The effect of loss offset provisions on the asymmetric behaviour of corporate tax revenues in the business cycle

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Abstract: This paper estimates the response of corporate tax revenues to the business cycle fluctuations and calculates a heterogeneous asymmetry in the tax revenue responses between booms and recessions using a new index of loss offset generosity provisions. I find strong short-run contemporaneous impact of business cycle on corporate tax revenues and a persistent asymmetric response of corporate tax revenues to booms and recession. Loss offset generosity provisions enhance this asymmetry. Countries with more generous loss offset provisions experience much more volatile response of corporate tax revenues to business cycle during recessions, magnifying the asymmetry of cyclicality. As a result the automatic stabilizer impact of corporation tax will differ between booms and recessions, being stronger and more effective in the latter, especially in countries that offer more generous loss-offset provisions.

Key Words: business cycle, corporate tax revenues, asymmetric fiscal policy, loss-offset provisions

JEL: E32, E6, H25, H32

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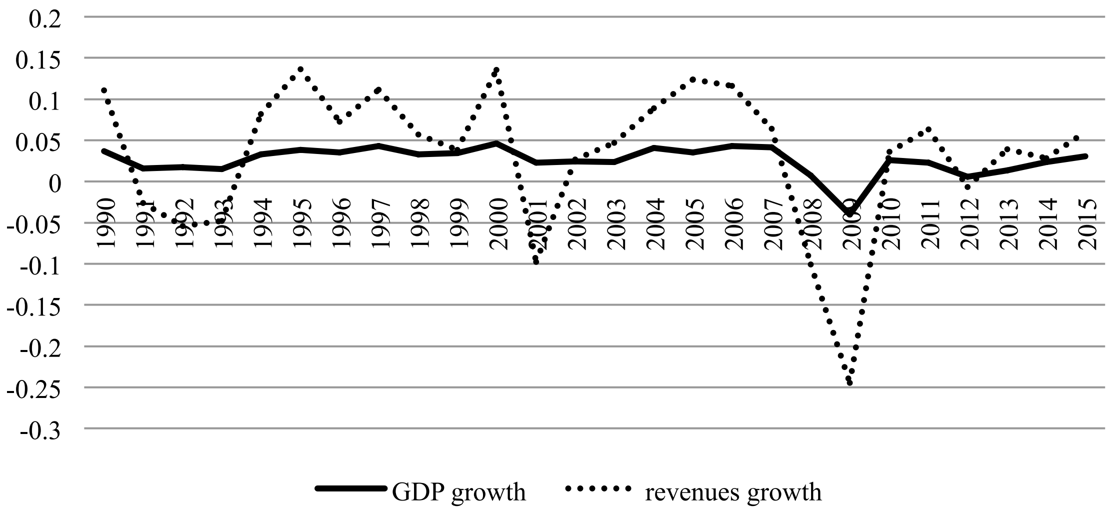
1 Introduction

Corporate tax revenues fluctuate with the business cycle (Figure 1). In booms employment increases and companies tend to make more profits, so they have more taxable income than in normal times. As a result, they will pay more tax and the total corporate tax revenue in the economy will increase. In contrast, in recessions employment declines, corporate profits decline and some companies may even experience losses. As a result companies pay less tax, which implies that corporate tax revenues collected by the government decline. This paper examines this response of corporate tax revenues to the business cycle, calling this relationship the 'cyclicality of corporate tax revenues'.

Figure 1. Unweighted OECD average GDP growth vs corporate tax revenue growth over the years.



The analysis of the cyclicality of corporate tax revenues feeds into the debate about the automatic stabilizing property of corporation tax. This is extremely relevant, especially after the severe consequence that the latest financial crisis had on growth in many countries. Due to the reduction in corporate tax revenues in response to business cycle fluctuations, government budget deficits increase. This keeps national income higher by maintaining aggregate demand. This happens automatically and reduces the size of recession. If the impact of fluctuations is asymmetric between booms and recessions, then the automatic stabilizer impact of corporation tax will differ between the episodes as well.

The key contributions of this paper are two-fold. First, it adds to the literature on the cyclicality of tax revenues by considering the cyclicality of a particular component of tax revenues - corporation tax revenues. I find that the short run contemporaneous impact of business cycle on corporate tax revenues is quite strong in normal times and in recessions, but it is much lower in booms; hence, corporate tax revenues are asymmetric with respect to business cycle fluctuations. Second, I provide novel evidence on how this cyclicality is related to the loss offset generosity provisions that various countries offer. I show that the loss offset generosity provisions enhance the asymmetry in the cyclicality of corporate tax revenues. Countries that are more generous in terms of the loss offset provisions, experience much more volatile response of corporate tax revenues to business cycle during recessions, magnifying the asymmetry of the cyclicality.

To be more specific, I find that corporate tax revenues react strongly to business cycle fluctuations. The short-run volatility of corporate tax revenues with respect to business cycle is in the range between 2.7% and 5.1%. What this means is that 1% shock to GDP changes the corporate tax revenues collected by 2.7% (using OLS) and up to even 5.1% (using instrumental variables approach). Since corporate tax revenues as a percentage of GDP have been stable over the years in most of the OECD countries, I would expect that these fluctuations are only short-lived and the relationship between corporate tax revenues and business cycle reverts to its long-run mean. I find the long-run elasticity of corporate tax revenues with respect to the business cycle to be one.

The cyclicality of fiscal policy has been analyzed extensively in the macroeconomic literature. Authors have mainly concentrated on the cyclical properties of government spending (Lane, 2003; Hercowitz and Strawczynski, 2004) or government spending and government revenues (Sorensen et al 2001; Lee and Sung, 2007; Hallerberg and Strauch, 2002; Sorensen and Yosha, 2001). However, there is not much work on the impact of business cycle on the components of government revenues and government spending, apart from contributions studying differences between cyclicality of direct and indirect taxes (Hallerberg and Strauch, 2002; Furceri and Karras, 2011). These authors find very weak to no evidence that direct taxes, are responsive to business cycle. The current paper challenges these conclusions, by showing how business cycles affect corporate tax revenues.

My second finding is that the responses of corporate tax revenues to the business cycle are asymmetric. The empirical evidence I provide suggests that corporate tax revenues are tied most strongly to the business cycle fluctuations in normal times and recessions. The relationship between the two is much weaker in booms. Previous literature has documented asymmetries in the response of fiscal variables over the business cycle (Hercowitz and Strawczynski, 2004; Lee and Sung, 2007; Sorensen and Yosha, 2001; Fatas and Mihov, 2013; Sancak et al, 2010). The general consensus is that the response of government spending and tax revenues to the business cycle tends to be quite strong in recessions relative to booms. What is more, government expenditures and revenues, even at the state level, have a strongly counter-cyclical response during recessions, but pro-cyclical response during booms (Lee and Sung, 2007; Sorensen and Yosha, 2001). This suggests that fiscal policy tends to mute economic booms to roughly the same degree it mitigates slowdowns.

The definition of booms and recessions is crucial when one wants to distinguish between the impact of business cycle in recession and booms. Most of the previous literature classifies all growth rate periods as either booms or recessions. In reality, most of the periods are actually normal times, neither a boom nor a recession. In this respect, another contribution of our paper lies in separating the episodes into three-phase business cycle rather than two-phase one (recession and boom) and comparing the impact of business cycle in normal times versus these extreme instances.[1]

[1] The importance of identifying three-phase business rather than two-phase one (recession and boom) has recently been outlined in Fatas and Mihov (2013). A majority of contributions to definitions of business cycle episodes as recessions and booms are coming from the literature on fiscal multipliers; see for instance Blanchard and Perotti (2002), Romer and Romer (2010), Ramey (2011), Auerbach and Gorodnichenko (2012)

In the second part of the paper I focus on heterogeneities in the responses of corporate tax revenues to the business cycle fluctuations. In particular, I consider how the size of the tax bases and the generosity of the loss-offset provisions affect the cyclicality parameters. The size of the tax base has been shown to be important in explaining the variation in the tax revenues (Devereux, 2006; Clausing, 2007; Kawano and Slemrod, 2012 and 2016; Suarez-Serrato and Zidar, 2017) together with the tax rate. Therefore it is crucial to control for both when estimating the effects of business cycles on corporate tax revenues. I show that the size of tax base affects the cyclicality of the corporate tax revenues. Specifically, the more generous the capital allowances, the more sensitive the corporate tax revenues are to the business cycle.

It has been documented in the literature that corporate tax systems are asymmetric with respect to profits and losses. When a company is making losses it does not pay any tax and even when it starts making profits again some countries allow provisions to offset past or future losses against positive taxable profits. I call these provisions loss-offset provisions. Therefore, in recessions and in periods following these episodes, corporate tax revenues would be lower than the behavior of corporate profits in countries with no loss-offset provisions would suggest.

Since this property is linked with the loss-offset provisions offered by countries, I would also expect that the cyclicality in recessions and in years following recessions would differ depending on how generous these loss-offset provisions are. To explore this, I construct a novel measure - the 'loss-offset generosity index'. This is an index variable that measures how generous a given country is in a given year with its loss-offset provisions; it ranges from 0 to 6. It summarizes whether a country allows loss carry forward, loss carry back and whether these are limited or not. It also includes group consolidation of losses and minimum tax. Using this index, I investigate how the response of corporate tax revenues to the business cycles varies between booms, recessions and normal times depending on how generous the loss-offset provisions offered by countries are.

I find that the more generous the loss offset provisions, the more responsive the corporate tax revenues are to output shocks. What is more, the effect is only significantly heterogeneous for recessions. According to the evidence presented, if a country faces a recession and does allow generous loss-offset, the decline in corporate tax revenues it faces will be larger. This, in turn, will enhance the stabilizing property of corporation tax in recession and in periods immediately following the recession. Countries with less generous loss-offset provisions will benefit less from this automatic adjustment and might suffer more from recession as a result.

The rest of the paper is organised as follows. Section 2 gives definition of booms and recession episodes. Section 3 sets up the empirical model and describes the data that is the basis for empirical analysis in section 4. I discuss heterogeneity of the cyclicality parameter in section 5 and conclude in section 6.

2 Booms and recessions: definitions

The most crucial aspect of the analysis of the asymmetric responses of corporate tax revenues to the business cycle is the definition of booms and recessions. Specifically, various definitions of booms and recession have different implications for where the identifying variation comes from. In this section I discuss several ways in which we can define the business cycle episodes and show the correlation between the episodes identified using each method. The data I use comes from the OECD Annual Accounts and includes information on the Gross Domestic Product (GDP) in national currency, current prices in millions. I convert it to constant prices using GDP deflator; taking logs and first differencing to obtain the growth rate of GDP. I work with this variable to define booms and recessions. Using GDP growth rates, we can define booms and recessions in four main different ways, which are summarized in Table 1.

Method 1 is based on the absolute values of growth rates, where the recession is defined as a year in which the growth rate is below a certain absolute threshold. This threshold has been defined in the literature as anything between 0 and 2 percent of the GDP growth rate. In turn, a boom is defined a year in which the growth rate is above a certain threshold; again the literature had identified those episodes using thresholds between 4 and 6 percent of GDP growth rate.

Method 2 is based on the distribution of growth rates in the sample. I sort growth rates by size and divide them into 20 percentile bins, each one consisting of 5 percent of observations. I define a recession as a year in which the growth rate is below a certain percentile threshold, while boom as a year in which the growth rate is above a certain percentile threshold. In this paper, I mainly focus on the episodes where recession is defined as bottom 10 percent of observations in terms of growth rates, while boom is defined as top 10 percent of observations in terms of growth rates. I also show results from an extreme case where booms are defined as top half of all observations in terms of growth rates, while recessions are bottom half of all observations in terms of growth rates.[2]

Method 3 is based on the distribution of growth rates in each year. For each year of the sample, I sort growth rates by size and divide the sample into percentile bins, each one consisting of 5% of observations. I define booms and recessions as in method 2. In turn, method 4 is based on the distribution of growth rates in each country. For each country I sort growth rates by size and divide the sample into percentile bins, each one consisting of 5% of observations. I define booms and recession as in method 2.

Table 1. Summary of definitions of booms and recessions.

Definition	Defining factor	Probable variation
Method 1	Real growth	Time-series & cross-section
Method 2	Percentile growth	Time-series & cross-section
Method 3	Within-year growth	Cross-section
Method 4	Within-country growth	Time-series

Definitions 1 and 2 are concerned with large episodes of booms and recessions in the whole sample. Therefore they could be skewed towards representing mainly the recent financial crisis. However, using either of those definitions, in the empirical strategy I will be able to use both the time series variation and the cross-sectional differences between

[2] The results are very robust to changing those thresholds.

countries to identify the effects of the business cycles on corporate tax revenues. Definition 3 relies on the cross-country variation in episodes within each year by effectively comparing the size of recessions and booms to the OECD average in each year. Hence, it is identifies the effects of asymmetries along the business cycle for country specific business cycle shocks. However, during good times when all OECD countries experience high growth rates, this method classifies bottom 10 percent of observations as recessions even though the countries might be actually growing strongly in terms of definitions 1 and 2. Definition 4 relies on the time-series variation within each country by comparing the size of the episodes to the country average over the analysis period. However, it is possible that a country that is persistently under or over performing relative to other countries and hence what id defined as boom for this country may not be a boom according to definitions 1 and 2.

Table 2. Correlation between recession (boom) episodes using various definitions. Note: here the episodes used are extreme recessions as per each definition and extreme booms.

Extreme recessions	Method 1	Method 2	Method 3	Method 4
Method 1	-			
Method 2	0.8482	-		
Method 3	0.3922	0.3697	-	
Method 4	0.7297	0.6889	0.2736	-
Extreme booms				
Method 1	-			
Method 2	0.8905	-		
Method 3	0.6624	0.6895	-	
Method 4	0.3689	0.3172	0.2241	-

Table 2 summarizes the correlation between various episodes of extreme booms and recessions depending on the method used to define the episode. In this table, an extreme boom is GDP growth rate over 6% using method 1 and in the top 10 percentile of observations using methods 2-4. In turn, an extreme recession is an episode of negative growth rate using method 1 and in the bottom 10 percentile of observations using methods 2-4. We can see that methods 1 and 2 generally tend to define very similar episodes of recessions and booms, as they are defined using overall periods of largest booms and recessions. Method 3 defines very different episodes of recessions than all other methods as it utilizes the cross sectional variation. The boom episodes defined by this method are more similar to those defined by methods 1 and 2, but not 4. Episodes of recession defined using method 4 are quite correlated with those using method 1 and 2, but episodes of booms defined using this method are not correlated at all across other methods.[3] It is important to note that larger percentile bins display larger correlation between each other. Further, the mean size of the episodes in each bin is slightly different depending on the method used.

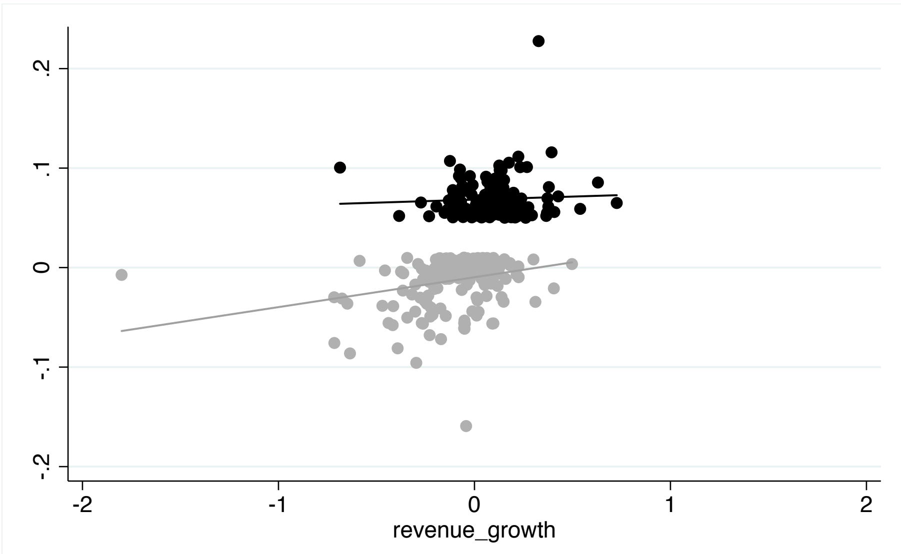
Considering that methods 1 and 2 define very similar business cycle episodes, in the empirical section I will focus on results using definition 2. In the robustness section, I show that using methods 3 and 4 generate similar results to method 2. Since each method defines slightly different boom and recession episodes, the results on business cycle asymmetries will

[3] For a list of extreme boom and recession episodes defined by each method see Tables 1A-4A in the Appendix.

compare across points in the business cycle and not across countries with different fiscal policies.

Finally, in Figure 2 I plot GDP growth data points against corporate tax revenues growth. Each dot corresponds to country-year observation. There seems to be a clear relationship between GDP and corporate tax revenues growth in the recession periods (grey dots), but not in booms (black dots). This motivates further investigation into the asymmetric effects of business cycles on the corporate tax revenues.

Figure 2. GDP and corporate tax revenues growth – country-year data points.



Note: Black dots represent boom periods as defined by the top 10 percent of GDP growth observations. Grey dots represent recession period as defined by the bottom 10 percent of GDP growth observations.

3 Data and Estimated Model

In this section I describe the theoretical basis for the estimation and discuss the simple model I estimate to fix the ideas. Each company, *j*, realizes its taxable profits and pays the corporate tax on this basis, using the statutory tax rate, τ_{it}, and the allowances for capital expenditures, $capall_{it}$, which are both common across all firms in each country. Here, *i* defines a country and *t* defines a year. Hence, each company pays tax based on its taxable profit π_{jit} after deductions, $capall_{it}$. The corporate tax revenues in each country in each year are the sum of all the corporate taxes paid by each company:

$$\begin{aligned} R_{it} &= \sum_{j=1}^{n} \tau_{it} \times \left(\pi_{jit} - capalll_{it}\right) \\ &= \tau_{it}\left(\sum_{j=1}^{n} \pi_{jit} - \sum_{j=1}^{n} capalll_{it}\right) = \tau_{it}(\Pi_{it} - PDV_{it}) \end{aligned} \tag{1}$$

Where Π_{it} is a sum of all taxable profits made by companies in that given year, while PDV_{it} is the present discounted value of capital allowances in country *i* in year *t* and τ_{it} is the top statutory tax rates. This is a large approximation for several reasons. First, some of the corporate tax systems are progressive and multiple corporate tax rates apply depending on the amount of profits made (for example small companies in UK pay lower corporate tax rate). However, as evidence from the UK shows, almost 90% of all tax paid is paid by the top 10% companies. Therefore one could argue that most of the profits are subject to the top statutory tax rate and these would make most of the corporate tax revenues in each country.

Second, I do not have an adequate measure of corporate profits on the country level. This is a problem, since one of the main ways in which the business cycle affects corporate tax revenues is through the cyclical nature of corporate profits. Instead, I will specify a reduced form equation where I use fluctuations in GDP as an approximation for business cycle and corporate profits fluctuations.

Third, I approximate the sum of all capital allowances in a given country in a given year by present discounted value of capital allowances. This is a crude approximation meant to serve as a proxy for a size of the tax base, which could be calculated separately from the effects of business cycle fluctuations on corporate tax revenues. The recent economic literature has discussed the importance of tax bases in explaining the variation in the tax revenues (Devereux, 2006; Clausing, 2007; Kawano and Slemrod, 2012 and 2016; Suarez-Serrato and Zidar, 2017). Therefore using GDP to proxy for both business cycle fluctuations and tax base fluctuations may confound the identification and attribute some of the effects of business cycle fluctuations to changes in the tax base rules across the OECD countries. In this paper I follow Devereux (2006) and account for the present discounted value (PDV) of capital allowances as a proxy for the tax base. I calculate the PDV for each country and each year using the Centre for Business Taxation Tax Database that compiles information on capital allowances for three types of assets – machinery, plants and buildings and intangible assets – across three methods of financing – debt, new equity and retained earnings. [4,5] I average the PDV of capital allowances across the asset types and financing methods.

To move from the accounting identity, as in equation (1) to estimating the relationship, I first take natural logarithm of the identity. Further, the non-stationary nature of the GDP and corporate tax revenue series means that estimation in levels would yield biased standard errors. To correct for the problem I use first differencing. This means that I will be estimating an equation of the form:

$$\Delta \ln(R_{it}) = \alpha + \beta_1 \Delta \ln(\tau_{it}) + \beta_2 \Delta \ln(GDP_{it}) + \beta_3 \Delta \ln(PDV_{it}) + \varepsilon_{it} \quad (2)$$

My dependent variable in the above regression is the annual growth rate of corporate tax revenues measured in millions of national currency. I use data provided by the OECD Revenue Statistics; I normalise it using GDP deflator to express it in constant prices.

[4] There is often discussion as to whether there is enough variation in the tax rates and tax bases in the OECD countries across time to identify the effects of changes in tax rates and tax bases on tax revenues. We discuss how the tax rates and effective marginal tax rates, which take into account the present discounted value of capital allowances change across the G20 countries in the "G20 Corporate Tax Ranking 2011" http://eureka.sbs.ox.ac.uk/3512/1/G20_Corporate_Tax_Ranking_2011.pdf

[5] For the methodology and assumptions used in the calculation of present discounted value of capital allowances see the "CBT Corporate Tax Ranking 2012"
https://www.sbs.ox.ac.uk/sites/default/files/Business_Taxation/Docs/Publications/Reports/cbt-tax-ranking-2012.pdf

Independent variables of consideration are GDP, corporate tax rates and PDV of capital allowances as discussed above. For gross domestic product (GDP) I use data as discussed in section 2. Corporate tax rates come from the CBT database. They include only top main federal rate of corporate tax and exclude local taxes and surcharges.[6]

The impact of business cycle on corporate tax revenues will be measured by the coefficient β_2 in equation (2). The interpretation of the coefficient is analogous to what Lane (2003) proposed on government spending- it measures the elasticity of corporate tax revenues with respect to output growth; i.e. that 1% increase in GDP would increase corporate tax revenues by β_2 percent. Also, positive β_2 implies pro-cyclical behaviour, while a value above unity means more than proportionate response to output fluctuations.

To obtain the asymmetric effect of business cycle on corporate tax revenues, I re-estimate equation (2) separating the effects of business cycle in recessions and booms from that in normal times. As a result I specify the following equation, where recession and boom are dummies as defined above:

$$\begin{aligned}\Delta\ln(R_{it}) &= \alpha + \beta_1\Delta\ln(\tau_{it}) + \beta_2\Delta\ln(GDP_{it}) + \beta_3\Delta\ln(PDV_{it}) \\ &+\gamma_{1R}\Delta\ln(GDP_{it})\times recession + \gamma_{1B}\Delta\ln(GDP_{it})\times boom + \varepsilon_{it}\end{aligned} \tag{3}$$

Here, I concentrate on coefficients γ_{1R} and γ_{1B} that will tell me how different the response of corporate tax revenues to business cycles is in booms and recessions in contrast to normal times - β_2. In the empirical specification I also interact the statutory tax rates and the PDV of capital allowances with booms and recessions to see whether the response of corporate tax revenues to tax rates and tax bases differs between the episodes as well as see whether the inclusion of fixed effects for business cycle episodes affects the estimated coefficient magnitudes.

4 Empirical Evidence

4.1 Baseline model

In the baseline specification in Table 3 I present results from equation (2) and I consider two types of models: with (columns 1 and 3) and without (columns 2 and 4) time fixed effects. The inclusion of time fixed effects implies that I take out the OECD wide business cycle shocks. As a result I interpret the coefficients on GDP as a response of corporate tax revenue growth to changes in country–specific GDP growth. In turn, when I exclude time FE I will be able to interpret the coefficients on GDP growth as a response of revenues growth to the OECD wide shocks in GDP.

Results from Table 3 indicate that the corporate tax revenues are strongly and significantly pro-cyclical with respect to the aggregate business cycles. A 1% increase in GDP would increase corporate tax revenues by 3.4% (column 4). This is quite a large effect. The results with time-fixed effects are smaller and suggest that countries respond differently to country-specific and aggregate output shocks. The effect of country specific business cycle

[6] The cyclicality coefficients do not change if I include local taxes and surcharges.

shocks is much smaller and equal to 2.1% change in corporate tax revenues in response to 1% GDP change (column 3). These results are directly comparable with Sorensen et al (2001), where the coefficient without the year FE on overall revenues is almost twice the size of the one with FE.

Table 3. Cyclicality of corporate tax revenues – OECD wide vs country-specific shocks.

VARIABLES	1	2	3	4
$\Delta \ln(\tau_{it})$	0.189	0.219	0.254	0.298
	(0.160)	(0.161)	(0.247)	(0.264)
$\Delta \ln(PDV_{it})$			-0.138	-0.212
			(0.211)	(0.210)
$\Delta \ln(GDP_{it})$	1.522***	2.684***	2.072***	3.390***
	(0.370)	(0.318)	(0.436)	(0.335)
Constant	-0.057*	-0.045	-0.111***	-0.065**
	(0.031)	(0.028)	(0.037)	(0.028)
Observations	808	808	647	647
R-squared	0.235	0.161	0.295	0.214
Country FE	YES	YES	YES	YES
Year FE	YES	NO	YES	NO
Business cycle FE	NO	NO	NO	NO

Note: τ_{it} is the top statutory tax rate, PDV_{it} is the present discounted value of capital allowances, GDP_{it} is gross domestic product. Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

If we treat equation (1) as identity we would expect the coefficient on the corporate tax rate to be 1. We can see in Table 3 that it is much smaller than that (0.25-0.3). There could be multiple reasons for that, one of them being the previously mentioned progressivity of the corporation tax system.[7]

4.2 Asymmetric cyclicality estimations

Table 4 presents the evidence of the asymmetric behaviour of corporate tax revenues using regressions without year fixed effects. Columns 1 - 10 show results for two different thresholds for recessions and booms; columns 1-5 define a recession to be an episode where the growth rate was in the bottom 10% of all GDP growth observations and boom to be an episode where the growth rate was in the top 10% of all GDP growth observations, columns 6-10 split the sample in half and define the top 50% of observations as booms and bottom 50% of observations as recessions.

I observe a very strong response of corporate tax revenues to business cycle shocks in normal times – the magnitude is somewhere between 3 - 4% response of corporate tax revenue to 1% GDP shock. In booms, the response is significantly smaller than in normal times (between 1 – 2.5%) while in recessions the response is not statistically significantly

[7] Furthermore, I would expect the long run relationship between corporate tax revenues and GDP shocks to be equal to 1. I can test that by estimating the single equation Error Correction Model.[7] I estimate the long run coefficient on GDP that is equal to 1. The short run response to the business cycle is similar to what I estimate using the OLS model and is 2.4%. The ECM also allows estimating the speed of return to equilibrium after a deviation. Here, the coefficient is negative and significant suggesting that deviations from equilibrium are corrected at about 10% per year.

different from normal times. The results in columns 6-10 indicate that if we split the sample in half, as the previous literature has done, the effect of GDP fluctuations is larger in recessions than in booms. However, the effect is not statistically significantly different between the two types of episodes.

The asymmetry between corporate tax revenues response in normal times versus in booms and recessions is prevalent; it holds irrespective of the threshold I use to define booms and recessions. Inclusion of more observations, with less extreme growth rates into each business cycle episode lowers the difference in the estimates of the response of business cycles to normal times and booms. This suggests that the response of corporate tax revenues to business cycles is quite strong during very large booms and recessions, but much smaller during mild booms and recessions. The inclusion of year fixed effects (results not shown here) does not change the main conclusion of the asymmetric model. The response of the corporate tax revenues to the business cycle is the strongest in normal times while much smaller in booms.

The results in Table 4 also show that the estimates of the effects of the business cycles on corporate tax revenues are not sensitive to the inclusion of tax base proxies (the coefficient on PDV of capital allowances is marginally significant in some specifications, but does not affect the magnitude of the GDP interactions[8]), interactions between tax rates and tax bases as well as interactions of tax rates with business cycles. The inclusion of business cycle fixed effects in columns 5 and 10 actually strengthens the results and highlights the differences between normal times, booms and recessions even further.

These results indicate that the approach taken by the previous literature in identifying the asymmetric response of tax revenues to GDP shocks may be inaccurate. The asymmetric response of corporate tax revenues to GDP shocks is much more intricate than just the difference between booms and recessions. My results suggest that the difference exists not between booms and recessions, but between normal times and booms and recessions. This may explain why the previous literature found no effects of business cycles on direct tax revenues.

4.3 Instrumental variables estimation

One of the concerns with the estimation of the effect of GDP on corporate tax revenues is the reverse causality problem. To account for this problem I use the instrumental variables approach. This issue is more serious when one considers the overall tax revenues, since they are large in proportion to GDP. Corporate tax revenues are on average about the size of 3% of GDP.

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[8] The coefficient on the PDV of capital allowances is negative in the specifications. The larger the PDV, the more generous the capital allowance deductions available to companies are. This means that for countries, which allow larger capital allowance deductions, the corporate tax revenues are smaller as the size of the tax base is smaller.

Table 4. Business cycle asymmetries using percentiles from overall distribution of GDP growth rates.

VARIABLES	(1) GDP_90	(2) GDP_90	(3) GDP_90	(4) GDP_90	(5) GDP_90	(6) GDP_50	(7) GDP_50	(8) GDP_50	(9) GDP_50	(10) GDP_50
$\Delta\ln(\tau_{it})$	0.201	0.291	0.455*	0.289	0.287	0.217	0.297			
	(0.163)	(0.264)	(0.232)	(0.179)	(0.178)	(0.161)	(0.264)			
$\Delta\ln(\tau_{it})\times boom$			0.145	0.301	0.385*			0.270*	0.285	0.330*
			(0.275)	(0.235)	(0.227)			(0.161)	(0.177)	(0.179)
$\Delta\ln(\tau_{it})\times recession$			-1.355	-1.655	-1.650			0.309	0.083	0.045
			(1.341)	(1.353)	(1.331)			(0.372)	(0.385)	(0.386)
$\Delta\ln(PDV_{it})$		-0.235	-0.288	-0.370*	-0.380*		-0.203	-0.206	-0.247	-0.245
		(0.210)	(0.238)	(0.220)	(0.226)		(0.208)	(0.200)	(0.216)	(0.209)
$\Delta\ln(GDP_{it})$	3.622***	3.742***	3.702***	3.694***	3.683***					
	(0.556)	(0.645)	(0.592)	(0.583)	(0.557)					
$\Delta\ln(GDP_{it})\times boom$	-1.599***	-1.131**	-1.135**	-1.039*	-2.677***	2.507***	3.134***	3.125***	3.222***	1.563***
	(0.493)	(0.562)	(0.561)	(0.548)	(0.802)	(0.314)	(0.367)	(0.407)	(0.431)	(0.483)
$\Delta\ln(GDP_{it})\times recession$	-0.834	0.165	0.788	0.950	-0.084	3.051***	3.926***	3.926***	3.942***	4.112***
	(1.215)	(1.169)	(1.059)	(1.090)	(1.451)	(0.586)	(0.512)	(0.514)	(0.516)	(0.518)
Constant	-0.075**	-0.076**	-0.073**	-0.074**	-0.074**	-0.043	-0.062**	-0.062**	-0.065**	-0.087***
	(0.032)	(0.034)	(0.032)	(0.032)	(0.031)	(0.028)	(0.028)	(0.028)	(0.028)	(0.029)
Observations	808	647	647	647	647	808	647	647	647	647
R-squared	0.176	0.221	0.242	0.263	0.268	0.162	0.216	0.216	0.229	0.240
Country FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Base-rate interaction	NO	NO	NO	YES	YES	NO	NO	NO	YES	YES
Year FE	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Business cycle FE	NO	NO	NO	NO	YES	NO	NO	NO	NO	YES

Note: τ_{it} is the top statutory tax rate, PDV_{it} is the present discounted value of capital allowances, and GDP_{it} is gross domestic product. An example on how to interpret the column headers: GDP_90 means that in this column the recession episodes (dummies) are defined as years when GDP growth rate is below 10th percentile of the GDP growth distributions in the sample, while boom episodes occur when GDP growth rate is above 90th percentile of GDP growth distributions in the sample. GDP_50 splits the sample in half and defines the top 50th percentile of observations as booms and bottom 50th percentile as recessions. Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

There is a large empirical literature offering different methods of measuring the impact of tax changes on output and growth, i.e. the tax multipliers. The methods include VARs as applied by Blanchard and Perotti (2002), narrative approach as offered by Romer and Romer (2010) or a combination of both discussed by Mertens and Ravn (2012). Each of these approaches offers unique advantages, but differs greatly in the size of the estimated responses of output to tax change shocks, ranging from a huge 3% effects offered by Romer and Romer to smaller than 1% offered by Blanchard and Perotti and Mertens and Ravn. Most of these studies use tax receipts as a measure of tax change. Hence, these multipliers can be interpreted as the impact of tax revenue changes on GDP. In spite of differing methodologies, what these approaches do not question is the direction and significance of the relationship. A positive tax shock, i.e. tax revenue increase has a negative impact on output growth.

The fact that the impact of tax revenues on GDP is negative means that the OLS coefficient on GDP in the baseline OLS regression may pick up this effect and may be biased downwards. To correct for that problem I find instruments that are correlated with GDP growth but are unrelated to corporate tax revenues. I use trade (imports and exports) weighted GDP of trade partner OECD countries. This type of instrument was proposed in the context of the cyclical fiscal policies by Jaimovich and Panizza (2007) and later also used by Lee and Sung (2007) and Ilzetzki and Vegh (2008). The trade weighted GDP of other OECD countries is strongly correlated with the country's own GDP. However, country's own fiscal policy should have negligible impact on GDPs of other countries, especially corporate tax policy.

To be more specific, for example, for Australian GDP growth instrumental variable I weight GDP growth of all other OECD countries by the amount of imports from each of those countries to Australia (or exports from Australia to all these countries). Thus I use GDP growth for each of these countries in each year and then weight each of these by exports (imports) to Australia. The intuition here suggests that a country can import a crisis from abroad. Alternatively, if I use exports to weight the GDP growth, then if growth rate in the country that imports large amount of products from Australia declines, that country will demand less exports from Australia and hence the growth rate in Australia will suffer.[9]

In Table 5 I present results from estimating the baseline model using 2-stage-least squared (2SLS) estimation using the instruments described above.[10] The sample used here is slightly smaller than in the OLS regressions due to the presence of some missing trade observations when I create the instrumental variables. The OLS coefficients on GDP growth are only slightly larger in this smaller sample, hence are not reported here. Column 1 uses export weighted GDP growth as an instrument for country's own GDP. Columns 2, 4, 5 and 6 use imports weighted GDP growth, while column 3 includes both export weighted and imports weighted GDP growth as instruments.[11]

[9] For robustness purposes, I also use lagged GDP growth as instrument variable. This estimation strategy has been used in this context by Braun (2001), Galí and Perotti (2003), and Lane (2003). This strategy is only valid in the absence of any serial correlation in the error term. I test for that and find serial correlation in the levels specification, but not in the differences one. Hence, this is also a valid instrument strategy albeit not my preferred one.

[10] I test for weak instruments, endogeneity of regressors, excluded instruments etc. They all seem to be in order for the regression results presented here.

[11] The instruments in column 3 pass Sargan test for overidentifying restrictions.

The results from the IV estimation are stronger than the OLS ones; they are almost twice as large in all cases. They suggest that the impact of business cycle on corporate tax revenues is between 4-5%. This would confirm the hypothesis that the OLS coefficients are downward biased and may indeed be affected by the reverse causality.

Table 5. IV baseline regressions.

VARIABLES	(1) IV:exports	(2) IV:imports	(3) IV:exports and imports	(4) IV:imports	(5) IV:imports	(6) IV:imports
$\Delta \ln(\tau_{it})$	0.214**	0.214**	0.214**	0.185**	0.257**	0.255**
	(0.087)	(0.088)	(0.087)	(0.085)	(0.117)	(0.117)
$\Delta \ln(PDV_{it})$						-0.197
						(0.234)
$\Delta \ln(GDP_{it})$	4.231***	4.349***	4.208***	2.992**	4.973*	5.088*
	(0.393)	(0.415)	(0.392)	(1.406)	(2.771)	(2.811)
Constant	-0.073***	-0.076***	-0.073***	-0.083*	-0.179*	-0.183*
	(0.012)	(0.013)	(0.012)	(0.047)	(0.106)	(0.107)
Observations	796	796	796	796	645	645
Country FE	YES	YES	YES	YES	YES	YES
Year FE	NO	NO	NO	YES	YES	YES
Business cycle FE	NO	NO	NO	NO	NO	NO

Note: τ_{it} is the top statutory tax rate, PDV_{it} is the present discounted value of capital allowances, and GDP_{it} is gross domestic product. The type of instrumental variable used in each column is outlined in the header of that column. Column 5 results report the coefficients as in column 4, but on the sample of observations with non-missing PDV observations. Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

In Table 6, I explore whether the use of 2SLS estimation strategy has any impact on the asymmetry results. I find that the effects from imports and exports weighted regression are very similar, hence I only report results for the exports weighted regressions. I not only instrument GDP growth in normal times, but also use exports weighted GDP growth to instrument for GDP growth in the interaction term leaving boom and recession dummies un-instrumented and exogeneous.[12]

The size of the normal times coefficient on the corporate tax revenues response to business cycle is larger than in the OLS regressions corresponding to the IV baseline regression. What is more, again the boom coefficient is significantly smaller than the normal times one, while the recessions coefficient is not statistically significantly different from the normal times one. The results are qualitatively similar to the OLS ones, though much larger in magnitudes. This is starkly visible when I look at the results from columns 5-8, which split the sample into half at the median growth rate. These clearly suggest that the response of the corporate tax revenues to the business cycle in recessions is more than twice as large as in booms.

[12] I could alternatively instrument the dummies too, using exports weighted boom and recessions dummies of OECD trade partners, but this creates some unnecessary additional endogeneity.

What is more, in IV estimations the coefficients on the impact of GDP shocks on corporate tax revenues are statistically significantly different between booms and recessions. In contrast, in OLS case they were statistically significantly different from normal times coefficient, but not from each other.

One of the reasons why the impact of recessions is much stronger here could be that the endogeneity bias created by the reverse causality has been shown to be stronger for recessions. For example, Auerbach and Gorodnichenko (2012) and Almunia et al (2010) find that GDP multipliers of government purchases are larger in recession. If that is the case, then the recession multipliers will bias the GDP OLS estimates for recessions even further downward than the boom estimates.

5 Heterogeneity of the cyclicality of corporate tax revenues

5.1 Tax base effects

The size of the tax base in each country may affect how strongly the corporate tax revenues react to business cycles; the broader the tax base is, the more sensitive the tax revenues could be with respect to business cycle fluctuations. In this section I discuss the heterogeneities in the response of corporate tax revenues to business cycles by analysing the interaction effects between GDP growth and tax base proxy. I further test whether this heterogeneous effect is symmetric across booms and recessions. In Table 7 I show results from estimating equation (2) using OLS (columns 1 and 2), 2-stage least squared method (column 3) and from estimating equation (3) using OLS (columns 4 and 5).

The results from Table 7 indicate that the size of the tax base, measured by present discounted value of capital allowances positively affects the relationship between GDP growth and corporate tax revenues. One standard deviation change in PDV (0.035) amplifies the cyclicality of corporate tax revenues with respect to business cycle by 0.5 (column 3). This means that for country with 1 standard deviation higher PDV (a broader tax base), a 1% change in GDP growth will result in 0.5% larger change in corporate tax revenues. This amplification effect is only significant in recessions (column 4), while in booms the size of the tax base does not significantly affect the response of corporate tax revenues to business cycle fluctuations.[13]

[13] I also interacted tax base with tax rate, but in my sample this interaction is insignificant, hence the results are not reported here (see Suarez Seratto – Zidar (2017) for discussion on average effects of tax rates and tax bases on state revenues).

Table 6. IV asymmetric regressions.

VARIABLES	(1) GDP_90	(2) GDP_90	(3) GDP_90	(4) GDP_90	(5) GDP_50	(6) GDP_50	(7) GDP_50	(8) GDP_50
$\Delta\ln(GDP_{it})$	4.990***	5.140***	5.391***	8.906				
	(1.341)	(1.529)	(1.497)	(8.236)				
$\Delta\ln(GDP_{it})\times boom$	-2.266***	-1.590*	-1.707*	-153.617	2.691***	3.020***	3.077***	-5.548
	(0.797)	(0.937)	(0.923)	(406.534)	(0.762)	(0.976)	(0.994)	(9.357)
$\Delta\ln(GDP_{it})\times recession$	-0.708	0.080	0.094	-4.127	5.455***	6.471***	6.463***	10.062**
	(2.771)	(3.277)	(3.246)	(16.462)	(0.918)	(1.149)	(1.151)	(4.135)
$\Delta\ln(\tau_{it})$	0.189**	0.292**	0.475***	0.029	0.203**	0.288**	0.260*	-0.003
	(0.086)	(0.114)	(0.128)	(0.986)	(0.087)	(0.115)	(0.137)	(0.224)
$\Delta\ln(\tau_{it})\times boom$			0.216	4.115			0.095	0.293
			(0.432)	(10.476)			(0.255)	(0.376)
$\Delta\ln(\tau_{it})\times recession$			-1.548***	-1.642				
			(0.369)	(2.009)				
$\Delta\ln(PDV_{it})$		-0.261	-0.331	0.047		-0.270	-0.262	-0.486
		(0.227)	(0.224)	(1.788)		(0.224)	(0.225)	(0.374)
Constant	-0.078**	-0.079*	-0.083*	-0.161	-0.046***	-0.055***	-0.056***	-0.006
	(0.039)	(0.043)	(0.043)	(0.207)	(0.015)	(0.017)	(0.017)	(0.056)
Observations	796	645	645	645	796	645	645	645
Number of country1	34	34	34	34	34	34	34	34
Country FE	YES	YES	YES	YES	YES	YES	YES	YES
Base-rate interaction	NO	NO	NO	YES	NO	NO	NO	YES
Year FE	NO	NO	NO	NO	NO	NO	NO	NO
Business cycle FE	NO	NO	NO	NO	NO	NO	NO	NO

Note: In all specification exports weighted GDP is used an instrumental variable for GDP. : τ_{it} is the top statutory tax rate, PDV_{it} is the present discounted value of capital allowances, and GDP_{it} is gross domestic product. An example on how to interpret the column headers: GDP_90 means that in this column the recession episodes (dummies) are defined as years when GDP growth rate is below 10th percentile of the GDP growth distributions in the sample, while boom episodes occur when GDP growth rate is above 90th percentile of GDP growth distributions in the sample. GDP_50 splits the sample in half and defines the top 50th percentile of observations as booms and bottom 50th percentile as recessions. Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.

Table 7. The heterogeneous effects of tax bases on the business cycle asymmetries.

VARIABLES	(1) OLS	(2) OLS	(3) IV:exports	(4) OLS: GDP_90	(5) OLS: GDP_50
$\Delta\ln(\tau_{it})$	0.254	0.296	0.300***	0.310*	
	(0.248)	(0.266)	(0.115)	(0.178)	
$\Delta\ln(PDV_{it})$	-0.310	-0.484*	-0.548*	-0.183	-0.137
	(0.252)	(0.262)	(0.286)	(0.200)	(0.397)
$\Delta\ln(GDP_{it})$	2.113***	3.412***	4.900***	3.687***	
	(0.441)	(0.331)	(0.440)	(0.558)	
$\Delta\ln(GDP_{it})\times\Delta\ln(PDV_{it})$	7.154	11.560*	13.543*		
	(6.575)	(6.379)	(7.638)		
$\Delta\ln(GDP_{it})\times boom$				-2.694***	1.540***
				(0.812)	(0.480)
$\Delta\ln(GDP_{it})\times recession$				-0.517	4.091***
				(1.508)	(0.507)
$\Delta\ln(GDP_{it})\times boom\times\Delta\ln(PDV_{it})$				-4.898	-2.976
				(15.390)	(11.939)
$\Delta\ln(GDP_{it})\times recession\times\Delta\ln(PDV_{it})$				32.543*	16.052
				(17.382)	(13.625)
Constant	-0.114***	-0.067**	-0.082**	-0.075**	-0.086***
	(0.037)	(0.028)	(0.013)	(0.032)	(0.030)
Observations	647	647	645	647	647
R-squared	0.296	0.217	0.233	0.272	0.242
Country FE	YES	YES	YES	YES	YES
Year FE	YES	NO	NO	NO	NO
Business cycle FE	NO	NO	NO	YES	YES

Note: τ_{it} is the top statutory tax rate, PDV_{it} is the present discounted value of capital allowances, and GDP_{it} is gross domestic product. An example on how to interpret the column headers: GDP_90 means that in this column the recession episodes (dummies) are defined as years when GDP growth rate is below 10th percentile of the GDP growth distributions in the sample, while boom episodes occur when GDP growth rate is above 90th percentile of GDP growth distributions in the sample. GDP_50 splits the sample in half and defines the top 50th percentile of observations as booms and bottom 50th percentile as recessions. Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

5.2. Loss offset provisions

5.2.1 Loss-offset generosity index

In this section I describe how I construct the novel loss-offset generosity index that I use to understand the effects of loss-offset provisions on the cyclicality of corporate tax revenues with respect to business cycle fluctuations. The index consists of 6 elements, which affect the generosity of loss-offset provisions: loss carry-forward (and its length), loss carry-back (and its length), national loss consolidation and minimum taxes; as sources I use the CBT tax database. The data in this database comes from Ernst & Young and International Bureau of Fiscal Documentation for 2002 – 2015 information. I augment this data before 2002 with information from Dreßler & Overesch (2011). As a result I have data on loss carry over, minimum tax and group consolidation for all OECD countries for the period 1996 – 2015.

Each component of the loss offset generosity index affects the measure in slightly different way. The larger the number of years carry-forward and back allowed, the more generous the loss treatment is (for discussion of properties and impact on investment see Dreßler & Overesch (2011). The availability of group loss offset provisions is a sign of a more generous loss offset provisions in that companies are allowed to offset losses in one subsidiary against profits in another and hence benefit from not paying tax in either of the subsidiaries. On the other hand minimum tax has a detrimental effect on the loss generosity parameter. As noted by Dreßler & Overesch (2011) if an alternative minimum tax is in place a subsidiary is obliged to pay the tax irrespective whether it makes losses or not. As a result of these rules, the construction of the loss-offset generosity index consists of 6 elements, where 1 is given if the statement is true; 0 otherwise. Hence a maximum value that the index could take is 6, minimum is 1 and the 6 statements are the following:

1. Loss carry forward is longer than 10 years (different thresholds explored)
2. Loss carry forward is unlimited
3. Loss carry back is allowed
4. Loss carry back is unlimited
5. Minimum tax does not exist
6. Group consolidation of losses is permitted – on national level[14]

Figure 3. Loss offset generosity parameter - distribution across countries; average over 1996 - 2015 for each country.

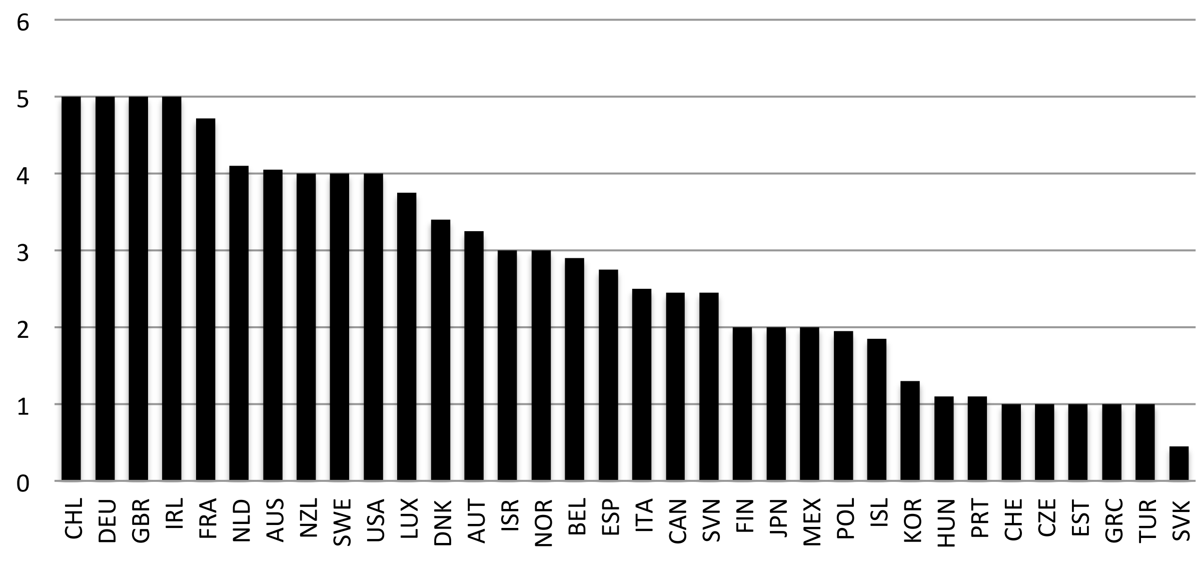
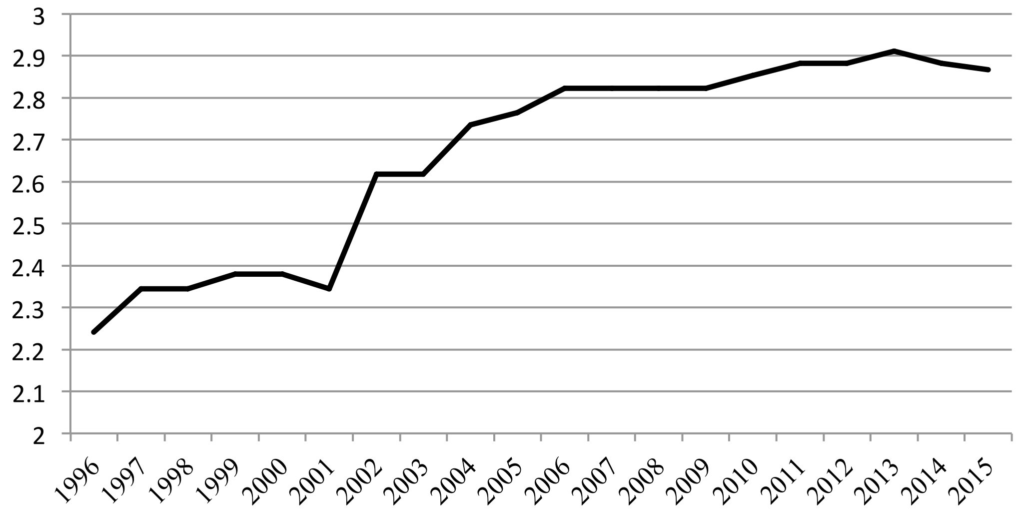


Figure 3 shows how the loss-offset generosity index is distributed across countries by calculating average value of the index over 1996-2015 for each country. There is a lot of variation in the index across countries; the index ranges from 5 in Chile, Germany, UK and Ireland to less than 1 in Slovakia. Non-integer values imply that some loss-offset provisions changed over the years. Figure 4 shows how unweighted average of the loss-offset generosity index for the OECD countries developed over time. The loss-offset generosity has increased

[14] In addition I explore whether there are any limits on loss carryforwards. This additional criteria does not change the results, hence I do not report the results using this criteria.

over the years, especially from 2001 until 2005. There have been fewer changes in the last 10 years, with some cut backs to the loss-offset generosity provisions in the last 2 years. What is more, most of the changes came from extensions in the number of years losses are allowed to be carried forward.

Figure 4. Development of loss - offset generosity index over time; unweighted OECD average.



5.2.2 Loss-offset generosity results

Using the index generate in section 5.1.1 I test whether an increase in the loss-offset generosity has an impact on the cyclicality of corporate tax revenues. Loss offset provisions generally apply when companies are making losses or in the following periods. It is important to note that loss carry back and loss carry forward will have slightly different effects on the cyclicality of the corporate tax revenues. For example loss carry forward provisions will influence revenues in the periods following recessions, as firms use the losses they incurred to offset them against positive profits. As a result more generous loss carry forward will mean weaker relationship between business cycle and corporate tax revenues in the periods after the recession, but not necessarily during the recession. In contrast, in case of group relief and loss carry back provisions past corporate tax payments are recovered, such that revenue does fall by more than it would without carryback provisions (or group relief), at the time when losses are incurred. Hence, group relief as well as loss carry back will strengthen the relationship between business cycle and corporate tax revenues.[15]

In general, I expect the effect of the business cycle on corporate tax revenues to vary with the generosity of the loss offset provisions; more generous loss carryback makes the cyclicality of corporate tax revenues with respect to business cycle larger. Companies are able to utilize the more generous loss offset provisions during recessions and thus their tax payments will be lower when the loss offset is larger – i.e. they will respond more severely to

[15] Loss carry back in the OECD data is accounted for in the same year. If a company is claiming tax credit for last year, the amount is used to reduce corporate tax revenue is a given year. The revenue numbers are not retrospectively amended.

the business cycle fluctuations. Further, loss carry forward provisions make the relationship between business cycles and corporate tax revenues stronger in the periods following the recession too as they reduce the revenues even though companies make positive profits. [16] Also, since loss offset provisions will mainly have an effect in recessions, rather than during booms, I estimate the heterogeneity of the response only for recession episodes.[17]

In Table 8 I present results from estimating equation (2) using OLS (columns 1 and 2) and instrumental variables approach (columns 3-5). The effect of loss-offset provisions on the cyclicality of the corporate tax revenues is investigated by interacting the index with GDP growth. The results indicate that the more generous the loss offset provisions, the lower the corporate tax revenues (the coefficient on the loss generosity index is negative across specifications). Further, loss offset generosity provisions amplify the cyclicality of corporate tax revenues in all, but one, specification. The magnitude of the effect in column 5 is such that 1 standard deviation increase in the loss offset generosity provisions (1.45) increases the cyclicality of corporate tax revenues by 0.83. This means that for country with 1 standard deviation higher loss offset generosity index, a 1% change in GDP growth will result in 0.83% larger change in corporate tax revenues.

Results in Table 8 highlight that it is crucial to include the proxy for the tax base here, as the size of the base is why loss-offset provisions tie revenues more closely to GDP. In the specifications controlling for the PDV of capital allowances (columns 2, 4 and 5) the magnitude of the interaction coefficient between loss offset generosity and GDP growth is smaller than in specifications which do not control for PDV of capital allowances. In the IV regression framework even though the magnitude of the coefficient declines, the coefficient on the interaction between loss-offset provisions of GDP growth remains significant. Further, even though the interaction between PDV and business cycle fluctuations is much larger in magnitude than the interaction between loss-offset generosity and business cycle fluctuations, the inclusion of that interaction does not affect the magnitude nor the significance of the effect that loss offset generosity has on business cycle fluctuations. Hence, loss offset generosity remains a significant determinant of how business cycle fluctuations affect corporate tax revenues on top of how tax bases affect that relationship.[18]

I further tested for the heterogeneity of the corporate tax revenue responses to business cycle fluctuations across business cycle phases – booms and recessions. The results from Table 9 indicate that the loss-offset previsions do not affect the asymmetric nature of the cyclicality of the corporate tax revenues once we control for the effect that tax bases have on this asymmetry. Specifically, the interaction effect between GDP growth, recession and loss offset generosity index is only significant in specifications that do not control for PDV of capital allowances (columns 1 and 5). Once I control for PDV in the remaining specifications, the effect of loss-offset provisions is still positive, smaller in magnitude and with larger

[16] Even though each of these provisions has slightly different impact on the nature of the relationship between the business cycle and corporate tax revenues, in the paper I report the joint effect of all of them as an index. When I look at the components of the index separately, the most important and significant is loss carryback.

[17] I have tested the booms heterogeneity and the interaction effect is insignificant.

[18] Note that a triple interaction between GDP fluctuations, loss offset generosity and tax base is insignificant, but positive which indicates that more generous capital allowances further enhance the effect of loss offset generosity on corporate tax revenue responses to business cycle fluctuations. However, this effect is reported with large standard errors.

standard errors. In turn, the effect of tax bases on the asymmetric response of corporate tax revenues to the business cycle persists even when one control for loss-offset generosity provisions.

Finally, the interaction effects between tax rates and loss offset generosity for booms and recessions are significant; in boom the effect is no different from normal times, in recession the effect of taxes on revenues is larger, but this effect is muted by the interaction with the loss offset provisions (the coefficients are not reported here). At the mean these interactions imply no different effect of tax rates on revenues in recessions than in normal times, but at the extremely generous loss-offset provision values I find that an increase in the tax rate may have no effect on corporate tax revenues.

Table 8. The heterogeneous effects of loss-offset provisions on the cyclicality of corporate tax revenues.

VARIABLES	(1) OLS	(2) OLS	(3) IV:exports	(4) IV:exports	(5) IV:exports
$\Delta\ln(\tau_{it})$	0.409***	0.373***	0.391***	0.368***	0.361***
	(0.121)	(0.129)	(0.115)	(0.117)	(0.117)
$\Delta\ln(PDV_{it})$		-0.321*		-0.306	-0.765**
		(0.184)		(0.196)	(0.301)
$\Delta\ln(GDP_{it})$	1.459**	2.695***	1.494**	2.983***	3.073***
	(0.613)	(0.624)	(0.688)	(0.842)	(0.843)
$\Delta\ln(GDP_{it})\times loss\_generosity$	0.477**	0.186	0.979***	0.603**	0.569**
	(0.219)	(0.218)	(0.247)	(0.275)	(0.275)
$loss\_generosity$	-0.028**	-0.023	-0.033**	-0.023	-0.021
	(0.014)	(0.015)	(0.016)	(0.016)	(0.016)
$\Delta\ln(GDP_{it})\times\Delta\ln(PDV_{it})$					19.600**
					(9.785)
Constant	0.048	0.025	0.024	-0.010	-0.016
	(0.064)	(0.067)	(0.044)	(0.048)	(0.048)
Observations	645	577	643	576	576
R-squared	0.226	0.284	0.203	0.255	0.261
Country FE	YES	YES	YES	YES	YES
Year FE	NO	NO	NO	NO	NO
Business cycle FE	NO	NO	NO	NO	NO

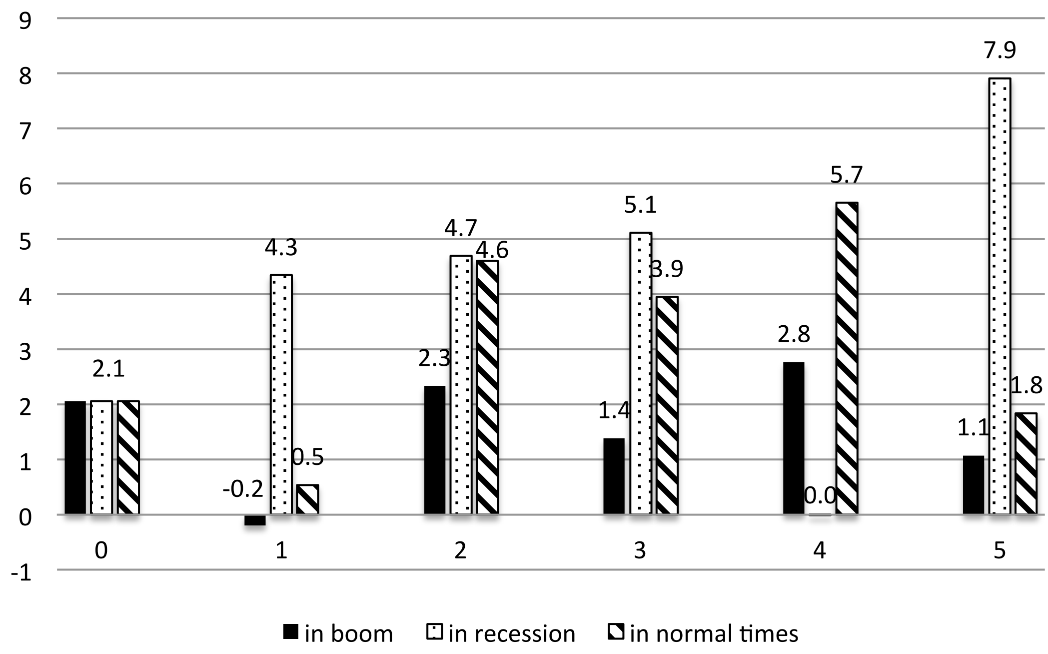
Note: τ_{it} is the top statutory tax rate, PDV_{it} is the present discounted value of capital allowances, and GDP_{it} is gross domestic product, *loss_generosity* is an index variable ranging from 0 to 5. An example on how to interpret the column headers: GDP_90 means that in this column the recession episodes (dummies) are defined as years when GDP growth rate is below 10th percentile of the GDP growth distributions in the sample, while boom episodes occur when GDP growth rate is above 90th percentile of GDP growth distributions in the sample. GDP_50 splits the sample in half and defines the top 50th percentile of observations as booms and bottom 50th percentile as recessions. Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

5.3 Non-linear effects of loss offset provisions

In this section I exploit the fact that the loss -offset generosity index is a categorical variable that ranges from 0-5 in my data. Hence, I explore whether the effects of loss-offset provisions on the cyclicality of corporate tax revenues could be non-linear and vary across the index values. Instead of interacting the loss-offset index with GDP growth linearly, I look at GDP growth effects on corporate tax revenues at each value of the loss-offset index separately by interacting the categorical values of the index with GDP growth. Further, I investigate whether these non-linear effects affect the asymmetric relationship between business cycles and corporate tax revenues.

In Figure 5 I plot a histogram of the regression results. For each loss-offset generosity value I calculate the elasticity of corporate tax revenues in normal times, booms and recessions. The elasticity of the corporate tax revenues with respect to business cycle in recessions increases as the loss-offset generosity parameter increases (apart from value 4 of the index), which confirms the regression results. Interestingly, the boom and normal times elasticities display non-linear effects; the calculated coefficients for normal times are quite large for index values of 2, 3 and 4, while much smaller for other values of the index. In turn, coefficients for booms are larger for index values of 1,2 and 4 than for other values of the index. The elasticities for index values of 2, 3 and 4 are significant in both cases, while they are insignificant for other categories of the index.

Figure 5. The elasticities of corporate tax revenues across various business cycle phases and at different values of loss-offset provisions.



6 Conclusion

In this paper I show that corporate tax revenues respond quite strongly to the business cycle fluctuations. I document the asymmetries in this response between booms and recessions using both OLS and IV estimation strategies. This paper also contributes to the debate about loss-offset generosity. I construct a loss-offset generosity index that I use to explore the heterogeneity of the tax revenue cyclicality. My findings suggest that the larger loss offset is allowed, the more responsive is corporate tax revenue to the business cycle. According to the evidence presented in this paper, if a country faces a recession and does allow generous loss-offset, the decline in corporate tax revenues it faces will be larger. This in turn will enhance the stabilizing property of corporation tax in recession. Countries with less generous loss-offset provisions will benefit less from this automatic adjustment and might suffer more from recession as a result.

Table. 9. Loss offset generosity and cyclicality of corporate tax revenues.

VARIABLES	(1) OLS: GDP_90	(2) OLS: GDP_90	(3) OLS: GDP_90	(4) OLS: GDP_90	(5) OLS: GDP_50	(6) OLS: GDP_50	(7) OLS: GDP_50	(8) OLS: GDP_50
$\Delta \ln(PDV_{it})$		-0.304*	-0.297	-0.152		-0.314*	-0.330*	-0.472**
		(0.184)	(0.183)	(0.182)		(0.184)	(0.177)	(0.239)
$\Delta \ln(GDP_{it})$	2.874***	3.003***	3.260***	3.268***				
	(0.470)	(0.503)	(0.545)	(0.546)				
$\Delta \ln(GDP_{it}) \times boom$	-1.096**	-0.620	-2.284***	-2.300***	2.352***	2.833***	1.530***	1.562***
	(0.505)	(0.496)	(0.766)	(0.770)	(0.340)	(0.345)	(0.458)	(0.460)
$\Delta \ln(GDP_{it}) \times recession \times loss\_generosity$	1.279***	0.686	0.739	0.672	0.822**	0.463	0.568	0.556
	(0.495)	(0.502)	(0.503)	(0.496)	(0.378)	(0.367)	(0.367)	(0.362)
$\Delta \ln(GDP_{it}) \times recession$	-2.253	-0.408	-0.295	-0.576	1.341	2.765**	2.591**	2.596**
	(1.490)	(1.537)	(1.615)	(1.595)	(1.165)	(1.098)	(1.095)	(1.076)
$loss\_generosity$			-0.015	-0.016			-0.018	-0.018
			(0.014)	(0.014)			(0.014)	(0.014)
$\Delta \ln(GDP_{it}) \times boom \times \Delta \ln(PDV_{it})$				-0.720				6.958
				(13.504)				(7.631)
$\Delta \ln(GDP_{it}) \times recession \times \Delta \ln(PDV_{it})$				27.468*				16.728
				(15.414)				(10.473)
Constant	-0.050	-0.054	-0.001	0.000	-0.054	-0.065*	0.065	0.064
	(0.035)	(0.035)	(0.067)	(0.067)	(0.035)	(0.034)	(0.068)	(0.068)
Observations	645	577	577	577	645	577	577	577
R-squared	0.240	0.294	0.301	0.305	0.227	0.291	0.303	0.308
Country FE	YES	YES	YES	YES	YES	YES	YES	YES
Year FE	NO	NO	NO	NO	NO	NO	NO	NO
Business cycle FE	NO	NO	YES	YES	NO	NO	YES	YES

Note: All regressions control for corporate tax rates and their interactions with business cycle periods. τ_{it} is the top statutory tax rate, PDV_{it} is the present discounted value of capital allowances, and GDP_{it} is gross domestic product, *loss_generosity* is an index variable ranging from 0 to 5. An example on how to interpret the column headers: GDP_90 means that in this column the recession episodes (dummies) are defined as years when GDP growth rate is below 10^{th} percentile of the GDP growth distributions in the sample, while boom episodes occur when GDP growth rate is above 90^{th} percentile of GDP growth distributions in the sample. GDP_50 splits the sample in half and defines the top 50^{th} percentile of observations as booms and bottom 50^{th} percentile as recessions. Robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

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Appendix

Table 1A. Extreme boom and recession episodes as defined using Method 1. Extreme recessions refer to episodes where GDP growth rate was negative, extreme booms refer to episodes where GDP growth was 6% or more.

extreme recessions; GDP growth <0		extreme booms GDP growth >6%	
country	episode years	country	episode years
Austria	2009	Chile	1991-1993, 1995-1997, 2004, 2006
Belgium	1993, 2009, 2013	Czech Republic	1995, 2005-2006
Canada	1991, 2009	Estonia	1997, 2000-2001, 2003-2007, 2011
Switzerland	1991-1993, 2009	Finland	1997
Chile	1999, 2009	Ireland	1995-2000, 2002, 2004, 2014-2015
Czech Republic	1997-1998, 2009, 2012-2013	Iceland	1998, 2004-2005, 2007
Germany	1993, 2002-2003, 2009	Israel	2000
Denmark	2008-2009	South Korea	1991, 1993-1996, 1999-2000, 2002, 2010
Spain	1993, 2009, 2011-2013	Luxembourg	1991, 1999-2000, 2007
Estonia	1999, 2008-2009	New Zealand	1993
Finland	1991-1993, 2009, 2012-2015	Poland	1995, 1997, 2007
France	1993, 2009	Slovak Republic	1996, 2005-2007
GBR	1991, 2008 - 2009	Slovenia	2007
Greece	1993, 2008-2013	Turkey	1993, 1995-1997, 2000, 2002, 2004-2006, 2010-2011, 2013
Hungary	1992-1993, 2009, 2012		
Ireland	2008-2009		
Iceland	1991-1992, 2009-2010		
Israel	2002		
Italy	1993, 2008-2009, 2012-2013		
Japan	1998-1999, 2008-2009, 2011		
South Korea	1998		
Luxembourg	2008-2009, 2012		
Mexico	2009		

Netherlands	2009, 2012-2013
Norway	2009
New Zealand	1991, 2008 - 2009
Portugal	1993, 2003, 2009, 2011-2013
Slovak Republic	1999, 2009
Slovenia	2009, 2012 - 2013
Sweden	1991-1993, 2008-2009, 2012
Turkey	1994, 1999, 2009
USA	1991, 2008-2009

Table 2A. Extreme boom and recession episodes as defined using Method 2. Extreme recessions refer to episodes where GDP growth rate was in the bottom 10th percentile of all observations, extreme booms refer to episodes where GDP growth rate was in the top 90th percentile of all observations.

extreme recessions; GDP growth <10th percentile		extreme booms GDP growth >90th percentile	
country	episode years	country	episode years
Austria	2009	Chile	1991-1993, 1995-1997, 2004, 2006, 2011
Belgium	1993, 2009	Czech Republic	1995, 2005-2006
Canada	1991, 2009	Estonia	1997, 2000-2007, 2011
Switzerland	1991, 2009	Finland	1997
Chile	2009	Ireland	1995-2000, 2002, 2004-2005 2014-2015
Czech Republic	2009, 2012	Iceland	1998, 2004-2005, 2007
Germany	1993, 2003, 2009	Israel	2000
Denmark	2009	South Korea	1991-1996, 1999-2000, 2002, 2010
Spain	1993, 2009, 2011-2013	Luxembourg	1991, 1998-2000, 2007
Estonia	1999, 2008-2009	New Zealand	1993
Finland	1991-1993, 2009, 2012-2013	Poland	1995-1997, 2006-2007
France	2009	Slovak Republic	1996-1997, 2005-2007
GBR	1991, 2009	Slovenia	2007
Greece	1993, 2009-2013	Sweden	2010
Hungary	1992, 2009, 2012	Turkey	1993, 1995-1997, 2000, 2002, 2004-2006, 2010-2011, 2013, 2015
Ireland	2008-2009		
Iceland	1992, 2009-2010		
Israel	-		

Italy	1993, 2008-2009, 2012-2013
Japan	1998, 2008-2009
South Korea	1998
Luxembourg	2008-2009
Mexico	2009
Netherlands	2009, 2012
Norway	2009
New Zealand	1991, 2008
Portugal	1993, 2003, 2009, 2011-2013
Slovak Republic	2009
Slovenia	2009, 2012 - 2013
Sweden	1991-1993, 2009
Turkey	1994, 1999, 2001, 2009
USA	2009

Table 3A. Extreme boom and recession episodes as defined using Method 3. Extreme recessions refer to episodes where GDP growth rate was in the bottom 10th percentile of GDP growth observations in a given year, extreme booms refer to episodes where GDP growth rate was in the top 90[th] percentile of GDP growth observations in a given year.

extreme recessions; GDP growth <10th percentile within each year		extreme booms GDP growth >90th percentile within each year	
country	episode years	country	episode years
Australia	2000	Australia	1992, 2009
Austria	2015	Austria	-
Belgium	2001	Belgium	-
Canada	1991, 2015	Canada	-
Switzerland	1995-1996, 2003	Switzerland	-
Chile	1999	Chile	1991-1997, 2004, 2006, 2008, 2010-2013
Czech Republic	1997-1998	Czech Republic	2005-2006, 2015
Germany	1996-1997, 2002-2005	Germany	-
Denmark	2007	Denmark	1994
Spain	2010-2013	Spain	-
Estonia	1999, 2008-2009	Estonia	1997, 2000-2007, 2011-2012
Finland	1991-1992, 2009, 2014-2015	Finland	1998
France	2006	France	-
GBR	-	GBR	-
Greece	1993, 2005, 2010-2014	Greece	2001, 2003
Hungary	1992, 1996, 2007, 2010	Hungary	2014
Ireland	2008	Ireland	1994 - 2002, 2004, 2014-2105
Iceland	1992, 1995, 2009-2010	Iceland	1998, 2004-2005, 2007, 2013
Israel	2001-2002	Israel	2008-2011, 2013
Italy	1996-1997, 2003-2007	Italy	-

Japan	1994, 1997-2002, 2006-2007, 2011, 2014	Japan	-
South Korea	1998	South Korea	1991-1996, 1999-2002, 2009-2010
Luxembourg	1995, 2008	Luxembourg	1991, 1998-1999, 2007, 2013-2014
Mexico	-	Mexico	2012
Netherlands	2002, 2004	Netherlands	-
Norway	-	Norway	2012
New Zealand	1998, 2000, 2008	New Zealand	1993, 1999, 2003, 2009, 2014
Portugal	1993-1994, 2003-2006, 2011-2012	Poland	2007-2009, 2011
Slovak Republic	2000	Portugal	-
Slovenia	2009, 2013	Slovak Republic	2005-2008
Sweden	1991, 1993	Slovenia	2008
Turkey	1994, 1999, 2001	Sweden	2010, 2015
USA	-	Turkey	1992-1993, 1995-1997, 2002-2006, 2010-2015
		USA	-

Table 4A. Extreme boom and recession episodes as defined using Method 4. Extreme recessions refer to episodes where GDP growth rate was in the bottom 10th percentile of GDP growth observations in a given country, extreme booms refer to episodes where GDP growth rate was in the top 90th percentile of GDP growth observations in a given country.

extreme recessions; GDP growth <10th percentile within each country		extreme booms GDP growth >90th percentile within each country	
country	episode years	country	episode years
Australia	1991, 2000, 2008	Australia	1997-1998, 2003
Austria	1993, 2009, 2013	Austria	1998-1999, 2007
Belgium	1993, 2009, 2013	Belgium	1997, 2000, 2004
Canada	1991-1992, 2009	Canada	1994, 1999-2000
Switzerland	1991, 1993, 2009	Switzerland	2000, 2006-2007
Chile	1999, 2009, 2014	Chile	1991-1992, 1995
Czech Republic	1997, 2009, 2012	Czech Republic	1995, 2005-2006
Germany	1993, 2003, 2009	Germany	1991, 2006, 2010
Denmark	1993, 2008-2009	Denmark	1994, 2000, 2006
Spain	2009, 2012-2013	Spain	1998-2000
Estonia	2009, 2009	Estonia	1997, 2000, 2006
Finland	1991-1992, 2009	Finland	1997-1998, 2000
France	1993, 2009, 2012	France	1998-2000
GBR	1991, 2008-2009	GBR	1994, 2000, 2003
Greece	2010-2012	Greece	2003-2004, 2006
Hungary	1992, 2009, 2012	Hungary	2002, 2004-2005
Ireland	2008-2009, 2012	Ireland	1997, 1999, 2015

Iceland	1992, 2009-2010	Iceland	2004-2005, 2007
Israel	2001-2002	Israel	2000, 2007, 2010
Italy	2009, 2012-2013	Italy	1994-1995, 2000
Japan	1998, 2008-2009	Japan	1991, 1996, 2010
South Korea	1998, 2009, 2012	South Korea	1991, 1995, 1999
Luxembourg	2008-2009, 2012	Luxembourg	1991, 1999, 2007
Mexico	-	Mexico	-
Netherlands	2009, 2012-2013	Netherlands	1997-1999
Norway	2008-2010	Norway	1994, 1996-1997
New Zealand	1991, 2008-2009	New Zealand	1993-1994, 1999
Poland	2001, 2012-2013	Poland	1995, 1997, 2007
Portugal	1993, 2009, 2012	Portugal	1991, 1997-1998
Slovak Republic	1999, 2009	Slovak Republic	1996, 2006-2007
Slovenia	2009, 2012	Slovenia	1999, 2006-2007
Sweden	1992-1993, 2009	Sweden	2000, 2006, 2010
Turkey	1994, 2001, 2009	Turkey	2004-2005, 2011
USA	1991, 2008-2009	USA	1997-1999