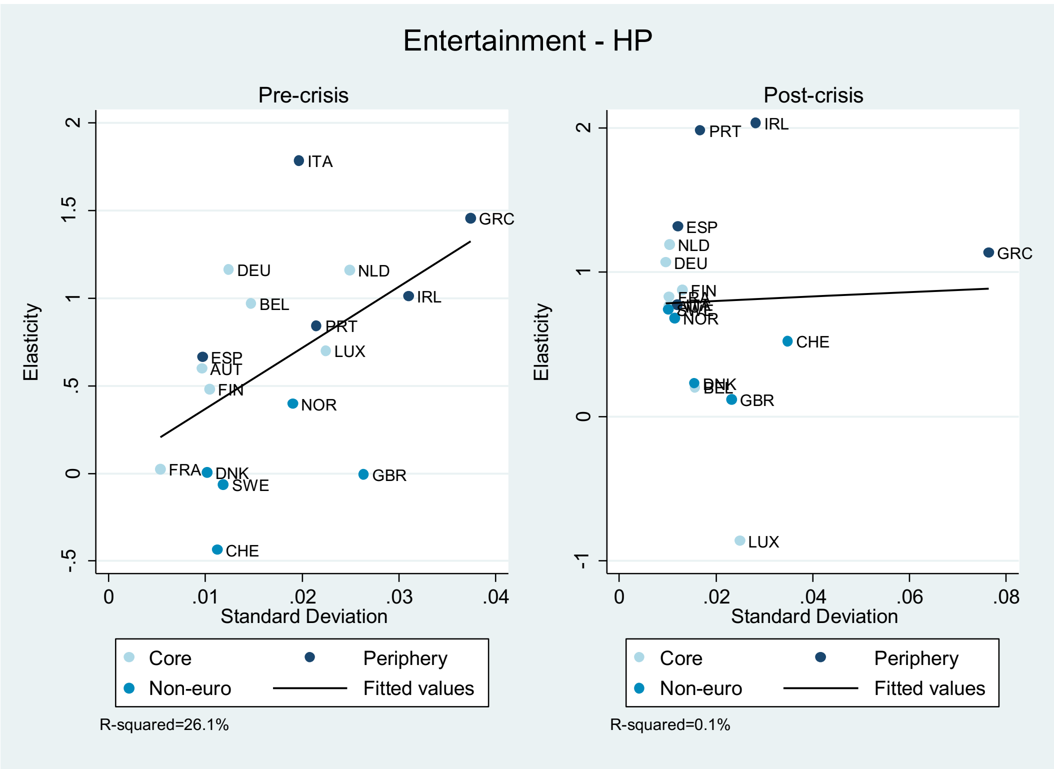

Figure A.21

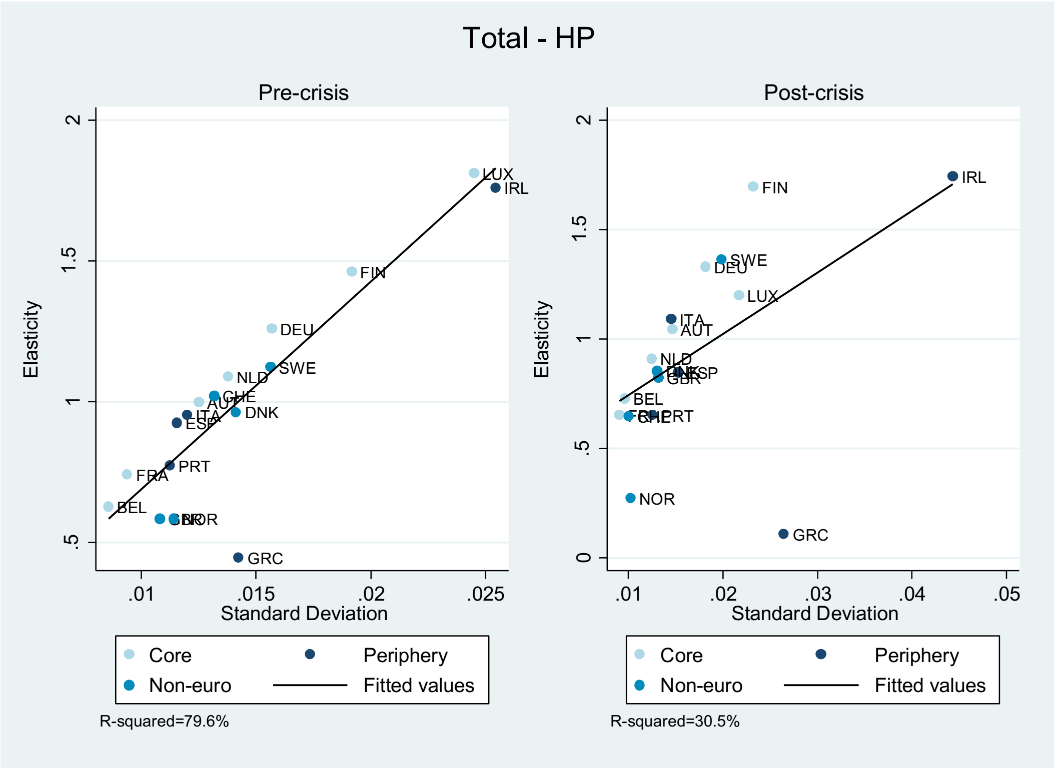
Total - HP
Pre-crisis
Post-crisis
Elasticity
Standard Deviation
Core
Periphery
Non-euro
Fitted values
R-squared=79.6%
R-squared=30.5%
LUX
IRL
FIN
DEU
SWE
NLD
CHE
AUT
DNK
ITA
ESP
PRT
FRA
BEL
GRC
NOR

Figure A.22