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Business cycle duration dependence and foreign recessions

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Abstract

We estimate business cycle regime switching logit models for G7 countries to determine the effect of duration of the current business cycle phase and of foreign recessions on the likelihood that expansions and recessions come to an end. With respect to expansions in a G7 country, we find that the probability they end roughly doubles each time another G7 country falls into a recession. We also find that expansions in the US and Germany are duration dependent, i.e. are more likely to end as they grow older. This contrasts with other G7 countries where expansions are not duration dependent. With respect to recessions in a G7 country, we find that the likelihood of them coming to an end is not affected by other G7 countries' recessions. We find duration dependence of recessions for all G7 countries, i.e. recessions that have gone on for a while are more likely to end.

Key words: Duration dependence; Recessions; Regime switching logit model; Business cycles

JEL: E32 ; C41

Non-technical Summary

In summer 2018, all G7 countries are in expansion. History suggests that this will not last and that at some point (at least some) G7 countries' economies will switch from an expansionary business cycle phase to a recessionary one. Furthermore, expansions and recessions are historically correlated among countries. Against this background, this study addresses four questions. First, do recessions in G7 countries spill over in the sense that they make domestic expansions more likely to end? Second, is the probability of a recession ending affected by other G7 countries' recessions? Spillovers might be important, because the G7 are integrated in the world economy through trade and financial linkages. A third question is whether expansions in G7 countries are duration dependent, i.e. are they more likely to end as they grow older? Given the considerable length of the current expansion, in especially Germany and the US, this question is particularly relevant. And finally, are recessions duration dependent?

To answer those questions we estimate regime switching logit models which model economies' transition between expansionary and recessionary business cycle phases. We use the monthly business cycle peak and through dates from the Economic Cycle research Institute (ECRI) to estimate those models. The model specification controls for duration dependence (i.e. expansions and recessions ending as a function of their duration) as well as whether foreign recessions affect the duration of expansions and recessions.

We find that recessions in G7 countries do increase the probability of domestic expansions prematurely ending but not for all G7 countries. Japan is less and in particular Canada is not vulnerable to foreign recessions. For the other G7 countries, the monthly recession probability roughly doubles for each extra G7 country in recession. For example, after 8 years of expansion, the probability of the US entering a recession goes from 2.7 percent when no other G7 country is in a recession, to 71.4 percent when all other G7 countries are in recession. The answer to our second question is a clear no. Foreign recessions are irrelevant for climbing out of a recession for all G7 countries. With respect to our third question, we find that only in the US and Germany the historical evidence shows that expansions are duration dependent, i.e more likely to end as they grow older. Finally, in all G7 countries, recessions are duration dependent.

Our results are particularly relevant for analysts and policymakers for two reasons. First, they show the vulnerability of expansions in the US and Germany as they grow older. Second, while considering the likelihood of current expansions continuing, foreign recessions should not be ignored and can substantially increase the risk of switching from an expansionary phase to a recessionary one.

1 Introduction

In summer 2018, all G7 countries are in expansion, with a quite long duration in many of them. Germany is experiencing its longest expansion since 1966 and the US is only a few months away of experiencing its longest expansion since Word War (WW) II. A question that arises is whether business cycles are duration dependent, i.e. whether they are more likely to end as they grow older.

We revisit this question because answers in the literature have thus far largely ignored the international dimension. An important factor potentially affecting the duration of domestic expansions is the occurrence of foreign recessions. One reason for the long expansion in the US could be that it has happened in a benign foreign environment. So even if expansions might not *de facto* be duration dependent their duration might be affected by spillovers from foreign recessions. Expansions might therefore end sooner in less benign foreign environments. Importantly if foreign recessions are important drivers of domestic business cycle phase changes (from expansion to recession or vice versa), leaving them out of the analysis might potentially bias the estimated effects of duration itself.

This paper revisits the question of duration dependence of domestic expansions and recessions by controlling for foreign recessions. To our knowledge this paper is the first to investigate the duration dependence combining it with a foreign recession impact for each G7 country (i.e. US, Japan, Germany, UK, France, Italy and Canada). We focus our analysis to the G7 countries because they are large enough to affect each other and capture the major tradable global currencies: US dollar, euro, Japanese Yen, British Pound and Canadian dollar.

Our paper is related to the literature on duration dependence of business cycles. Most of this literature has investigated the question of duration dependence for the US largely in isolation, independent of foreign recessions affecting the likelihood of US expansions (or contractions) ending. The question of business cycle duration dependence has spun a literature that tests for its presence either non-parametrically (Diebold and Rudebusch, 1990) or using duration models or regime switching time series models. Sichel (1991), Durland and McCurdy (1994), Zuehlke (2003), Ohn et al. (2004) and Layton and Smith (2007), referring to the US business cycle, all have found evidence of duration dependence for post WW II contractions, i.e. older recessions are more likely to end. The US evidence on duration dependence of post WW II expansions is, however, mixed. Zuehlke (2003) finds that US expansions die of old age, Layton and Smith (2007) report weakly significant duration dependence of expansions, whereas the other studies find no evidence for it.

Castro (2010, 2013) extends this literature by analysing duration dependence for thirteen industrial economies. He reports duration dependence for expansions and contractions. Importantly Castro (2010) analyzes the idea that other factors besides duration can affect the likelihood of expansions and contractions ending. Among other variables he introduces the presence of peaks in the US business cycle as an explanatory variable in other countries duration of

expansions and contractions. He finds evidence that when the US economy reaches a peak, the likelihood of expansions ending in other countries increases.

We extent Castro (2010) by explicitly modelling that foreign recessions might affect the termination probability of expansions (and recessions). We not only investigate the US business cycle as in Castro (2010) but also the cycles in other large countries. We consider all G7 countries because they are large enough to have a possible influence on the domestic business cycle of other G7 countries.

We answer four questions: (i) Is the likelihood of an expansion ending affected by other G7 countries' recessions? (ii) Is the likelihood of a recession ending affected by other G7 countries' recessions? (iii) Are expansions in G7 countries duration dependent? (iv) Are recessions in G7 countries duration dependent? The first two questions are new, with the important extra dimension that we control for foreign (i.e. G7) recessions. These two questions are obviously important in and of themselves. They determine whether independent of duration, G7 recessions matter for domestic business cycle phase changes. The final two questions are the traditional ones being asked in this literature.

We show that recessions in other G7 countries are important of why expansions in G7 countries end, except in Canada, but are unimportant for recessions ending. We also report duration dependence of expansions only in the US and Germany and duration dependence of recessions in all G7 countries. These answers to our questions are derived from regime switching logit models, for each of the G7 countries, where countries move between an expansionary and a recessionary state.

The rest of this paper is structured as follows. In section 2 we describe the data and methodology. Section 3 discusses the results and section 4 provides robustness checks. Section 5 concludes.

2 Data and methodology

We estimate regime switching logit models, following Layton and Smith (2007). To estimate such models, we need a dating of the business cycle. We use the monthly business cycle peak and trough dates from the Economic Cycle Research Institute (ECRI) for the G7 countries. The duration dependence studies by Castro (2010, 2013) have also used these business cycle chronologies and contain a deeper discussion of the advantages of this data. ECRI uses National Bureau of Economic Research style procedure to date classical business cycle turning points for various countries. It is based on a variety of economic indicators rather than a single one like GDP and is consistently applied across countries. The widely accepted ECRI chronology starts earliest in January 1948 and ends in December 2016. The business cycle consists of two phases, expansions and recessions. Hence we observe whether a country k in month t is in an expansion, $S_t^k = 1$, or is in a recession, $S_t^k = 0$.

Table 1 summaries the business cycle chronologies in the G7 countries. Three observations

emerge from the table. Firstly, the average duration of expansions varies between 5 and 7 years, with the exception of the UK and Canada with a much longer average expansion length of 11 to 12 years. The latter can in part be explained that both economies have traditionally benefited from commodities, notably oil. Secondly, the average length of a recession varies in a narrow range between 12 and 26 months. The third observation, related to the other two, is that the number of expansions and recessions is comparatively high in the US (11) and low (4 to 5) in the UK and Canada.

Table 1: Business cycle chronologies in G7 countries (1948-2016)

Country	Expansions					Recessions				
	No	Duration				No	Duration			
		Mean	SD	Min	Max		Mean	SD	Min	Max
US	10	59	35	11	119	11	12	4	7	19
JA	8	72	87	12	226	9	18	10	6	33
DE	5	72	18	53	98	6	26	12	10	40
UK	4	152	89	45	264	5	20	5	12	24
FR	7	75	54	21	182	8	17	8	10	33
IT	6	75	50	24	165	7	23	12	11	43
CA	4	145	102	27	277	5	19	4	14	25

Notes: Duration is measured in terms of months. SD refers to standard deviation, min to minimum and max to maximum. Completed expansions and recessions only. Sample beginnings different across countries: November 1948 (US), January 1953 (JAP), March 1966 (Germany), January 1951 (UK), November 1957 (France), January 1964 (Italy), May 1953 (Canada). Source: ECRI website at https://www.businesscycle.com, updated in March 2018.

We now define the statistical model that describes our business cycle data. Let i and j represent the actual state transition from time t-1 to time t, i.e. $(i, j) \in \{(0,0),(0,1),(1,0),(1,1)\}$. The business cycle dating data gives a time series of state transitions, i.e$\{(i^*, j*)_t, t = 1, ...T\}$. The state dependent logit model is fully defined by the transition probabilities. Let P_t^k be the transition matrix of country k at time t,

$$P_t^k = \begin{bmatrix} p_{00}^{kt} & p_{01}^{kt} \\ p_{10}^{kt} & p_{11}^{kt} \end{bmatrix} \tag{1}$$

with p_{00}^{kt} being the probability of staying in a recession from time t-1 to time t and p_{11}^{kt} being the probability of staying in an expansion from time t-1 to time t. The probability of switching to an expansion from a recession is given by $p_{01}^{kt} = 1 - p_{00}^{kt}$. The probability of falling into a recession from an expansion is given by $p_{10}^{kt} = 1 - p_{11}^{kt}$.

Specifically, the conditional state transition probability of country k at time t from state i to state j is given by:

$$p_{ij}^{kt} = P(S_t^k = j \mid S_{t-1}^k = i, X_{t-1}^k) \tag{2}$$

where X_{t-1}^k is a vector of explanatory variables.

As in Layton and Smith (2007) we use the logit form for p_{ij}^{kt}, The conditional probability of staying in an expansion (1,1) is

$$p_{11}^{kt} = \frac{exp(\alpha^k X_{t-1}^k)}{1 + exp(\alpha^k X_{t-1}^k)} \tag{3}$$

The conditional probability of staying in a recession (0,0) is

$$p_{00}^{kt} = \frac{exp(\beta^k X_{t-1}^k)}{1 + exp(\beta^k X_{t-1}^k)} \tag{4}$$

The logistic functional form guarantees the conditional probabilities being between 0 and 1. Let the indicator function $h_t(i,j) = 1$ if $(i,j) = (i^*, j^*)_t$ and $h_t(i,j) = 0$ otherwise. Than the likelihood function of the observed data is:

$$L(\alpha^k, \beta^k) = \prod_{t=1}^{T} \sum_{i=0}^{1} \sum_{j=0}^{1} h_t(i,j) p_{ij}^{kt} \tag{5}$$

The parameters are estimated using maximum likelihood.

Four different models are considered based on different sets of explanatory variables X_{t-1}^k. The first, most parsimonious, model is one with constant transition probabilities. In this case $X_{t-1}^k = 1$.

Given our interest in whether the transition probabilities depend on the duration of the current phase, a second model includes duration as the single explanatory variable, i.e. $X_{t-1}^k = \{1, D_{t-1}^k\}$. The duration D_t^k is the number of months a country k is in a particular state (expansion or recession). We have $D_t^k = D_{t-1}^k + 1$ if $S_t^k = S_{t-1}^k$ and $D_t^k = 1$ when $S_t^k \neq S_{t-1}^k$.

A third model adds recession dummies for other G7 countries as explanatory variables. Let $R_{t-1}^{US} = 1$ when the US is in a recession at time t-1 (and zero otherwise), likewise let $R_{t-1}^{JA} = 1$ when Japan is in a recession at time t-1 (and zero otherwise) and similarly define the variables $R_{t-1}^{DE}, R_{t-1}^{UK}, R_{t-1}^{FR}, R_{t-1}^{IT}, R_{t-1}^{CA}$ for the other G7 countries. For each country we estimate the model which includes foreign recession dummies. Model 3 allows the transition probabilities to change when other G7 countries are in recession. For instance, consider the US , the third model explanatory variables include duration and recession dummies for other G7 countries, i.e. $X_{t-1}^k = \{1, D_{t-1}^k\ R_{t-1}^{JA}, R_{t-1}^{DE}, R_{t-1}^{UK}, R_{t-1}^{FR}, R_{t-1}^{IT}, R_{t-1}^{CA}\}$. Model 3 is similarly defined for the other

G7 countries.

One potential problem with model 3 is that it contains a large number of parameters. It has 8 coefficients per business cycle phase, and therefore 16 in total. Especially when recessions are rare and/or highly correlated among G7 countries, estimating this model might run into numerical problems. Indeed, below we will show that in a few cases severe multicollinearity problems appear. To be more precise, the Hessian of the log likelihood is close to being singular. To solve this problem we assume that the coefficients on the foreign recession dummies are equal. This equality implies that the effect on the transition probabilities is not dependent on which country of the G7 goes into recession, but is still dependent on the number of G7 countries in recession. If the coefficients are equal we can replace 6 coefficients per phase with just 1 coefficient. Let R_t^{G7exk} be the number of G7 countries (excluding country k) that are in recession, varying thus between 0 and 6. Consider the model for the US, if we assume that the coefficients for $R_{t-1}^{JA}, R_{t-1}^{DE}, R_{t-1}^{UK}, R_{t-1}^{FR}, R_{t-1}^{IT}, R_{t-1}^{CA}$ are all equal we have that $\gamma_1 * R_{t-1}^{JA} + \gamma_2 * R_{t-1}^{DE} + \gamma_3 * R_{t-1}^{UK} + \gamma_4 * R_{t-1}^{FR} + \gamma_5 * R_{t-1}^{IT} + \gamma_6 * R_{t-1}^{CA} = \gamma * R_t^{G7exk}$.

So the explanatory variables of model 4 are $X_{t-1}^k = \{1, D_{t-1}^k\, R_{t-1}^{G7exk}\}$. Note that models 1 to 4 are nested and therefore the likelihood ratio is used to test the restrictions between the models. For instance model 4 is model 3 with 10 parameter restrictions, namely that all 6 parameters on the recession dummies in both business cycle phases are identical within each phase.

3 Empirical results

Table 2 reports the estimates of models 1 and 2. The log likelihood ratio tests indicate that, for all G7 countries, model 1 with constant transition probabilities has to be rejected relative to model 2 where transition probabilities depend on duration. Our results for the US confirm those of Layton and Smith (2007) which also reject constant transition probabilities in favor of a model including duration dependence. Two other conclusions emerge from Table 2. First, duration dependence of expansions is only found for the US and Germany (see α_2). This finding of positive duration dependence is in line with G7 (Castro, 2010 and 2013) and US evidence (Zuehlke, 2003; Layton and Smith 2007). It suggests that expansions in the US and Germany are more likely to end as time progresses. Secondly, recessions are duration dependent (see β_2) in all G7 countries. It implies that climbing out of a recession is a matter of time across all the G7 countries.

Table 2: Estimates of regime switching logit model with constant transition probabilities (Model 1) and with duration (Model 2)

	US		JA		DE		UK		FR		IT		CA	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
	Expansion parameters													
α_1 constant	4.21^{***}	5.22^{***}	4.31^{***}	4.12^{***}	4.50^{***}	7.71^{***}	5.15^{***}	6.47^{***}	4.39^{***}	4.96^{***}	4.36^{***}	5.07^{***}	5.11^{***}	6.06^{***}
	(0.32)	(0.68)	(0.36)	(0.54)	(0.45)	(1.69)	(0.50)	(1.13)	(0.38)	(0.66)	(0.41)	(0.75)	(0.50)	(1.03)
α_2 duration		-0.02^{**}		0.00		-0.06^{**}		-0.01^{*}		−0.01		−0.01		−0.01
		(0.01)		(0.01)		(0.02)		(0.01)		(0.01)		(0.01)		(0.01)
	Recession parameters													
β_1 constant	2.43^{***}	4.93^{***}	2.84^{***}	4.17^{***}	3.21^{***}	5.24^{***}	2.94^{***}	8.52^{***}	2.77^{***}	4.07^{***}	3.08^{***}	4.20^{***}	2.89^{***}	7.08^{***}
	(0.31)	(0.95)	(0.34)	(0.78)	(0.42)	(1.19)	(0.46)	(2.77)	(0.36)	(0.76)	(0.39)	(0.81)	(0.46)	(2.01)
β_2 duration		-0.26^{***}		-0.09^{**}		-0.10^{**}		-0.35^{**}		-0.10^{**}		-0.06^{*}		-0.29^{***}
		(0.08)		(0.04)		(0.04)		(0.14)		(0.04)		(0.03)		(0.11)
Ln L	−90.34	−81.23	−77.36	−74.60	−52.91	−45.86	−44.45	−36.99	−68.22	−64.76	−60.94	−58.33	−44.05	−37.86
L-ratio test	18.21^{***}		5.50^{*}		14.10^{***}		14.92^{***}		6.91^{**}		5.22^{*}		12.37^{***}	
Nobs	818	818	768	768	610	610	792	792	710	710	636	636	764	764

Notes: Standard errors below estimates, with *** denoting $p < 0.01$,** $p < 0.05$ and * $p < 0.10$. The L-ratio tests the null hypothesis that the restricted model holds (i.e $\alpha_2 = 0$ and $\beta_2 = 0$). It is χ^2 distributed with d.f.=2.

Table 3 reports the estimates of models 3 and 4. For the UK and Canada the standard errors for model 3 cannot be estimated due to multicollinearity. This is not surprising because both countries faced a comparatively low number of recessions over the sample and therefore a high correlation among the recession dummies considered. For model 3 most recession dummies are insignificant. This is clearly due to multicollinearity as evidenced by the fact that for expansions, once imposing equality of the recession dummy coefficients (i.e. model 4) the sum of the dummies turns significant for all G7 countries (except Canada). This reasoning is further strenghtened by the likelihood ratio test which indicates that model 4 against model 3 cannot be rejected for the G7 countries, with the exception of Japan and Canada. Based on these outcomes, model 4 is preferred.

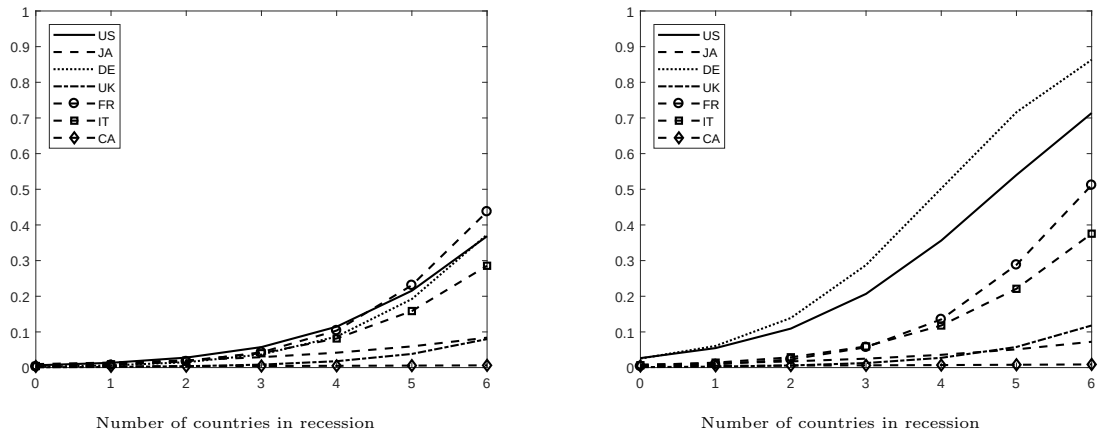
Four conclusions emerge from the estimated regime switching model with foreign recessions. First, foreign recessions significantly matter for falling into a recession (see α_3) for all G7 countries, with the exception of Canada. The effect is only marginally significant for Japan. Second, foreign recessions are irrelevant for climbing out of a recessions, as reflected by insignificant β_3 for all the G7 countries. Third, controlling for foreign recessions, expansions remain duration dependent in the US and in Germany and not the other G7 countries. Fourth, controlling for foreign recessions, domestic recessions remain consistently duration dependent (see significant β_2) across all the G7 countries.

Table 3: Estimates of regime switching logit model with foreign recessions (Models 3 and 4)

	US		JA		DE		UK		FR		IT		CA	
	Model 3	Model 4	Model 3	Model 4	Model 3	Model 4	Model 3	Model 4	Model 3	Model 4	Model 3	Model 4	Model 3	Model 4
	Expansion parameters													
α_1 constant	7.04***	6.51***	4.70***	4.46***	17.92**	8.38***	8.85	7.56***	6.94***	6.26***	6.16***	5.84***	5.78	6.11***
	(1.09)	(0.95)	(0.67)	(0.61)	(7.09)	(1.59)	.	(1.19)	(1.20)	(0.92)	(1.16)	(0.98)	.	(1.02)
α_2 duration	−0.04***	−0.03***	0.00	0.00	−0.17**	−0.05**	−0.02	−0.01	−0.01	−0.01	−0.01	−0.01	0.00	−0.01
	(0.01)	(0.01)	(0.01)	(0.01)	(0.08)	(0.02)	.	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	.	(0.01)
α_{US} recession			1.52		−4.76		1.43		0.29		−1.75*		−1.42	
			(1.54)		(8.04)		.		(1.05)		(0.99)		.	
α_{JA} recession	0.13				−3.42**		−0.48		−2.10**		−0.68		81.02	
	(0.92)				(1.68)		.		(1.07)		(1.33)		.	
α_{DE} recession	−1.27		−0.37				−1.29		−0.36		−0.39		−0.10	
	(0.90)		(1.33)				.		(0.93)		(1.20)		.	
α_{UK} recession	0.57		0.63		1.57				−0.11		−2.01		−0.81	
	(1.18)		(1.44)		(2.82)				(1.38)		(1.96)		.	
α_{FR} recession	−0.28		−0.31		−9.49*		−1.23				0.39		97.02	
	(1.38)		(0.90)		(4.92)		.				(1.81)		.	
α_{IT} recession	−0.79		−1.55*		6.37		−0.15		−1.27				−1.85	
	(1.05)		(0.81)		(5.29)		.		(0.93)				.	
α_{CA} recession	−3.41***		−1.36		2.65		−3.98		−3.04*		1.43			
	(0.92)		(1.19)		(8.03)		.		(1.77)		(2.10)			
α_3 recession G7		−0.75***		−0.37*		−0.92***		−0.78***		−0.95***		−0.75**		−0.11
		(0.28)		(0.22)		(0.31)		(0.28)		(0.27)		(0.30)		(0.32)
	Recession parameters													
β_1 constant	5.14***	4.69***	8.71***	4.45***	5.97***	4.59***	8.54	9.47**	6.40***	5.59***	4.11***	3.79***	330.55	6.33***
	(1.26)	(0.98)	(2.68)	(0.99)	(2.22)	(1.37)	.	(3.71)	(1.83)	(1.46)	(1.17)	(0.98)	.	(2.08)
β_2 duration	−0.38***	−0.33***	−0.31***	−0.1**	−0.15**	−0.09**	−0.40	−0.44**	−0.18**	−0.15**	−0.07*	−0.05*	−27.51	−0.34***
	(0.12)	(0.09)	(0.11)	(0.04)	(0.06)	(0.04)	.	(0.20)	(0.07)	(0.06)	(0.04)	(0.03)	.	(0.13)
β_{US} recession			9.11		−1.21		32.01		0.95		0.82		169.71	
			(277.67)		(1.52)		.		(1.45)		(1.65)		.	
β_{JA} recession	1.07				1.47		16.24		−0.16		0.31		−113.25	
	(1.04)				(1.27)		.		(1.28)		(0.99)		.	
β_{DE} recession	−1.13		2.66*				39.87		−0.77		1.10		307.84	
	(1.20)		(1.38)				.		(1.25)		(1.53)		.	
β_{UK} recession	0.21		−10.24		−1.59				−2.42		−2.50		125.95	
	(0.97)		(277.49)		(1.47)				(1.66)		(1.65)		.	
β_{FR} recession	0.94		0.78		0.42		−0.83				0.42		−54.31	
	(1.21)		(1.10)		(1.11)		.				(0.95)		.	
β_{IT} recession	0.98		−5.18		1.46		−37.09		−0.48				−27.06	
	(1.17)		(1.98)		(1.38)		.		(1.25)				.	
β_{CA} recession	1.06		1.57		0.09		−1.34		0.39		0.25			
	(0.88)		(1.98)		(1.28)		.		(1.45)		(1.53)			
β_3 recession G7		0.40*		−0.11		0.23		0.50		−0.37		0.16		0.71
		(0.21)		(0.22)		(0.32)		(0.44)		(0.25)		(0.26)		(0.59)
Ln L	−69.16	−75.75	−62.06	−73.25	−34.24	−41.69	−28.32	−32.56	−54.51	−57.31	−52.05	−55.08	−20.14	−36.89
L-ratio test		13.18		22.38**		14.90		8.48		5.60		6.06		33.50***
Nobs	818	818	768	768	610	610	792	792	710	710	636	636	764	764

Notes: Standard errors below estimates, with *** denoting $p < 0.01$,** $p < 0.05$ and * $p < 0.10$. The L-ratio tests the null hypothesis that the restricted model holds. It is χ^2 distributed with d.f.=10.

Fig. 1 plots the monthly probability of falling into recession after four, respectively, eight years of expansion as a function of the number of G7 countries in a recession, using the estimates of model 4 that includes foreign recessions. The first observation is that it is important to take account of foreign recessions. Recession probabilities if not a single G7 country is in recession are much lower than if one or more G7 countries are in recession. The recession probability roughly doubles for each extra country in recession. For example, after 8 years of expansion, the monthly probability of the US entering a recession goes from 2.7 percent when no other G7 country is in a recession, to 71.4 percent when all other G7 countries are in recession. Canada is the exception, where the recession probability is unaffected by other G7 countries' recessions.



(a) After 4 years (b) After 8 years

Figure 1: Probability of falling into recession after 4 and 8 years of expansion

Second, comparing panel (b) with (a) nicely illustrates the significant duration dependence of expansions in the US and Germany. History suggests an aging expansion in these two countries.

4 Robustness

How robust are our four key findings? Seven robustness checks provide no indication to change our findings with respect to foreign recessions and duration dependence. Regarding our first key new finding, Table 4 presents seven robustness checks for the estimated impact of foreign recessions during expansions, α_3.

The first robustness check excludes in the recession variable, R_t^{G7exk}, one country at a time. So e.g. the variable 'Recession G7 excl. US' in the regression for Germany is defined as $R_{t-1}^{JA} + R_{t-1}^{UK} + R_{t-1}^{FR} + R_{t-1}^{IT} + R_{t-1}^{CA}$. One could think that results are driven by one particular country. This is not the case. The key finding remains. For Canada the results remain insignificant. In robustness checks 2, 3 and 4 we use a different weighting of cumulating recessions in G7 countries. The coefficients hardly change using fixed (bilateral) trade weights, monthly variable trade weights or weights using equity market capitalisation. Trade links are likely more important

Table 4: Robustness results: recession G7 coefficient α_3

Recession var.	US	JA	DE	UK	FR	IT	CA
	1. Excluding one country						
Recession G7 excl. US	-0.75 ***	-0.49 *	-1.22 ***	-0.94 ***	-1.19 ***	-0.70 **	-0.08
Recession G7 excl. JA	-1.07 ***	-0.37 *	-0.90 ***	-0.91 ***	-0.92 ***	-0.73 **	-0.36
Recession G7 excl. DE	-0.84 **	-0.46 *	-0.92 ***	-0.90 ***	-1.15 ***	-0.95 ***	-0.16
Recession G7 excl. UK	-0.68 **	-0.44 *	-1.01 ***	-0.78 ***	-0.99 ***	-0.84 **	-0.16
Recession G7 excl. FR	-0.98 ***	-0.41 *	-0.89 **	-0.87 ***	-0.95 ***	-0.79 **	-0.24
Recession G7 excl. IT	-0.93 ***	-0.31	-1.06 ***	-0.95 ***	-0.99 ***	-0.75 **	0.05
Recession G7 excl. CA	-0.49 *	-0.41	-1.28 ***	-0.75 **	-1.02 ***	-0.83 ***	-0.11
	2. Bilateral fixed trade weights						
Recession G7	-0.87 ***	-0.18	-1.08 ***	-0.68 ***	-0.76 ***	-0.55 **	-0.14
	3. Monthly varying trade weights						
Recession G7	-0.57 **	-0.28	-0.86 ***	-0.67 **	-0.76 ***	-0.70 ***	-0.12
	4.Equity market capitalisation weights						
Recession G7	-0.31	-0.07	-0.71 ***	-0.40 *	-0.47 **	-0.63 ***	-0.09
	5. Additional country composite leading indicator (level)						
Recession G7	-0.60 *	-0.49 **	-0.92 ***	-0.74 **	-1.02 ***	-0.78 **	-0.14
	6. Additional country composite leading indicator (6 month rate of change)						
Recession G7	-0.85 ***	-0.35	-0.95 ***	-0.76 **	-1.03 ***	-0.57	-0.11
	7. Sample ending in July 2007 before Great Recession						
Recession G7	-0.76 **	-0.32	-0.59	-0.54	-1.07 ***	-1.33 ***	-0.02

Notes: Estimated α_3, with *** denote $p < 0.01$,** $p < 0.05$ and * $p < 0.10$.

than financial links, because the effects are consistently less precisely estimated when using stock market capitalisation weights. For the US they turn statistically insignificant.

The next two robustness checks 5 and 6 consider the OECD composite leading indicator in order to capture a potential impact of fundamental factors. This is in line with Layton and Smith (2007) and Castro (2010) who add leading indicators as explanatory variables. We find that adding the OECD leading indicator either in level or six-month rate of change does not change our results.

Finally, in robustness check 7 we show that the estimates are not exclusively driven by the Great Recession (i.e we let our sample end in July 2007). The foreign recession coefficients become, as expected given the exclusion of the unprecedented period of increased business cycle synchronisation among G7 countries (Antonakakis, 2012), statistically less significant. They remain significant for the US, France and Italy, but no longer for Germany and the UK. More importantly, the coefficients remain sizeable negative for all countries except again Canada, in line with the full-sample results. We can conclude that defining differently the recession dummy variable, adding other model variables and excluding the Great Recession don't matter. We continue to find that the probability of falling into recession increases with the number of other G7 countries in recession, for all G7 countries except Canada (and to some extent Japan).

Our second key new finding is also found to be robust. The foreign recessions coefficients during recessions, β_3, remain insignificant for all countries in all seven robustness checks (results

not shown), except for the US where it is sometimes (weakly) significant (as was also the case in Table 3).

Table 5: Robustness results: duration dependence coefficient α_2

Recession var.	US	JA	DE	UK	FR	IT	CA
	1. Excluding one country						
Recession G7 excl. US	-0.03 ***	0.00	-0.06 ***	-0.01	-0.01	-0.01	-0.01
Recession G7 excl. JA	-0.04 ***	0.00	-0.04 **	-0.01	-0.01	-0.01	-0.01
Recession G7 excl. DE	-0.03 ***	0.00	-0.05 **	-0.01	-0.01	-0.01	-0.01
Recession G7 excl. UK	-0.03 ***	0.00	-0.06 ***	-0.01	-0.00	-0.01	-0.01
Recession G7 excl. FR	-0.03 ***	0.00	-0.04 **	-0.01	-0.01	-0.01	-0.01
Recession G7 excl. IT	-0.03 ***	0.00	-0.04 **	-0.01	-0.00	-0.01	-0.01
Recession G7 excl. CA	-0.03 **	0.00	-0.06 ***	-0.01	-0.00	-0.01	-0.01
	2. Bilateral fixed trade weights						
Recession G7	-0.02 **	0.00	-0.07 ***	-0.01	-0.01	-0.01	-0.01
	3. Monthly varying trade weights						
Recession G7	-0.03 ***	0.00	-0.05 ***	-0.01	-0.00	-0.01	-0.01
	4.Equity market capitalisation weights						
Recession G7	-0.02 **	0.00	-0.06 ***	-0.01	-0.00	-0.01	-0.01
	5. Additional country composite leading indicator (level)						
Recession G7	-0.03 ***	0.01	-0.05 **	-0.01	-0.00	-0.01	-0.01
	6. Additional country composite leading indicator (6 month rate of change)						
Recession G7	-0.03 **	0.00	-0.05 ***	-0.01	-0.01	-0.00	-0.02
	7. Sample ending in July 2007 before Great Recession						
Recession G7	-0.03 ***	-0.01	-0.05*	-0.01	-0.01	0.01	-0.00

Notes: Estimated α_2, with *** denote $p < 0.01$,** $p < 0.05$ and * $p < 0.10$.

The seven robustness checks results also confirm our answers to the two traditional questions addressed also by others. Independent of the number of recessions abroad, expansions in the US and Germany remain duration dependent throughout (as shown in Table 5). Recessions remain significantly duration dependent (results not shown) except in a few cases when adding the leading indicator, which suggests some role for fundamentals.

5 Conclusion

For all G7 countries, we estimated regime switching business cycle models with two phases in which recessions from the other G7 countries were introduced in order to test whether the ending of domestic expansions and recessions where influenced by these other recessions. We also revisited the question of duration dependence of expansions and recessions.

Our estimates reveal that G7-recessions do matter for falling into recession for all G7 countries except Canada, and to a lesser extent also Japan. Monthly domestic recession probabilities roughly double each time another G7 country falls into a recession. Strikingly we found an asymmetry, the likelihood of climbing out of a recession is found to be independent of other G7 countries recessions. These results are new to the literature.

In terms of duration our results are in accord with the literature. While the ending of recessions in all G7 countries is just a matter of time, only in the US and Germany expansions become more likely to end as they grow older. The model does not provide an answer why only for the US and Germany expansions are found to be duration dependent. Factors that might play a role are domestic monetary policy and/or external trade, because the two countries have been globally the key monetary policy players and trade partners. We leave it to future research to investigate why the US and Germany are different from the other G7 countries.

Finally, our results indicate that while considering the likelihood of current expansions continuing, foreign recessions should not be ignored. They are important and expansions increasingly might end once one country falls into recession. A detailed analysis of common and country-specific fundamental and policy-related factors underlying these stylised business cycle facts is an interesting avenue for future research.

References

[1] Antonakakis, N. 2012. The great synchronization of international trade collapse. Economics Letters 117 (3), 608–614.

[2] Castro, V., 2010. The duration of economic expansions and recessions: more than duration dependence. Journal of Macroeconomics 32 (1), 347–365.

[3] Castro, V., 2013. The duration of business cycle expansions and contractions: are there change-points in duration dependence? Empirical Economics 44 (2), 511–544.

[4] Diebold, F.X., Rudebusch, G.D., 1990. A non-parametric investigation of duration dependence in the American business cycle, Journal of Political Economy 98 (3), 596–616.

[5] Durland, J.M., McCurdy, T.H., 1994. Duration-dependent transitions in a Markov Model of U.S. GNP growth. Journal of Business and Economic Statistics 12 (3), 279–288.

[6] Layton, A.P., Smith, D.R., 2007. Business cycle dynamics with duration dependence and leading indicators. Journal of Macroeconomics 29 (4), 855–875.

[7] Ohn, J. Taylor, L.W. Pagan, A. 2004. Testing for duration dependence in economic cycles. Econometrics Journal, 7 (2), 528–549.

[8] Sichel, D.E., 1991. Business cycle duration dependence: a parametric approach. Review of Economics and Statistics 73 (2), 254–260.

[9] Zuehlke, T.W., 2003. Business cycle duration dependence reconsidered. Journal of Business and Economic Statistics 21 (4), 564–569.

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