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The duration of acceleration cycle downturns: duration dependence, international dynamics and synchronisation

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Abstract
This paper analyses the factors that affect the duration of economic downturns using data for growth (acceleration) cycles for 13 industrialised countries over the period 1950–2018. Our findings show that downturn periods die of old age. We also find that when trading partners are in a downturn, the duration of a country's downturn is likely to be shorter, a likely outcome of common stabilisation mechanisms or terms of trade changes. Additionally, more open economies are found to experience shorter downturn periods and European Union countries show a higher level of synchronisation than the others. Lastly, trade linkages are found to intensify acceleration cycle synchronisation.

Keywords Acceleration cycles · Economic downturns · Duration dependence · Synchronisation

JEL Classification C41 · E32

1 Introduction

Economic systems are inherently characterised by fluctuations in economic activity. Classical business cycles are defined as alternating phases of expansion of aggregate economic activity and phases of recessions (Burns and Mitchell, 1946). While classical business cycles have been thoroughly studied (see de Bondt and Vermeulen, 2018; Castro, 2010, 2013; and references therein), much less is known about growth rate or acceleration cycles.

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Acceleration cycles are defined as alternating phases of accelerating economic activity, i.e. increases in the growth rate, and decelerating economic activity, i.e. decreases in the growth rate (Harding, 2004). They are thus akin to the first derivative of classical business cycles. Acceleration cycles are much more frequent and volatile than classical cycles, and there can be several full acceleration cycles during a full business cycle.

The study of acceleration cycles is particularly important for policymakers, investors and other economic agents, because their turning points tend to precede those of classical business cycles. Therefore, they can be seen as early warnings for business cycles turning points. That is, the beginning of an acceleration cycle downturn period could be the forewarning of the beginning of classical cycle downturn period (recession). Additionally, prolonged acceleration cycle downturn periods are more likely to lead to classical cycle downturn periods (recessions).

Another reason that motivates the study of acceleration cycles is that they can be useful during prolonged phases in classical business cycles. Relevant examples are the euro area prior to 2008 and emerging economies like India or China. From 1989 to 2019, China recorded no business cycle turning points but, according to ECRI data, it record 19 growth (acceleration) turning points. Hence, to understand the dynamics of classical cycles it is fundamental to look at underlying acceleration cycles.

These are the main reasons to analyse the duration of acceleration cycles. For that endeavour, we employ the growth rate cycle chronology provided by the Economic Cycle Research Institute (ECRI), which is based on the acceleration approach, over a panel of 13 industrialised countries spanning over the period of 1950–2018.

We investigate a wide range of factors that may affect the duration of acceleration cycle downturns. We begin by analysing the impact of time itself, by addressing the issue of whether downturn periods are more likely to end as they grow older. We then explore the role of international influences and the potential impact of trade channels. To do so, we look at the relationship between the cycle phase of the most important trade partners and trade openness. Lastly, we investigate the issue of synchronisation in acceleration cycles, as a means of assessing for the presence of common or distinctive patterns amongst our sample of countries. This allows us to better understand the role of international influences amongst the countries under investigation. For the duration analysis we employ Weibull and frailty models, while to investigate cross-country synchronisation we use simple correlation analysis.

The remainder of this paper is structured as follows: the next section reviews the empirical literature on the duration of economic cycle phases. Section 3 presents the empirical model, while Sect. 4 describes the data and presents the hypotheses to test. The main empirical results are discussed in Sect. 5, complemented with some robustness checks. Finally, Sect. 6 concludes.

2 Literature review

Business cycles (periods of recessions and expansions) have been widely studied in the literature. A substantial part of this literature also looks at growth cycles, defined as deviations of the growth rate from its long-run trend (Mintz, 1969). However, acceleration cycles, defined as acceleration and deceleration of the growth rate, have been very scarcely explored.

The main question in this broad literature is whether the likelihood of a phase of the cycle ending is dependent on its duration, which is referred to as duration dependence. The study of the duration of a cycle's phases requires the use of survival analysis, for which both parametric and nonparametric duration models can be used. Nonparametric models have a limited scope and usually represent the first step of the analysis before moving to the parametric ones that can better detect the presence of duration dependence (Sichel 1991). Moreover, the generally small sample size of business cycles restricts the power of nonparametric models. In his study, Sichel (1991) uses a Weibull model and NBER's chronology for the US business cycle from 1854 to 1990 and finds significant evidence of positive duration dependence for contractions in the post-WW2 era, but not for the pre-war period.

The Weibull model is the most widely used in this literature, as it allows for the estimation of a flexible and monotonically changing duration dependence parameter, and it also allows for the inclusion of covariates. Diebold and Rudebusch (1990) and Diebold et al. (1990, 1993) use the Weibull model and an exponential–quadratic hazard model to study the business cycles of the US, France, Germany and the UK. Similarly to Sichel (1991), they find evidence of positive duration dependence for recessions on the post-war era, but no evidence for the pre-war era. Extending Sichel (1991) work, but using a generalised Weibull model, Zuehlke (2003) finds evidence of positive duration dependence for both pre- and post-war periods of recessions in the US. Using a different methodology—Markov regime-switching models—Durland and McCurdy (1994), Kim and Nelson (1998), Lam (2004), Iiboshi (2007) all find evidence of positive duration dependence for recessions. These models regard the business cycle as an unobserved stochastic process; hence, they do not require the use of a business cycle chronology. Lastly, Abderrezak (1998) provides evidence of positive duration dependence for acceleration cycles using a Weibull model and a growth rate cycle chronology provided by ECRI's predecessor covering 11 industrial countries over the period of 1948 to 1992.

So far, these papers have only investigated the effect of time on the likelihood of a recession ending, while they do not account for any other factors that might also affect the duration of a cycle phase. Moving a step forward, Di Venuto and Layton (2005) and Layton and Smith (2007) develop a multinomial regime-switching logit model and apply it to the US and Australia. They not only provide evidence of positive duration dependence, but they also show that some leading economic indicators can have some explanatory power in predicting the turning points of the cycle.

Castro (2010, 2013) expands the scope of analysis by introducing a wide range of covariates concerning leading indicators, other economic variables and also political variables. He is also the first one to employ discrete-time duration models to the analysis of business cycles, which he applies to 13 industrial countries using the business cycle chronology developed by the ECRI. He provides additional evidence of positive duration dependence and also tests for the effect of international influences as proxied by the US cycle. His findings suggest that recessions are likely to be shorter if they are preceded by longer expansions. This latter issue had also been theorised and empirically investigated by Zellner (1990), who provided similar evidence for the

US in the pre-war period. On the other hand, Sichel (1991), Abderrezak (1998) and Yildirim (2015) do not find such evidence.

Taş and Cunedioğlu (2014) use a Weibull model to study 22 countries, using ECRI and NBER business cycle chronologies, combined with their own chronology of Turkey's cycle. They test for the role of structural characteristics—trade and financial openness, institutional quality—and of macroeconomic policy. The latter raises issues of endogeneity, as macroeconomic policy is most likely to be affected by the duration of a recession, which they try to tackle by using instrumental variables. Their findings suggest that expansionary monetary policy is highly effective in reducing the duration of recessions, while fixing the exchange rate does not have any effect. They also show that expansionary fiscal policy can have adverse effects on the duration of recessions. Regarding structural variables, they provide evidence that countries with higher trade openness tend to experience longer recessions.

Using the OECD's reference turning point chronology—which is constructed on the deviation cycle concept[1]—for 23 industrial countries over the post-1956 period, Yildirim (2015) provides additional evidence of positive duration dependence and also shows that higher saving rates, trade openness, productivity growth and depth of the phase tend to shorten downturn periods.

In a more recent study, de Bondt and Vermeulen (2018) extend Castro's (2010) study by modelling the role of foreign recessions in determining the probability of a recession ending. They use ECRI's business cycle chronology for the G7 countries and regime-switching logit models. Their findings provide additional evidence of positive duration dependence for recessions for all G7 countries. They also find that the probability of a recession ending is not affected by the other G7 countries' recessions. In contrast, the probability of an expansion ending roughly doubles when another G7 country falls into a recession. Hence, while foreign recessions significantly matter for a country entering into a recession, they do not matter for exiting one.

As evidenced in the above literature, duration dependence has been widely documented for classical business cycles, while less evidence exists for growth (deviation) or acceleration cycles. Additionally, only a handful of studies have looked at the effect of regressors on the duration of cycles' phases. This paper seeks to address some of these gaps, by investigating the duration of acceleration cycle downturns and also a range of structural and international relations factors that might affect them. For that purpose, we use the growth rate cycle chronology from the ECRI, which is based on the acceleration approach, that has only been used for individual countries rather than in a panel approach.

The study of acceleration cycle downturns is important for policymakers, as it is the first indication of potential subsequent recessions. It is also important to improve our understanding of the factors that prolong downturn periods, as such protractions can raise the likelihood of a transition to a classical recession.

[1] Deviation (growth) cycles are defined as the difference between the series representing aggregate economic activity and its long-term trend.

3 Methodology

Survival analysis has been used to model the duration of economic cycle phases. In this study, we employ the Weibull model, which allows for the estimation of the duration dependence parameter, but also for the inclusion of covariates.

In duration models, the duration variable measures the length of a spell, which in our analysis is the number of quarters that a country stays in a downturn phase. It is assumed to be a continuous random variable, T, which is set to zero when a downturn in each country starts, i.e. each country has its own individual clock. When countries are in a downturn, they face a probability of exiting this state. As they move in and out of downturns, they face different spells at risk, while before entering a downturn state again, a period of upturn occurs. Hence, we have multiple observations for each country, which experience discontinuous risk intervals.

A useful concept in duration analysis is the hazard function, which in this case represents the probability of exiting a given state (downturn) in the short interval of time Δt after t, conditional on being in that state at time t. This gives us the rate at which downturns will end at a duration of t time periods (quarters), conditional on having survived until t. The unconditional probability of the random variable T being smaller than a certain value t is given by the cumulative distribution function $F(t) =$ Prob$[T < t]$. We can also specify the distribution of the random variable T, by the so-called survivor function which can be defined as $S(t) =$ Prob$[T \geq t] = 1 - F(t)$, i.e. the probability of survival until time t. The corresponding density function is then given by $f(t) = \mathrm{d}F(t)/\mathrm{d}t$. The hazard function can then be expressed in terms of the distribution function as $h(t) = f(t)/S(t)$.

The hazard function is used to estimate the effect of time on the probability of exiting a spell, and consequently, it evaluates the presence of duration dependence. If the hazard is increasing in time, i.e. if $\mathrm{d}h/\mathrm{d}t > 0$, then the instantaneous rate of exiting a state increases with the spell duration. In this case, the longer a downturn is, the greater the likelihood of this downturn ending will be.

When parametric models are used, a specific distribution is imposed, which restricts the hazards in terms of their relationship with duration. The most popular distribution in economic cycles duration literature is the Weibull, which allows for a monotonically changing hazard. Its functional form is given by:

$$h(t) = p\lambda t^{p-1}, \tag{1}$$

where p is known as the shape parameter and λ as the scale parameter. p measures the degree of duration dependence. If $p > 1$, the conditional probability of a downturn ending increases with time, and thus, we have positive duration dependence; if $p = 1$, there is no duration dependence and the Weibull is equivalent to an exponential distribution; if $p < 1$, there is negative duration dependence. The scale parameter λ can be used to include covariates by assuming a functional form of the type $\lambda = \exp(\beta' x_i)$, where x_i is a vector of covariates. Then the Weibull hazard is given by:

$$h(x; t) = \exp(\beta' x_i) p t^{p-1} \tag{2}$$

The scale parameter is assumed to be fixed for the duration of each spell, and thus, the covariates function value is fixed for each spell. Hence, only time-invariant covariates can be included in the specification. The implication is that the effect of the covariates is the same at any time during the spell.

The Weibull model can be estimated by maximum likelihood, and the resulting log-likelihood function is given by:

$$lnL = \sum_{i=1}^{n}[c_i lnh(t_i, x_i) + lnS(t_i, x_i)], \quad (3)$$

where c_i indicates the censored observations. Hence, $c_i = 0$, if the observations are censored, i.e. if at the end of our sample time period they occupy the state under analysis (downturn), and $c_i = 1$, if we observe the end of the spell (downturn). In our sample, the censored observations refer to the countries that are in a downturn during the last quarter observed, i.e. at the 4th quarter of 2018. As we do not observe the end of these downturns, we impose an artificial end at the last quarter of the sample. In total, we have 7 censored observations.

4 Data

In this section, we describe the data used for the duration variable and covariates and present the hypotheses to test some descriptive statistics.

4.1 ECRI growth rate cycle chronology

The key variable in the study of the duration of economic cycles is concerned with the cycle itself. We use ECRI's growth rate cycle chronology, which is based on the acceleration cycle approach. To obtain the respective turning point dates, the ECRI follows a similar approach to that used by the NBER to identify classical business cycles.[2] As the ECRI uses the acceleration approach to identify turning points, we will refer to the phases of the cycle as *acceleration cycle upturns* and *downturns*.

Acceleration cycles turning points indicate the start or end of negative economic shocks. At an acceleration cycle peak, the growth rate of economic activity stops increasing and starts to decrease. Depending on the severity of the shock, the growth rate could then reaccelerate, or it could continue decreasing and turn negative, which could culminate in a recession. This means that an acceleration cycle downturn necessarily predates a recession, but not all acceleration downturns turn to recessions. Figure 1 provides a clear example of this dynamics for the US by contrasting its quarterly GDP growth with the growth rate (acceleration) cycle downturn periods identified

[2] To establish a turning point, the NBER and ECRI look at the co-movement of a range of coincident economic indicators relating to four factors: employment, income, output and sales. When most of those indicators, in level terms, fall or rise concurrently, a cyclical turning point in the business cycle is identified. When their growth rate accelerates or decelerates concurrently, a cyclical turning point in the growth rate (acceleration) cycle is identified.

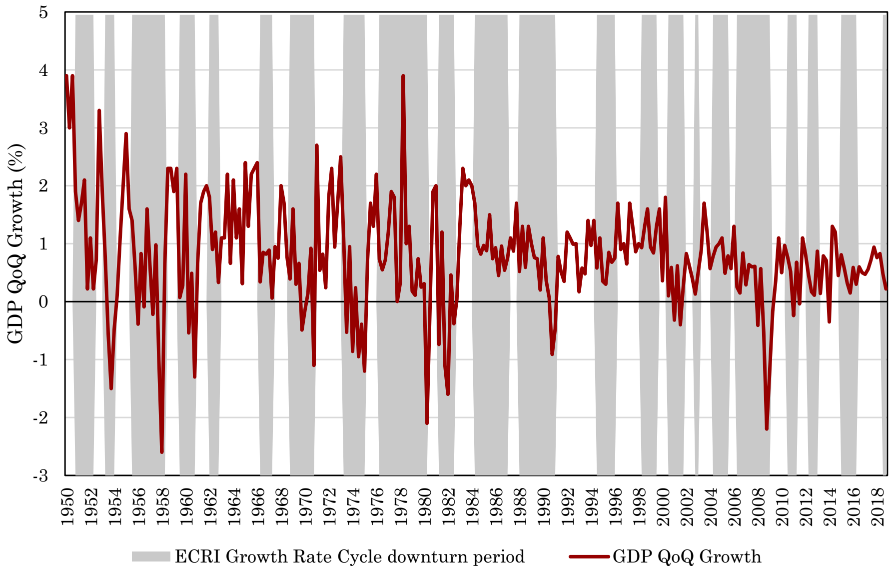

Fig. 1 US quarterly GDP growth and ECRI downturn periods.*Sources* OECD GDP data, ECRI growth rate cycle chronology

by the ECRI. With a single exception, all GDP contractions observed are preceded by the start of an acceleration cycle downturn, while not all acceleration downturns are followed by a GDP contraction.[3]

The ECRI dataset consists of 21 market-oriented economies—13 industrialised and 8 emerging market economies.[4] It covers the period of 1948–2018, on a monthly basis. Due to the unavailability of monthly data for some regressors, we switch to quarterly frequencies, based on the quarter in which the turning point is identified.

Furthermore, to avoid heterogeneity issues in our duration models, we restrict the sample to the 13 industrialised countries only.[5] Based on the ECRI turning point dates, we construct a duration variable that records the duration of each phase of the cycle, in quarters, by country. The peak of the cycle is included in the upturn period, while the trough in the downturn. Table 1 provides the summary descriptive statistics of our sample. The first column of both downturns and upturns gives us the number

3 For a picture on the average quarterly GDP growth during upturns and downturns for all the countries in our sample, please see Table 8 in Appendix.

4 Industrialised countries included in the sample: Australia, Austria, Canada, France, Germany, Italy, Japan, New Zealand, Spain, Sweden, Switzerland, the UK and the US. Emerging market economies excluded from the sample: Mexico, Brazil, Russia, China, India, Korea, Taiwan and South Africa.

5 The hazard function used assumes that all the observed downturn duration times are realisations of the same random variable T and come from the same probability distribution. In economic terms, this means that the countries under investigation need to exhibit acceleration cycles that do not systematically differ. If this assumption fails, then the estimated coefficients will be inconsistent. There are strong evidence suggesting that cycles in emerging market economies are systematically different to those of industrial economies (Calderón and Fuentes 2014). Hence, to avoid this issue we decided to narrow down our sample, a similar approach followed by Castro (2010) and Yildirim (2015).

Table 1 Descriptive statistics for upturns and downturns, 1950–2018

	Duration of downturns						Duration of upturns					
Countries	Obs.	Mean	Median	Sd	Min.	Max.	Obs.	Mean	Median	Sd.	Min.	Max.
UK	18	6.7	5.5	3.9	2	13	18	7	6	3.1	3	14
Germany	17	6.3	5	2.9	2	13	17	6.8	6	3.7	2	16
US	22	7.2	6	3.9	2	17	22	5.4	4	3.1	2	13
Canada	25	6	6	2.6	2	12	25	5.2	5	2.5	3	15
France	17	8.8	8	5.2	2	21	17	6.8	6	2.9	2	13
Italy	20	5.2	4.5	3	1	13	20	5.7	5.5	3.4	1	13
Spain	13	7.2	6	3.2	3	15	13	8.8	7	5	2	20
Switzerland	13	9.2	8	6.2	3	22	13	6.6	7	3.3	2	13
Sweden	15	5.5	5	2.8	2	12	15	6	6	3.3	1	12
Austria	18	5.5	4.5	3.3	2	12	18	6.2	6.5	3.1	2	12
Japan	23	5.4	5	3.6	1	15	23	5	4	2.4	2	11
Australia	20	6.8	6.5	3	3	14	20	6.5	6.5	2.9	2	12
New Zealand	14	7.5	7	4.8	2	19	12	6.6	4	4.3	2	14
Total	235	6.6	6	3.8	1	22	233	6.2	6	3.3	1	20

The duration of downturns and upturns is measured in quarters. The chronologies for each country do not start all in the same year (see ECRI source). Sd: Standard deviation; obs.: observations

Sources: ECRI website at https://www.businesscycle.com/ecri-business-cycles/international-business-cycle-dates-chronologies

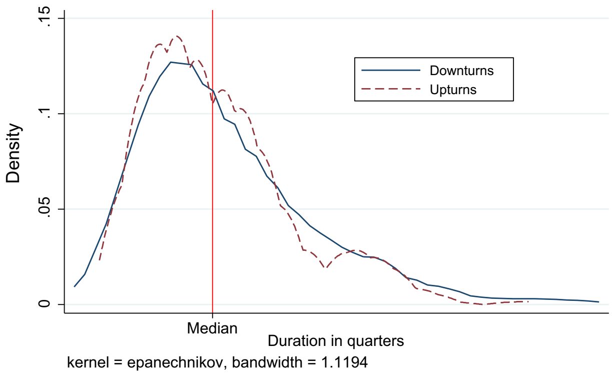

Fig. 2 Kernel density estimates for the duration of upturns and downturns, 1950–2018

of spells recorded for each country under the period of observation. The full sample ranges from 1950 to 2018; however, individual countries have different time ranges; hence, the panel is unbalanced. As sample periods are different amongst countries, the number of spells recorded for each country should not be used as comparison of the frequency of phases. The total sample size is equal to the total number of downturns recorded, i.e. 235 downturn periods observed.

The second column gives us the mean duration of each phase. Even though we do not investigate upturns in this paper, it is interesting to make a comparison between them at this point. The average duration of both upturns and downturns is slightly higher than six quarters. This similarity of mean duration for both phases of the acceleration cycle is in strike contrast to the findings of Castro (2010) for classical cycles that the average duration of expansions is four to five times higher than that of contractions. Both results are consistent with the theory of cycles, which suggests this asymmetry in classical cycles and a symmetry in acceleration cycles (Majetti, 2012). Nevertheless, we observe that downturns have slightly higher variability than upturns, as well as a slightly broader range.

Complementary to Table 1, Fig. 2 depicts the Kernel density estimates for both upturns and downturns duration. The distribution of both phases is heavily right-skewed and is quite similar for both phases of the cycle. The median duration of censored downturns, i.e. those that ended in our sample period, is equal to six quarters, indicating that 50% of the downturns last more than 6 quarters.

4.2 Covariates and hypotheses to test

The first hypothesis to test is whether duration dependence is present in the downturn phases. Given the evidence in the business cycles literature, we expect to find evidence of positive duration dependence for downturn phases, i.e. we anticipate that the likelihood of downturn phases ending will increase with their "age".

The first control variable used is the duration of the previous phase of the cycle (upturn), in quarters (*Previous upturn duration*). This variable is employed to test whether the duration of the preceding upturn affects the duration of a downturn phase. As noted in the literature review, some papers present evidence that longer expansions tend to be followed by shorter recessions. Hence, we also conjecture that this may happen with acceleration cycles.

The next variable to be considered in our analysis is trade openness (*Trade openness*), defined as imports plus exports over GDP. These data are drawn from the OECD's Quarterly National Accounts, measured in US dollars (volume estimates; fixed PPPs). The purpose of this variable is to assess the role of the country's openness to international markets on the duration of downturn phases. The business cycles literature provides mixed evidence on that matter: Taş and Cunedioğlu (2014) find that more open economies tend to experience longer recessions, while Yildirim (2015) obtains the opposite result. No evidence exists of such a relationship for acceleration cycles, so we have no clear expectation for this covariate.

To investigate the role of international influences arising from the global economy on the duration of downturn periods, we use the US cycle as a proxy for the global economic conditions or international cycle as in Castro (2010). We add a dummy to our model that takes the value of 1 if the US is in a downturn in the first quarter of the downturn period, and 0 otherwise (*US downturn*). A similar approach is used by Claessens et al. (2012). We expect to find that poor economic conditions in the US will reduce the probability of another country exiting from a downturn period, consequently increasing the duration of downturns.

To fine tune the analysis of the role of international influences, we also look at the effects from the countries' trade partners. For each of the 13 countries in our sample, we identify the top exporting destination country, as well as the top import source country, over the period 1948–2018 on an annual basis. Then we create two chronological classifications, based on each approach.[6] The international trade flows data were drawn from the Direction of Trade Statistics (DOTS) dataset of the IMF. Based on pure trade flows, we view these classifications as proxies for stronger economic, historical and political ties between the resulting pairs of countries.

Based on these classifications and on the ECRI chronologies, we derived two binary variables, taking the value of 1 if the leading export destination/import source country is in a downturn at the start of a downturn, and 0 otherwise (*Export country downturn* and *Import country downturn*, respectively). These two variables are meant to evaluate the role of the state of the cycle in trade partner countries on the duration of a downturn period. On a similar basis to the US variable, we expect to find that poor economic conditions in trade partner countries will worsen the ability of a country to exit a downturn and thus will increase its duration.

Additionally, as a robustness check, we also construct dummies looking at the state of the US and trade partners cycles at the quarter immediately preceding the last (*US downturn_lq*, *Export country downturn_lq* and *Import country downturn_lq*). These are meant to test for international influences towards the end of the downturn period. The full list of variables, respective definitions and descriptive statistics can be found in Tables 2 and 3.[7] Interestingly, the cycle dummies for both the US and the most

[6] The full list is given in Table 9 in Appendix. In cases where the most important trade partner identified is one for which the ECRI does not provide cycle chronologies, we use instead the next in turn trade partner for which cycle data are available.

Table 2 Description of the covariates

Variable	Description
Previous upturn duration	The duration of the previous phase of the cycle (upturn), in quarters
Trade openness	Exports + imports as a per cent of GDP at the start of the downturn
US downturn	= 1 if the US is in a downturn at the start of a downturn
Export country downturn	= 1 if the leading export country is in a downturn at the start of a downturn
Import country downturn	= 1 if the leading import country is in a downturn at the start of a downturn
US downturn_lq	= 1 if the US is in a downturn in the quarter preceding the last
Export country downturn_lq	= 1 if the leading export country is in a downturn in the quarter preceding the last
Import country downturn_lq	= 1 if the leading import country is in a downturn in the quarter preceding the last

Sources: ECRI, IMF, OECD

Table 3 Descriptive statistics for the covariates

Variable	Obs.	Mean	Sd	Min.	Max.
Previous upturn duration	227	6.1	3.3	1	20
Trade openness	222	44.0	26	7.2	131
US downturn	235	0.76	0.43	0	1
Export country downturn	231	0.66	0.48	0	1
Import country downturn	232	0.64	0.48	0	1
US downturn_lq	235	0.75	0.43	0	1
Export country downturn_lq	233	0.74	0.44	0	1
Import country downturn_lq	233	0.72	0.45	0	1

Sd Standard deviation;*obs.* observations
Sources: ECRI, IMF, OECD

important trading partners seem to indicate a high degree of synchronisation of their cycles, as in the majority of the cases the pairs of countries are simultaneously in a downturn.

As a way of complementing our main empirical analysis, we also briefly investigate the issue of the synchronisation of the cycle. For this part of the analysis, we use the ECRI's growth rate cycle chronology to create downturn dummies for each country taking the value of 1 if the country was in a downturn at that quarter, and 0 otherwise. The same variable was created for the leading import and export countries.

[7] For the correlation matrix, see Table 10 in Appendix.

5 Empirical analysis

In this section, we present the main empirical results and some robustness checks. We start by exploring the issue of synchronisation of acceleration cycles and the move to the baseline Weibull model, testing for duration dependence and the relevance of our covariates. Next, we explore heterogeneity issues by splitting the sample into EU and non-EU countries and by estimating frailty models. Finally, we briefly discuss the results of some additional robustness checks.

5.1 Synchronisation of the cycles

Before proceeding to the main survival analysis, we briefly investigate the issue of cycles synchronisation using simple correlation analysis, aiming to complement our empirical findings and set the ground for some of our robustness checks.

We use a simple Pearson pairwise correlation coefficient, for all the possible pairs of countries in the sample, using a binary downturn dummy, which takes the value of 1 if the country is in a downturn at a given quarter and 0 otherwise. We also compute pairwise correlations for the downturn dummies of each country and their most important trade partners and the US (see Tables 11 and 12 in Appendix). Lastly, we compute the sample averages of these sets of correlations, for three different sample groups: all countries, EU countries and non-EU countries. The respective results are presented in Table 4.

Starting with the pooled average country group correlations (row 1), we observe a positive correlation of the downturn dummies, which is relatively weak for the full sample but stronger for the EU subsample. This indicates a greater synchronisation of the cycles of EU economies when compared to non-EU ones. EU countries share a high degree of economic integration, have strong trade and financial links between each other, and are affected by the same EU-wide policies. This is particularly acute for countries within the Eurozone, who share the same monetary policy.

Evidence for the existence of a euro area business cycle is abundant in the business cycle synchronisation literature (Konstantakopoulou and Tsionas, 2014). However,

Table 4 Average cross-country correlations of acceleration cycle downturns

Average pairwise correlation	All countries	EU countries	Non-EU countries
1.Pooled	0.22	0.30	0.20
2.Country—US	0.25	0.25	0.26
3.Country—Leading Export Country	0.32	0.34	0.30
4.Country—Leading Import Country	0.31	0.32	0.30

'1. Pooled' is the average of all the possible pairwise correlation coefficients of each country group. The next three rows regard the average correlation of each country's downturn dummy and that of the US, and the corresponding leading export/import country. The US are excluded from the computation of the mean correlation with respect to the US, as this would upward bias our measure different patterns are identified in terms of the specific groups of countries converging to a common business cycle, as well as the strengthening of this synchronisation through time, which is related to the institutional changes taking place in the continent. Crucial milestones that strengthened linkages and increased synchronisation are the formation of the European Union, the Maastricht Treaty, the Single European Market, the Stability and Growth Pact, and the creation of the European Monetary Union (Papageorgiou et al., 2010). While we do not investigate this issue in depth, our tentative results are broadly in line with that literature.

Turning to the US (row 2), we observe a marginally higher synchronisation in relation to the US for the full sample, which is lower than that amongst EU countries. This suggests that the industrialised countries in our sample do not have significantly stronger links with the US than they have amongst themselves, which would lead to a significantly higher acceleration cycle synchronisation.

Moving on to rows 3 and 4, we observe that the average of the pairwise correlations between trade linked countries is higher than the average of the pooled pairwise correlations in row 1, for all three country groups (all countries, EU and non-EU). This means that trade linkages intensify synchronisation and could play a role in explaining acceleration cycles' behaviour. This finding is in line with the relevant literature that identifies trade as an underlying factor that enhances synchronisation (Frankel and Rose, 1998; Baxter and Kouparitsas, 2005; Berge, 2012).

Overall, while we only briefly investigate synchronisation, we can derive two tentative conclusions: (i) synchronisation is higher in the group of EU countries when compared to the non-EU one and (ii) trade linkages intensify the degree of synchronisation. This suggests that European integration and trade linkages can be important in explaining acceleration cycles' behaviour.

5.2 Main parametric estimates—Weibull model

Turning to the survival analysis, we start by using Kaplan–Meier procedure for a first insight on duration dependence based on the raw data information and without imposing any parametric assumptions. The Kaplan–Meier hazard rate, reported in Fig. 3, was found to increase in time, indicating that the longer a country stays in a downturn phase the greater the likelihood that it escapes this downturn. This gives us the first indication of positive duration dependence and suggests that a parametric model that allows for an increasing hazard may be well suited for this data.

Therefore, we move on to the estimation of the fully parametric Weibull model, which is reported in Table 5. Column 1 presents the basic parametric estimates for duration dependence without conditioning on any covariates. The estimated shape parameter, p, is larger than one in all specifications, providing significant evidence of positive duration dependence. This means that, on average, acceleration cycle downturns in industrial countries are more likely to end as they become older.[8]

[8] More specifically, a 1% increase in the duration of a downturn is associated with around 0.8% (p-1) increase in the hazard of it ending, ceteris paribus. See Allison (2014, Ch.3) and note that, from the baseline hazard function, we get: $\ln h(t) = \alpha + (p-1)\ln t$.

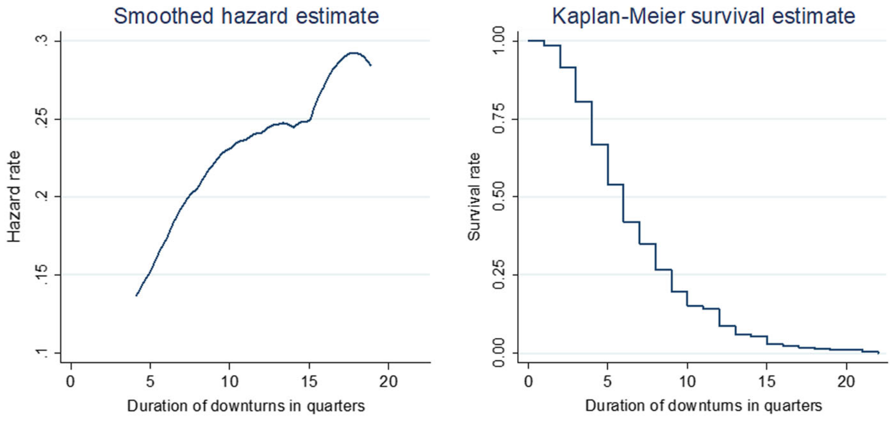

Fig. 3 Kaplan–Meier hazard and survival estimates for downturns

Positive duration dependence was expected, as GDP growth tends to be mean reverting. An acceleration or deceleration phase will drive growth of economic activity away from its long-run trend, which cannot be sustained indefinitely. As such, we would anticipate positive duration dependence to be exhibited in acceleration cycles. As the ECRI's growth rate cycle chronology has only been studied for a few individual countries, and never in a more complete panel approach, the above finding represents our first contribution to the literature.

Concerning the covariates, we start by testing whether the duration of the preceding upturn is affecting the duration of a downturn period. We find no evidence of such a relationship, which suggests that prolonged growth rate increases do not lead to longer deceleration phases, as a means of stabilising the growth rate.

Next, we turn to the role of structural characteristics of the economy and test the effect of trade openness. Our results indicate that trade openness does not have significant power in explaining the duration of downturn periods. Our estimated coefficients are small in magnitude, as trade openness is expressed in percentages, with a p-value of around 0.15. We believe that the reason for the non-relevance of trade openness in our estimates is that its variability mainly regards the cross section rather than the time series in our sample. Hence, it mostly differs from country to country rather than between years for the same country. As our cross-sectional size is relatively small, i.e. 13 countries, this estimate might not be representative of the population. Consequently, investigating a larger panel of countries could potentially provide more reliable estimates and a different conclusion. Additional evidence on this issue is provided in the robustness analysis.

Global economic conditions or the international cycle are proxied by the US cycle and accounted for in our model with a dummy variable indicating whether the US was in a downturn at the first quarter of the downturn period (*US downturn*). The coefficient of interest is not statistically significant, indicating that international influences originating from the US do not affect the duration of acceleration cycle downturns in

Table 5 Parametric estimations of duration dependence and determinants of the duration of downturns

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
p	1.864^{+}	1.850^{+}	1.848^{+}	1.841^{+}	1.878^{+}	1.902^{+}	1.823^{+}	1.861^{+}	1.875^{+}
	(0.098)	(0.100)	(0.105)	(0.103)	(0.099)	(0.104)	(0.107)	(0.110)	(0.113)
Previous upturn duration		0.007					0.004	0.010	0.006
		(0.014)					(0.014)	(0.014)	(0.013)
Trade openness			0.006				0.005	0.005	0.004
			(0.004)				(0.004)	(0.004)	(0.003)
US downturn				− 0.065			− 0.114		
				(0.161)			(0.149)		
Export country downturn					0.306**			0.273**	
					(0.132)			(0.122)	
Import country downturn						0.353***			0.311***
						(0.118)			(0.110)
Constant	− 3.782***	− 3.777***	− 3.983***	− 3.667***	− 3.986***	− 4.062***	− 3.829***	− 4.181***	− 4.188***
	(0.204)	(0.268)	(0.336)	(0.227)	(0.221)	(0.249)	(0.403)	(0.408)	(0.413)
Wald test ~ X^2(k)		0.636	0.153	0.686	0.020	0.003	0.545	0.077	0.034
Pseudo-log(L)	− 212.98	− 207.22	− 203.04	− 196.17	− 206.53	− 206.10	− 185.30	− 195.05	− 194.52
No. of downturns	235	227	222	213	231	232	199	216	216

p is the shape parameter for duration dependence

The reported Wald test gives the p-value of the joint statistical significance test for the k regressors included in the model. Pseudo-log (*L*) is the maximized pseudo-log-likelihood value

The US is excluded from the sample when the US downturn dummy (US downturn) is included in the mode

Sample size varies according to specification and the availability of data for each covariate used, as well as the exclusion of the US when relevant

+ indicates that p is significantly higher than 1 (positive duration dependence) using a one-sided test with a 5% significance level. Robust standard errors, clustered by country, are shown in parentheses

***, **, * indicate levels of significance at the 1%, 5% and 10% level, respectively other industrial countries. In accordance to our finding of no higher cycle synchronisation with the US, these results suggest there are no significant channels from the US affecting the acceleration cycles' behaviour.

While not directly comparable with the findings of Castro (2010) for classical business cycles, it is worth contrasting them. Castro finds that when the US enters into a recession, the likelihood of expansions ending in other countries increases. On the other hand, when the US exits a contraction and enters into an expansion, the likelihood of a recession ending elsewhere does not change. This means that the international influences from the US affect the likelihood of a country falling into a recession, but not the likelihood of exiting from one. In that sense, our findings for acceleration cycles are similar, in the sense that they show that the state of the US economy at the start of a downturn period does not have an effect on the likelihood of exiting a downturn, and hence, it does not affect its duration.

Additionally, we examine the role of international influences originating from the most important trade partner of each country. This channel of international influences is modelled in the same way as with the US, i.e. we include a dummy indicating whether the most important trade partner at that period was also in a downturn at the first quarter of a downturn. We consider two variables: one concerning the leading export country (*Export country downturn*) and the other concerning the leading import country (*Import country downturn*).[9] Both variables are found to have a statistically significant positive coefficient. This implies that if the trade partner country is in a downturn phase at the start of the downturn, the hazard of a country exiting a downturn phase is higher, and thus its duration shorter. This finding is contrary to our expectations, as we were initially expecting that a good economic stance on the trade linked country would create a positive spillover, stimulating the economic activity in the country facing a downturn, and would thus enable it to exit the downturn faster. This should be especially true in the case of the leading export country, as there is a direct positive demand effect from the country' trade balance.

However, our findings point us into the opposite direction. A possible explanation for this finding could be that in cases like the EU, where economic integration of member countries is very high, coincident downturns in some countries could enable aggregate EU-wide fiscal stabilisation policies, a more expansionary monetary policy by the European Central Bank, or other counter cyclical interventions. Such mechanisms could explain why coinciding downturns might be more likely to end, and thus have shorter durations. This argument is investigated further in the robustness checks below.

Another possible explanation could be related to a terms of trade change. If the most important trading partner is in a downturn phase, this could be associated with a deterioration of their terms of trade. This could be driven by an exchange rate depreciation or a weakening of the relative inflation rates between trading partners. If so, this could, on the other side of the coin, mean an improvement in the terms of trade of the country at hand. If this holds true, then an improvement in the terms of trade would support the country's growth rate which would explain why a downturn

[9] The *Export country downturn*, *Import country downturn* and *US downturn* variables often identify the same countries and are thus modelled separately to avoid multicollinearity issues.

period would end faster. Given the strong trade links between the respective pairs of countries this could explain the strong significance of those variables.

5.3 Sample heterogeneity across EU and non-EU countries

As already discussed in the data section, the countries included in our sample need to be homogeneous in the sense that they exhibit similar acceleration cycles. Despite the use of an arguably homogeneous sample of large, industrialised economies, they may still exhibit a different cycle behaviour. As a robustness check to this potential threat, we split the sample into two groups to investigate potential differences. As the cross-country dimension of our sample is quite small, there are not many possible splits. An arguably intuitive split is between EU and non-EU countries. The results of this exercise are presented in Table 6.[10]

The estimated parameter for duration dependence (p) seems to be robust to the split of the sample, as it remains largely similar in magnitude and always statistically significant as before. The duration of the previous phase remains insignificant in all specifications, but trade openness turns statistically significant for the sample of EU countries. The EU coefficient is positive indicating that, on average, more open economies are more likely to exit a downturn and thus face shorter downturns.[11] This suggests that more open EU economies are more resilient in facing negative economic shocks as they get through them more quickly. More open EU economies may also benefit more from positive spillovers from other EU countries or common EU stabilisation mechanisms than less open economies with weaker links. This could also explain why this result is restricted to our EU sample.

Turning to the most important trade partner variables, the coefficients for the leading export and import country dummies (*Export country downturn* and *Import country downturn*) are still statistically significant and higher in magnitude in the EU sample. However, for the non-EU sample, they lose explanatory power and turn insignificant. Hence, the significant estimates of the full sample models seem to be largely driven by the EU countries. These results add support to our argument on the existence of EU-wide stabilisation mechanism that could explain the initially unexpected result of coinciding downturns having shorter durations. However, such a mechanism does not seem to exist for the non-EU countries.

We can formally test the null hypothesis of equality of parameters across the two groups of countries using a likelihood ratio test that relies on the log-likelihood values reported in Tables 5 and 6. By comparing the basic models with no covariates, we find that the duration dependence parameter is robust to the split of the sample. At the same time, we reject the null of parameters equality for the models that include trade openness alone and the models including *Export country downturn* and *Import country downturn*. Hence, the estimated parameters might differ across the two samples and

[10] The *US downturn* covariate was also tested, but it remained insignificant across all specifications. The regression results are available in Table 13 in Appendix.

[11] In particular, a one percentage point rise in trade openness leads to an increase in the likelihood of a downturn ending by about 1.5%. For details on this interpretation see Allison (2014, Ch.3). In particular, 100(exp(β)-1) gives the percentage change in the hazard for each unitary increase in the respective explanatory variable.

Table 6 EU and non-EU countries estimates

	EU countries						Non-EU countries					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
p	1.885$^+$	2.019$^+$	1.958$^+$	1.994$^+$	2.065$^+$	2.067$^+$	1.850$^+$	1.798$^+$	1.834$^+$	1.850$^+$	1.803$^+$	1.813$^+$
	(0.111)	(0.130)	(0.077)	(0.086)	(0.128)	(0.122)	(0.164)	(0.143)	(0.159)	(0.167)	(0.147)	(0.153)
Previous upturn duration					0.022	0.017					0.002	− 0.001
					(0.036)	(0.035)					(0.013)	(0.011)
Trade openness		0.016***			0.014***	0.013***		− 0.001			− 0.001	− 0.001
		(0.005)			(0.004)	(0.004)		(0.002)			(0.002)	(0.002)
Export country downturn			0.429**		0.460***				0.211		0.122	
			(0.204)		(0.174)				(0.167)		(0.145)	
Import country downturn				0.461***		0.420**				0.283*		0.199
				(0.170)		(0.196)				(0.168)		(0.168)
Constant	− 3.779***	− 4.774***	− 4.160***	− 4.240***	− 5.188***	− 5.052***	− 3.799***	− 3.676***	− 3.897***	− 3.976***	− 3.757***	− 3.810***
	(0.229)	(0.494)	(0.177)	(0.189)	(0.624)	(0.600)	(0.342)	(0.370)	(0.361)	(0.417)	(0.468)	(0.507)
Wald test ~ X^2(k)		0.00	0.04	0.01	0.00	0.00		0.79	0.21	0.09	0.75	0.47
Pseudo-log(L)	− 106.430	− 98.737	− 100.479	− 100.480	− 91.993	− 92.499	− 106.246	− 99.412	− 104.847	− 104.387	− 97.744	− 97.460
No. of downturns	118	116	116	117	111	111	117	106	115	115	105	105

See notes in Table 5

the unrestricted models for EU and non-EU countries might be preferred to the full sample.

Overall, the observed differences in the estimates between the two samples, as well as in the relevant formal tests, indicate that the full sample of countries exhibits heterogeneity in the respective acceleration cycle behaviour, and thus, the assumption that all downturn duration times come from the same probability distribution might not hold. More specifically, EU countries seem to exhibit a different acceleration cycle behaviour relatively to non-EU countries, at least in some respects.

5.4 Neglected heterogeneity

We concluded above that heterogeneity across countries may play an important role in the analysis of acceleration cycles. To account for different country-specific factors that may affect downturns duration, we also consider neglected heterogeneity (frailty) models. These models introduce a random effects term in the specification, which is meant to capture all the unobservable exogenous variables that are not included in the specification. This is a useful robustness check against a potential misspecification of our earlier models.

Following Lancaster (1979), we re-specify the hazard function by including an unobservable random variable which is independently and identically distributed for all countries and assumed to follow the Gamma distribution. As presented in Eq. 1 above, the hazard function of the Weibull model is given by $h(t) = p\lambda t^{p-1}$, where p is the shape parameter and λ is the scale parameter. Introducing the latent random effects term, the hazard becomes:

$$h^*(t) = v_i h(t) = \left[1 - F^*(t)\right]^{\sigma^2} h(t) \tag{4}$$

where v_i is the latent random variable, F^* is the cumulative distribution function conditional on v and σ^2 is the variance of v. This model is also estimated using maximum likelihood techniques and provides an estimate of the σ^2 parameter, which is reported as θ (theta). If $\sigma^2 = 0$, then there is no neglected heterogeneity present in the sample and the model becomes a standard Weibull model. A likelihood ratio test, with null hypothesis of H_0: $\sigma^2 = 0$, can then be used to test for random effects.

In the presence of neglected heterogeneity that is not accounted for, the duration dependence parameter is known to be downward biased. This happens, because all the individuals, or countries in our case, that have the unobservable characteristics that make them more likely to exit a particular state (downturn) are the ones that leave that state first. If those individuals, or countries, leave first, then the ones that are left in the sample are those that are less likely to exit that state. This may result in a falsely identified negative duration dependence, or just induce a downward bias in the duration dependence parameter. The coefficients of the observed covariates might also be biased, but the direction of this bias cannon be known a priori.

Table 7 presents the results of the frailty model for the full specification, across the three sample groups (to be compared with models 7–9 in Table 5). The first thing that we need to look at is the results of the reported likelihood ratio test for H_0: $\theta = 0$,

Table 7 Neglected heterogeneity models

	All countries			EU countries			Non-EU countries		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
p	1.954^{+}	1.985^{+}	1.988^{+}	2.022^{+}	2.085^{+}	2.096^{+}	1.853^{+}	1.906^{+}	1.898^{+}
	(0.109)	(0.105)	(0.106)	(0.154)	(0.157)	(0.158)	(0.161)	(0.147)	(0.150)
Previous upturn duration	0.011	0.017	0.012	0.025	0.019	0.013	0.005	0.016	0.012
	(0.023)	(0.022)	(0.022)	(0.033)	(0.034)	(0.035)	(0.035)	(0.030)	(0.031)
Trade openness	0.011***	0.010***	0.009**	0.016***	0.014***	0.012**	0.006	0.008	0.006
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.005)	(0.011)	(0.009)	(0.010)
US downturn	− 0.036			− 0.147			− 0.029		
	(0.176)			(0.237)			(0.285)		
Export country downturn		0.318**			0.482**			0.107	
		(0.151)			(0.211)			(0.220)	
Import country downturn			0.318**			0.467**			0.134
			(0.150)			(0.220)			(0.224)
Constant	− 4.400*** (0.394)	− 4.700*** (0.367)	− 4.632*** (0.358)	− 4.836*** (0.519)	− 5.193*** (0.530)	− 5.053*** (0.519)	− 3.986*** (0.808)	− 4.333***(0.600)	− 4.266*** (0.609)
ln(θ)	− 2.166*** (0.645)	− 2.262*** (0.643)	− 2.399*** (0.675)	− 4.709 (4.785)	− 3.941 (2.517)	− 3.635* (1.977)	− 2.124 (1.805)	− 2.023 (1.341)	− 2.266 (1.646)

Table 7 (continued)

	All countries			EU countries			Non-EU countries		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
LRT($\theta = 0$) ~ $X^2(1)$	0.003	0.004	0.008	0.411	0.322	0.270	0.324	0.166	0.240
LR test ~ $X^2(k)$	0.050	0.006	0.006	0.013	0.002	0.003	0.965	0.811	0.781
Log(L)	− 181.60	− 191.64	− 191.64	− 96.12	− 91.89	− 92.31	− 83.37	− 97.27	− 97.21
No. of downturns	199	216	216	112	111	111	87	105	105

See notes in Table 5

The LRT($\theta = 0$) test gives the p-value of the likelihood ratio test with one degree of freedom for the null hypothesis of the parameter $\theta = 0$. Under the null, the homogeneity assumption is satisfied, i.e. there is no neglected heterogeneity. The reported likelihood ratio test (LR test) gives the p-value of the joint statistical significance likelihood ratio test for the k regressors included in the model where parameter θ is the variance in the heterogeneity across countries. The null is decisively rejected in all the full sample models, while it is upheld in all the EU and non-EU models. This implies that heterogeneity is present in the full sample Weibull models and might induce bias in the estimated parameters, while this heterogeneity fades out when we split the sample into EU and non-EU countries.

Hence, there are unobserved factors specific to EU countries that are affecting their ability to exit downturn periods, which systematically differ from the corresponding factors for the non-EU countries. These results give further ground to our earlier conclusion that EU countries exhibit a different acceleration cycle behaviour relatively to non-EU ones, and also potentially support our argument about common EU-wide stabilisation mechanisms explaining why coinciding downturns seem to be shorter in duration. Hence, the split of the sample into EU and non-EU countries is very well suited for our data and that the analysis should be conducted either separately for each group of countries or by including random effects to account for the neglected heterogeneity in the pooled models.

Regarding the impact of this neglected heterogeneity in the estimated parameters, we observe that the shape parameter p is now slightly higher, indicating that there was a small downward bias in our earlier estimates, as expected from theory. However, the differences are negligible and do not change our earlier conclusions. The range of the shape parameter in the main estimates of Table 5 is [1.823–1.902], while it now becomes [1.853–2.096].

Regarding the covariate estimates, previous phase duration and the US cycle dummy remain insignificant. Trade openness is statistically significant for the full sample and for the EU sample, but insignificant in the non-EU sample. This is in accordance with the sample-split models in Table 6, which found trade openness to be significant for EU but not for non-EU countries. We also observe that when we account for neglected heterogeneity, trade openness becomes significant for the full sample estimates too, reflecting the effect observed in the sample of EU countries. Regarding the estimates for the leading export and import countries, our earlier findings for the separate analyses seem to be robust: the respective coefficients remain significant for the EU countries but not for the non-EU ones.

Overall, we found significant evidence of neglected heterogeneity in the full sample models, which further supports the argument of a different acceleration cycles behaviour across EU and non-EU countries, and highlights the relevance of trade openness and trade partner influences in the sample of EU countries.

5.5 Additional robustness checks

In some additional robustness checks—not reported here but available upon request—we also tested for the role of international influences arising from the US and trade partners towards the end of downturn periods, instead of the start. This was modelled in a similar way to the regressions with *US downturn*, *Export country downturn* and *Import country downturn*, but looking at the state of the cycle of those countries at the end of the downturn period instead of the start.

The estimates were found to be statistically insignificant, indicating that the phase of acceleration cycles in the US and trade partners at the end of downturn periods do not affect their duration. Hence, the US cycle seems to play no role at either end of downturn periods, while trade partner countries' conditions are only important at the start of a downturn, a finding that is consistent with the argument of the existence of EU-wide stabilisation mechanisms. All other variables, including the duration dependence parameter, remained robust to the change in specification.

We also re-estimated our main models using the Cox proportional hazards model and formally tested for the proportional hazards assumption using the Schoenfeld residuals and the Grambsch and Therneau (1994) test. The Cox model is a semi-parametric model that only imposes a distributional assumption to the covariates vector, while retaining a flexible baseline hazard. Because of that, it can serve as a robustness check against the possibility that the parametric assumption of the Weibull model does not hold. The Cox model estimates were similar to those of the Weibull model, while the proportional hazards assumption was satisfied, suggesting the consistency of our previous estimates.

6 Conclusions

This paper draws from the extensive classical business cycles literature to provide new insights on the duration of downturn phases of acceleration cycles, i.e. accelerations and decelerations in growth rates of economic activity. An acceleration cycle downturn provides the first indication of a potential subsequent recession and can act as an early warning indicator for policymakers. We employ Weibull and frailty duration models over the ECRI's growth (acceleration) cycle dataset for a panel of 13 countries to investigate the issue of duration dependence and the role of international trade influences in determining the length of a downturn period.

Our findings confirm the existence of positive duration dependence, i.e. that downturns are more likely to end as they grow older, a result that concurs with the empirical findings for business cycles. We found no effect of the duration of the previous phase of the cycle on the duration of a downturn, while economies that are more open to trade experience shorter downturn periods.

We also observe that the state of the US cycle at the start of a downturn is not important in explaining the length of a downturn period, meaning that global economy effects do not seem to be important in explaining deceleration phases. However, we found that if the primary trading partner of a country is also in a downturn at the start of a downturn, then its duration is likely to be shorter. One possible reason for this is that coinciding downturns in EU countries may enable EU-wide countercyclical mechanisms that might ultimately shorten the duration of downturn periods. Another explanation could be the fact that an improvement in the terms of trade for the country entering into a downturn phase could expedite its exit from that state via a strengthening of its trade balance.

Furthermore, we investigated the existence of heterogeneous effects by splitting the sample and by employing frailty models. We found significant evidence of a distinct acceleration cycle behaviour of EU countries when compared with non-EU ones. Additionally, we briefly investigated the issue of cycles synchronisation and found evidence of greater synchronisation in EU economies and of trade linkages intensifying synchronisation across all the countries in our sample.

Overall, this paper finds that downturns are more likely to end as they grow older, but also highlights the importance of the international trade environment. More open economies are found to experience shorter downturns, while evidence points out to common stabilisation mechanisms across EU countries that help them to escape downturns faster.

Further research is required to better understand some of these issues. An interesting topic of further research would be the relationships between the different types of cycles—classical (business), growth (deviation) and acceleration cycles. It would also be interesting to look deeper into the international influences that have been identified and seek to unravel the mechanisms that could shape acceleration cycles' behaviour. Lastly, discrete-time models, such as regime-switching, logit/probit or complementary log–log models, would allow for the inclusion of time-varying covariates, which is a limitation of the Weibull model that we employed.

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Appendix

See Tables 8, 9, 10, 11, 12 and 13.

Table 8 GDP quarterly growth mean, by ECRI growth rate cycle phase

	Upturn	Downturn	Difference
Australia	1.1	0.6	0.6
Austria	0.9	0.3	0.6
Canada	1.1	0.5	0.7
France	0.9	0.6	0.3
Germany	1	0.2	0.7
Italy	0.9	0.2	0.7
Japan	1.1	0.7	0.4
New Zealand	0.9	0.4	0.6
Spain	0.8	0.4	0.4
Sweden	0.8	0.2	0.6
Switzerland	0.8	0.3	0.5
UK	0.9	0.3	0.6
US	1.3	0.4	0.8
Total	1	0.4	0.6

Sources: OECD, ECRI

Table 9 Most important trade partners chronologies

Leading exports destination country		Leading import source country	
Trade partner	Time period	Trade partner	Time period
Australia			
China	2009–2018	China	2006–2018
Japan	1966–2008	US	1987–2005, 1977–1984, 1966–1975
UK	1948–1965	Japan	1985–1986, 1976
		UK	1948–1965
Austria			
Germany	1950–2018	Germany	1952–2018
Italy	1948–1950	US	1948–1951
Canada			
US	1948–2018	US	1948–2018
France			
Germany	1961–2018	Germany	1958–2018
Algeria [Germany, UK]	1948–1960	US	1948–1957
Germany			
US	2015–2018, 1959	The Netherlands [China, France]	2000–2018, 1973–1986
France	1961–2014, 1948–1949	France	1987–1999, 1968–1972

Table 9 (continued)

Leading exports destination country		Leading import source country	
Trade partner	Time period	Trade partner	Time period
The Netherlands [US, France]	1960, 1950–1958	US	1948–1967
Italy			
Germany	1953–2018	Germany	1959–2018
US	1952	US	1948–1958
UK	1950–1951		
Argentina [UK]	1948–1949		
Japan			
China	2018, 2009–2012	China	2002–2018
US	2013–2017, 1948–2008	US	1948–2001
New Zealand			
China	2013–2018	China	2011–2018
Australia	1989–2012, 1984–1985, 1981	Australia	1987–2010, 1976–1983, 1973–1974
Japan	1987–1988, 1983, 1981	Japan	1984–1986
US	1986, 1979–1980	UK	1975, 1948–1972
UK	1982, 1948–1978		
Spain			
France	1974–2018	Germany	2004–2018, 1986–1992
US	1966–1973, 1950	France	1993–2003
Germany	1965	US	1950–1985
UK	1951–1964, 1948–1949	Argentina [UK, US]	1948–1949
Sweden			
Germany	2016–2018, 2011, 2006–2008, 1986–2000, 1983–1984, 1980–1981, 1978, 1961–1966, 1959	Germany	1952–2018
Norway [Germany, UK]	2012–2015, 2009–2010, 1982, 1977, 1975	UK	1948–1951
US	2001–2005, 1985		

Table 9 (continued)

Leading exports destination country		Leading import source country	
Trade partner	Time period	Trade partner	Time period
UK	1979, 1976, 1967–1974, 1960, 1948–1958		
Switzerland			
Germany	2014–2018, 1954–2012	Germany	2014–2018, 1952–2012
Hong Kong, China [Germany]	2013	UK	2013
US	1948–1953	US	1948–1951
UK			
US	1993–2018, 1981–1989, 1956–1978	Germany	2002–2018, 1999, 1982–1966, 1978–1979,
Germany	1990–1992, 1979–1980	US	2000–2001, 1997–1998, 1980–1981, 1954–1977, 1951, 1949
Australia	1948–1955	Canada	1952–1953, 1948
		Australia	1950
US			
Canada	1948–2018	China	2007–2018
		Canada	1992–2006, 1990, 1948–1984
		Japan	1991, 1985–1989

For some of the countries identified, growth rate cycle chronologies are not provided by the ECRI. Those are replaced with the next in line, for which ECRI chronologies exist; they are provided in square brackets

Data sources: IMF, Direction of Trade Statistics (DOTS) database. In this dataset, imports are reported on a cost, insurance and freight (CIF) basis, while exports are reported on a free on board (FOB) basis

Table 10 Correlation matrix for all variables

Variable	*Duration*	*Previous upturn duration*	*Trade openness*	*US downturn*	*Export country downturn*	*Import country downturn*	*US downturn_lq*	*Export country downturn_lq*	*Import country downturn_lq*
Duration	1								
Previous upturn duration	− 0.0005	1							
Trade openness	− 0.1692	− 0.0161	1						
US downturn	0.0852	0.0296	− 0.061	1					
Export country downturn	− 0.1347	0.0521	0.0907	0.4834	1				
Import country downturn	− 0.1566	0.0829	0.1317	0.4108	0.7977	1			
US downturn_lq	− 0.0898	0.0171	0.1101	0.2074	0.0191	− 0.0255	1		
Export country downturn_lq	− 0.0823	0.0273	0.2402	− 0.025	0.1239	0.0334	0.4162	1	
Import country downturn_lq	− 0.0713	− 0.0045	0.2796	0.0194	0.0829	0.1232	0.4231	0.7738	1

The correlations are calculated for the observations that all variables are available, accounting to a sample size of 216 observations

Table 11 Cross-country pairwise correlations of growth rate cycle downturns

Country	United Kingdom	Germany	United States	Canada	France	Italy	Spain	Switzerland	Sweden	Austria	Japan	Australia	New Zealand
United Kingdom	1												
Germany	0.227	1											
United States	0.317	0.326	1										
Canada	0.315	0.296	0.538	1									
France	0.304	0.303	0.293	0.301	1								
Italy	0.293	0.202	0.178	0.238	0.355	1							
Spain	0.381	0.356	0.223	0.212	0.455	0.216	1						
Switzerland	0.293	0.401	0.094	0.217	0.177	0.076	0.367	1					
Sweden	0.274	0.278	0.257	0.244	0.261	0.322	0.293	0.222	1				
Austria	0.028	0.507	0.161	0.250	0.284	0.200	0.379	0.398	0.299	1			
Japan	0.241	0.238	0.147	0.197	0.231	0.213	0.126	0.069	0.056	0.214	1		
Australia	0.207	0.122	0.175	0.176	0.126	0.087	0.094	0.259	0.245	0.147	0.049	1	
New Zealand	0.155	− 0.024	0.319	0.289	0.080	0.066	− 0.040	0.103	0.073	− 0.021	0.122	0.311	1

The correlations regard the downturn dummy (= 1 if in a downturn or 0 otherwise) of each country

Table 12 Cross-country pairwise correlations of growth rate cycle downturns with respect to the US and the leading export/import countries (LEC/LIC)

Country	US	LEC	LIC
United Kingdom	0.32	0.24	0.23
Germany	0.33	0.29	0.39
United States	1.00	0.54	0.45
Canada	0.54	0.54	0.54
France	0.29	0.30	0.32
Italy	0.18	0.20	0.20
Spain	0.22	0.46	0.30
Switzerland	0.09	0.40	0.41
Sweden	0.26	0.37	0.28
Austria	0.16	0.51	0.51
Japan	0.15	0.11	0.06
Australia	0.18	- 0.01	0.11
New Zealand	0.32	0.24	0.23

Table 13 EU and non-EU sample estimates for *US downturn*

	EU countries		Non-EU countries	
	(1)	(2)	(3)	(4)
p	1.893^{+}	2.013^{+}	1.792^{+}	1.768^{+}
	(0.111)	(0.147)	(0.183)	(0.151)
Previous upturn duration		0.026		− 0.009
		(0.032)		(0.009)
Trade openness		0.016***		− 0.002*
		(0.005)		(0.001)
US downturn	− 0.138	− 0.163	0.016	− 0.123
	(0.268)	(0.231)	(0.203)	(0.201)
Constant	− 3.690***	− 4.830***	− 3.656***	− 3.341***
	(0.250)	(0.603)	(0.414)	(0.448)
Wald test ~ X(k)	0.606	0.000	0.937	
Pseudo-log(L)	− 106.24	− 96.14	− 89.55	− 83.48
No. of downturns	118	112	95	87

Notes: See notes on Table 5

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