Total factor productivity (TFP) and fiscal consolidation: How harmful is austerity?

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Abstract

Departing from the expansionary austerity literature, this study assesses empirically whether fiscal consolidation propagates changes in the supply side of the economy that can potentially influence total factor productivity (TFP). Using a panel dataset of 26 OECD countries over the period 1980-2016 and employing panel vector autoregressive and panel cointegration techniques, we present evidence of both short-run and long-run negative effects of fiscal consolidation on TFP. The short-run impact is disproportionately more damaging for the TFP of low debt countries, while, contrary to the expansionary austerity thesis, our empirical results would advise against spending-driven fiscal consolidation, since such consolidation undermines capacity, due to the importance of government spending in shaping productive capital. Our results have serious policy implications for the implementation and design of fiscal adjustment programmes.

JEL Classification: E62, C23, H68

Keywords: total factor productivity, fiscal consolidation, OECD countries, austerity, growth

'*Efficient public spending can increase productivity through, for example, improving education systems or public investment in key infrastructures'* Mario Draghi, President of the ECB, Speech at the Academy of Athens, 1/10/2019

'*Despite the long-term benefits of increasing the share of productive public expenditure, after the Great Recession most Member States implemented fiscal adjustment plans that hit disproportionally productive investment'*, European Fiscal Board, 2019

1. Introduction

The effect of fiscal consolidation on output and other macroeconomic fundamentals such as, consumption, investment and employment has been the main focus of the existing austerity literature. The focus is mainly on the demand side effects of austerity with inconclusive empirical findings. Intuitively, the debate is focused on whether austerity in the form of fiscal consolidation is expansionary, contractionary or neutral with reference to output. Early contributions from Blanchard (1990); Bertola and Drazen (1993); Sutherland (1997); Alesina et al (2002); Giavazzi and Pagano (1990, 1995); Ardagna (2004); Alesina and Perotti (1997) support empirically the existence of expansionary austerity effects. The thesis of expansionary fiscal contraction received renewed support in the period following the 2007/8 financial crisis (Alesina and Ardagna, 2010), in an effort to reconcile fiscal consolidation efforts with growth and demand concerns. The main argument is that fiscal contraction stimulates growth -contrary to conventional Keynesian wisdom- through credibility channels (Giavazzi and Pagano, 1990). Accordingly, an increase in tax today works in a precautionary fashion eliminating the need of

larger increases in the future. Both consumers and investors perceive this as a policy signal for tax cuts in the future, so they form expectations for higher disposable income, thus higher consumption and investment.

A crucial aspect of the growth-austerity nexus yet attracting no attention is whether austerity propagates changes in the supply side of the economy that can potentially influence the growth rate of productivity. In other words, our knowledge is limited as to whether austerity programmes undermine the economy's productive capacity through underinvestment in neuralgic sectors such as infrastructure, technology and innovation.[1] If this concern is valid then adverse effects are likely to spread affecting the evolution of aggregate productivity in the long-run. At the moment, the expansionary austerity literature tells us very little about whether fiscal consolidation impairs or enhances measures of technical progress such as: Total Factor Productivity (TFP). TFP is highly informative about the supply-status of the economy in measures such as technological advancement, competitiveness and export performance but it also embodies substantial welfare implications (Delgado et al., 2012). Drivers of TFP are -among others- investment in public infrastructure, education and research and development (R&D), which are mainly publicly funded sectors that shape the productive capacity of the national economy. Understanding the dynamics of the fiscal consolidation-TFP nexus becomes increasingly important in association with recent evidence (Fernald et al., 2017) that documents a substantial slowdown in TFP, especially in the post 2009 period. Another important policy perspective of our research question is related to the remarkable deceleration of TFP in the euro-area, where virtually no single economy has exhibited a positive growth rate of TFP since the global financial crisis of 2008 (Van Ark, 2014). At the same time, there is evidence that the share of productive expenditure in total primary public expenditure, which includes infrastructure, R&D and education, has dropped in nearly all euro-area economies since the crisis (European Fiscal Board, 2019). Is the evidence on decelerating TFP compatible with the expansionary fiscal contraction thesis, which has anchored the politics of the austerity debate and offered the intellectual rationale for pursuing harsh fiscal consolidation in a number of advanced countries? To the best of our knowledge, the present paper is the first one that seeks to address this question analyzing both the short and long-run effects, of austerity on productivity.

The paper employs evidence from a sample of 26 OECD countries over the period 1980-2016 to explore the linkages between fiscal consolidation and TFP. The conventional

[1] Stiglitz (2015) in a similar line of reasoning argues that the decline in GDP during the crisis that can be accounted for by declines in physical and human capital falls short of the actual decline in GDP, therefore suggesting that there is a missing "dark matter" related to the effects of the prolonged crisis and austerity policies.

approach to identify austerity and more broadly discretionary fiscal policy adjustments is through changes in the Cyclically Adjusted Primary Balance (CAPB). Alternatively, we employ a "narrative approach" that consults a wide range of contemporaneous policy documents that announce government fiscal actions (Devries et al., 2011). The appealing characteristic of the "narrative approach" is that the measure of fiscal consolidation is regarded as strictly exogenous[2] and it can be decomposed into spending cuts and tax hikes. The main drawback of the "narrative approach" is that the time period covered is shorter and the number of countries is smaller.[3]

We start the analysis with a panel vector autoregressive (PVAR) econometric specification, which is commonly used in the expansionary austerity literature in identifying the evolution of TFP after episodes of fiscal consolidation. The VAR approach helps us to understand the short-run reaction of TFP after fiscal consolidation episodes. Next, to understand how fiscal adjustments drive TFP in the long-run, we use panel cointegration techniques. Furthermore, one needs to acknowledge that productivity enhancing and (or) productivity repressing effects from austerity might be both present in the sample impacting differently on countries with different structural features.

One of the most crucial features that can justify a beneficial use of austerity policy is public debt sustainability. Governments are likely to be proactive when encountering debt sustainability concerns, so any decision for contractionary fiscal action might bring productivity gains when the ratio of debt to GDP exceeds a certain threshold. To capture the existence of such effects, we replicate separately estimations for groups of countries with different levels of debt burden. Finally, with the use of the "narrative approach" we decompose fiscal consolidation into spending cuts and tax hikes to identify whether TFP responds differently between the two components of fiscal consolidation.

The paper implements a series of robustness tests in the definition of key variables and estimation techniques. Our findings reveal that austerity in the form of fiscal consolidation impacts negatively in productivity both in the short and long-run. The negative effect is not driven by the method used to measure fiscal consolidation and productivity. Regarding the long-run effects of austerity on TFP, we have used a number of different econometric estimators and in all the estimated coefficient of fiscal consolidation is negative. The paper is

[2] For recent studies on the problem of endogeneity of fiscal consolidation decisions, see De Cos and Moral-Benito (2013 and 2016), Guajardo et al (2014), Yang et al (2015) and Breuer (2017).

[3] Historical narrative data was previously used in the expansionary austerity literature (Guajardo et al., 2014; Jordà and Taylor, 2016). These studies indicate that fiscal consolidation contracts private consumption and GDP growth. The magnitude of this effect is around to 0.75 and 0.65 percentage point losses after a one percent increase in fiscal consolidation.

structured as follows: section 2 is taking as a starting point the key theoretical arguments discussed in the agenda of the expansionary austerity literature, and puts forward additional factors that could affect the fiscal adjustment-productivity nexus. Section 3, first presents empirical results from the response of TFP to fiscal consolidation episodes using a PVAR framework. This part also identifies whether the pattern of the TFP-fiscal consolidation relationship varies with the level of public debt; then, panel cointegration techniques are employed to treat more systematically the short- and long-run dynamics of the fiscal adjustment-TFP nexus. Finally, as a further refinement, panel cointegration is applied to distinguish between taxes and expenditure effects on TFP. Section 3, also presents and discusses results from several sensitivity checks. Section 4 concludes.

2. Productivity and Fiscal Adjustments: Some Theoretical Considerations

The neoclassical thesis states that a sound fiscal policy is vital in achieving stable macroeconomic conditions that promote growth and prosperity (Daniel, 2006). This argument is further investigated in the expansionary austerity literature, which links cuts in government spending to structural reforms aimed at improving public sector efficiency (European Commission, 2007). Alesina and Ardagna (2010) find that a one percentage point higher government spending to GDP leads to a 0.75 percentage point lower growth.[4] On the basis of the neoclassical proposition, fiscal loosening can cause adverse effects on productivity mainly via two channels: (i) crowding out private investment and (ii) triggering uncertainty.[5] Continuous loosening of the fiscal stance not only leads to higher interest rates, but also discourages business and entrepreneurial activities, as the government usually focuses on unproductive spending that has limited scope for generating substantial growth returns in the long-run (Furceri and Sousa, 2011). Fiscal imbalances are commonly identified (Ardagna, 2004) in economies that fail to attract the appropriate level of private investment, which potentially leads to low levels of capital deepening and output per worker. The second channel

[4] Other evidence of expansionary austerity effects is found in Ardagna (2004) whereby a reduction of the primary spending to GDP ratio by one percentage point increases GDP growth by 0.5 percentage point. Romer and Romer (2010) show that increases in tax revenue are effective in reducing budget deficit without causing significant output losses.

[5] Other stimulative channels identified in the expansionary austerity scenario include credibility gains and lower inflation risks. There might also be gains in the labour market through cuts in public employment that stimulate wages and jobs in the private sector. A more detailed discussion for fiscal adjustment associated gains can be found in Daniel (2006). More recently, it has also been argued that the predictability of fiscal policy matters for the size of crowding out effects (Cavallari and Romano, 2017).

mainly focuses on the uncertainty induced in the economy due to continuous loosening in the budgetary balance. The main source of uncertainty is how and when this unsustainable condition will be fixed to avoid debt unsustainability problems. In other words, the policy objective that concerns primarily investors is whether fiscal consolidation will be implemented via spending cuts or higher average tax rates. The latter case is widely regarded as a source of volatility and risk, which again turns into a disincentive for private investment. An unstable fiscal environment might affect the type and quality of investment, as investors prefer investment projects with short-term returns to long-term investment engagement, while it is the latter the one that typically provides more productivity benefits for the economy.

On the other hand, the productivity of government spending is an important aspect of the puzzle when the effectiveness of fiscal policy is assessed. A major component of government spending in advanced economies is on developing and maintaining infrastructure which drives output in the private sector.[6] Causality is found to run from public capital to aggregate productivity, which can be taken as evidence that inadequate public investment accounts for productivity slowdowns. Stagnation in the level of per capita income in advanced economies is usually attributed to factors related to insufficient public investment in sectors such as transport and energy (Bloom et al., 2013). The logic is straightforward; sectors with substantial scope to generate productivity spillovers are usually funded under public schemes. Therefore, underinvestment in periods of fiscal consolidation triggers negative consequences in other downstream sectors, which results in an overall productivity slowdown. Fernald (1999) ratifies this argument for roads building and economic growth in the US, while Roller and Waverman (2001) find a similar effect for telecommunication infrastructure in a sample of OECD countries. The elasticity of private output to changes in public investment varies across countries but it tends to be high even in cases of public investment in semi-productive activities (Leeper et al. 2010).[7]

More recently Rodrik (2016) casts doubt on another milestone underlying the expansionary austerity hypothesis: structural reforms. Austerity programmes are often accompanied with an ambitious structural reform agenda of a "big bang" type - do as many changes as possible, as quickly as possible. Such pro-market reforms include, for instance, deregulation of labour market (breaking union monopoly power), and removal of barriers to entry and privatization of state assets. Although the overarching goal is to reallocate factors

[6] See Bom and Ligthart (2014) for a detailed meta-analysis on the productivity of public capital.
[7] Recent literature (Aghion et al., 2010 and 2014) point out that, in the presence of credit constraints, even cyclical fiscal adjustments can generate long run impacts through substitution of long-term productivity-enhancing investment for less productive short-term investment.

towards more productive sectors, any serious assessment of the actual results from structural reforms and their impact on aggregate productivity indicates much less optimism (Rodrik, 2016). A bold economy-wide liberalization programme as a complement of austerity might actually drive resources towards unproductive (low value added) sectors and the outcome achieved can be quite the opposite than a boost of aggregate productivity.[8]

On the whole, the fiscal adjustment-growth nexus still remains fragile without robust findings on any stand. The existing literature neglects the effect of austerity on productivity, while there are reasons to argue that tightening fiscal policy could also lead to undesired effects. The expansionary austerity literature so far remains silent on the nature of the austerity-productivity relationship, which can have both short-and long-run aspects. The main contribution of our paper is to fill in this gap. At the same time, our analysis also improves our understanding of the recently highly topical policy debate on whether austerity could be self-defeating. The design and pace of warranted fiscal consolidation has become an issue of controversy with several authors arguing that reductions in deficits have ended up delivering higher debt-to-GDP ratios thus, accelerating the effects of the negative debt-growth spiral (Ersoy and Yanmaz, 2016; Heimberger, 2017; House et al., 2017; Fatás and Summers, 2018). Although the debt-to-GDP ratio is not of primary concern in the present paper, exploring the effects of austerity on TFP certainly provides a plausible line of reasoning one can put forward within a broader fiscal sustainability perspective.

3. Empirical Strategy

3.1 Data Description

We gather data from 26 OECD countries over the period 1980-2016. We follow Blanchard (1993) in defining fiscal consolidation as large observed improvements in the cyclically adjusted primary balance (CAPB). CAPB is intended to capture discretionary fiscal policy by excluding the estimated effects of business cycle fluctuations on the government budget. Therefore, taxes and transfers are cyclically adjusted with net interest payments also to be subtracted. CAPB is a discretionary measure of fiscal policy as it excludes interest payments from past government liabilities on accumulated debt. Changes in the CAPB (*dcapb*) can then be used to identify large-scale fiscal adjustments, known as fiscal consolidation episodes

[8] Unless structural reforms are carefully planned as a targeted, selective removal of key obstacles impeding growth, this policy can eventually backlash even in the long run.

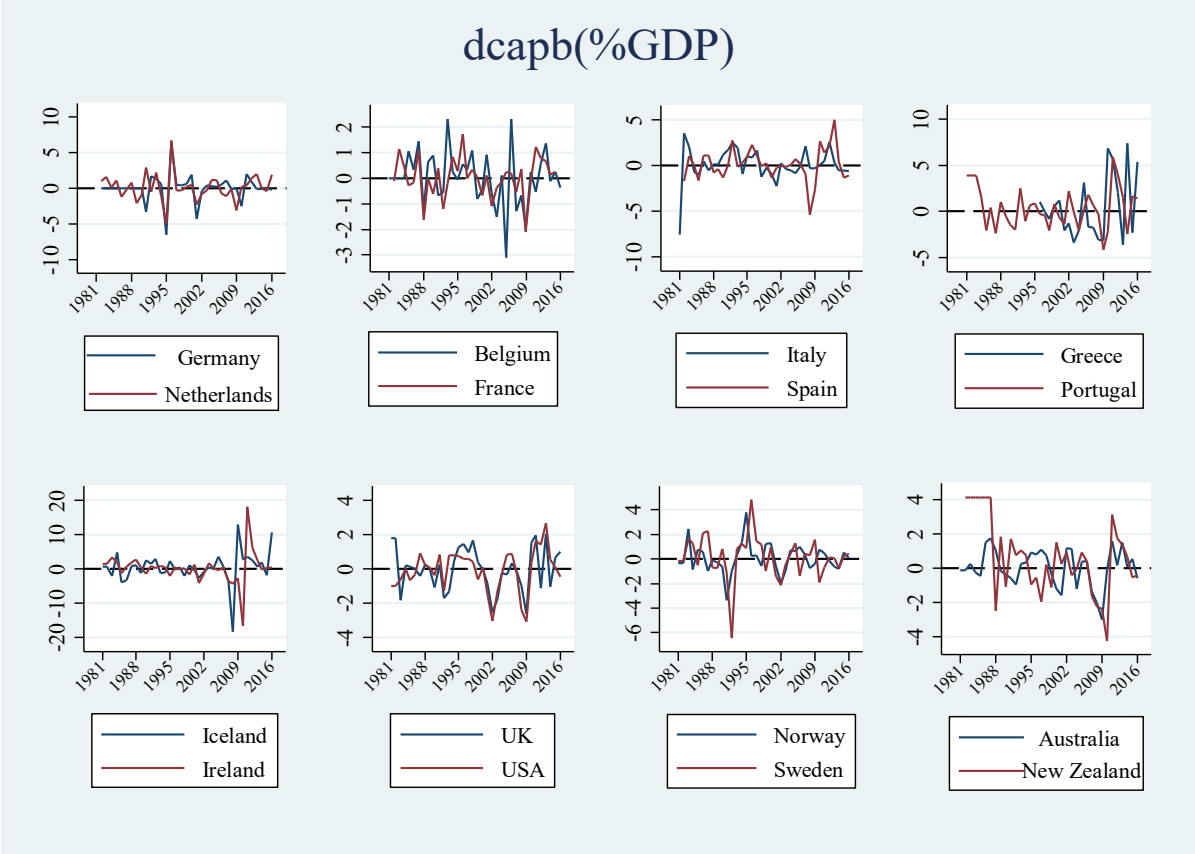
(FCE). An alternative approach to CAPB is to identify fiscal adjustments endogenously (Wiese et al., 2018). Despite the merits of this approach, its use in our context can be problematic as it applies an "one size fits all" criterion of fiscal adjustments, while it does not identify the end of fiscal adjustment.[9] Instead, we use two alternative measures of CAPB, namely $CAPB^{O}$ and $CAPB^{E}$ for robustness. The superscript O refers to our own calculations for the derivation of CAPB, broadly in harmony with the European Commission methodology and E refers to the CAPB measure directly taken from the OECD Economic Outlook series (for details see Appendix D). For the purposes of the descriptive analysis, we present results only from $CAPB^{E}$, while in the econometric specification section 3.3, we test both variables to ensure that results are not driven from methodological differences in the definition of the variable.[10]

Figure 1 shows changes in CAPB over time for a sub-sample of the 26 OECD countries. The countries shown in the graphs are those conveying information about events that are accompanied with substantial variations in *dcapb*. For the group of countries not shown in Figure 1, *dcapb* movements are smoother over time. Germany and the Netherlands implement substantial fiscal tightening in mid-1990s. Fiscal expansion after German re-unification in 1991 was followed by a severe programme of fiscal adjustment. Spain implemented a tight fiscal policy after 2009 while Italy did likewise at a smaller intensity. A similar pattern of fiscal loosening just before 2009 is observed in Greece, Portugal, Ireland and Iceland with severe fiscal tightening to follow in the upcoming years. The latter four countries implemented severe austerity in early 2010s in exchange of a bailout programme for maintaining external debt sustainability. A common feature of bailout programmes is a rapid and front-loaded fiscal adjustment as it becomes clear in those graphs. There is a fiscal loosening in UK and USA in early 2000s and fiscal tightening in the aftermath of the 2008-9 financial-banking crisis with bailout programmes for rescuing the financial system in these countries. With the exception of Norway and Sweden, the timing of fiscal consolidation in the post 2009 period is a common feature for all countries in Figure 1 - including New Zealand and to a lesser extent Australia. The intensity of fiscal adjustment was stronger in Ireland, Greece, Portugal and Spain that encounter issues with debt sustainability and severe international borrowing constraints.

[9] See Kleis and Moessinger (2016) and Amo-Yartey et al. (2012) for an overview of the criteria used to define fiscal consolidation episodes (FCE). In the alternative approach of endogenously identified fiscal adjustments (Wiese at al., 2018) the latter continues as long as the change in CAPB is positive, which seems an arbitrary choice. In addition, the methodology used in Wiese et al. (2018) does not subtract interest payments accepting as part of CAPB an expenditure that is well outside the control of the government. An endogenous identification of fiscal adjustment also requires a large number of observations per country that are not available even for many OECD countries, which makes it even more restrictive in our case.

[10] The degree of correlation between the two alternatives definitions of CAPB is in the order of 0.65.

Figure 1: Change in Cyclical Adjusted Primary Balance (dcapb), for Selected OECD Countries 1981-2016



Notes: Numbers on the y-axis represent changes in CAPB as shares to GDP. The higher the share the higher the level of fiscal tightening. The shares can also be negative as the level of fiscal loosening increases.

3.2 Results from a Panel Vector Auto-regression (PVAR) Model

We first specify a Panel Vector Autoregressive (PVAR) model to address the short-run dynamics of the bi-variate relationship between fiscal consolidation episodes and TFP. The PVAR model explores the dynamic relationship between fiscal policy shocks and reaction of TFP growth using Impulse–Response Functions (IRF). The IRF describes the reaction of one variable to the innovations of another variable while all other forces of the system are held constant. We prefer using PVAR estimations to generate IRFs to the alternative of local projections (Banerjee and Zampolli, 2019) as the latter methodology tends to display more bias as well as higher variance, resulting in less accurate confidence intervals for the IRFs (Jordà, 2005; Kilian and Kim, 2009). The PVAR is specified as follows:

$$z_{it} = \gamma_i + \sum_{h=1}^{H} B z_{it-h} + \upsilon_{it} \quad (1)$$

where $z_{it} = [FCE_{it}, \Delta tfp_{it}]$ is a vector of endogenous variables, Δtfp is the difference in logs of Total Factor Productivity (growth rates), *FCE* is fiscal consolidation episodes, *B* is a 2×2 coefficient matrix and υ_{it} is 2×1 error term. Index *h* gives the order of lags in the PVAR. Subscripts *i* and *t* denote countries and years, respectively. The length of the PVAR is specified at two lags as indicated from the Bayesian information criterion (BIC) (Appendix B1). Fiscal consolidation episodes (*FCE*) are defined under the CAPB^{E} in three ways to capture different intensities in the implementation of fiscal consolidation attempts, while the TFP measurement is described in Appendix A1. At the end of this section, we replicate results considering a measure of labour productivity (output per hours works, OECD, 2018) (LP), which is less informative than TFP though more straightforward in calculations and less sensitive to measurement bias.

We prefer specifying a parsimonious two variables PVAR following Bachmann et al. (2013) as it is easier to identify. The cost of this choice is an omitted variable problem that we partially address in panel cointegration estimation in the next section. Although, the focus of the current analysis is to unveil how TFP responds to a FCE, we are far from claiming that fiscal realisations are potentially the only drivers of TFP in the short run. For instance, Cette et al. (2016) in a similar line of argument with ours, show that lower real interest rates are responsible for productivity slowdown in a small group of developed economies. This scenario might be also present in our data, nevertheless estimating a higher dimensionality PVAR will further challenge the identification strategy without adding many insights in the key question under investigation.

In formulating (1), we specify term γ_i (fixed effects) to account for individual country heterogeneity in the panel structure of the data. Fixed effects estimators are inconsistent in the presence of endogeneity therefore, GMM is applied to estimate (1) using as instruments lagged values of endogenous variables as per Holtz-Eakin et al. (1988). To rule out the bias between fixed effects and lagged values of endogenous regressors, we take first-differences. We apply the forward mean differentiating method, which removes for each country only the forward means of all available future observations (Arellano and Bover, 1995). Since past realizations are not included in the first differencing transformation, lagged values of the untransformed level variables can still be used as instruments for the transformed endogenous variables in GMM. The resulting estimate of *B* is then used to construct the IRFs. Estimates are specified

within 95% confidence intervals with bootstrapped standard errors drawn after 200 iterations (Lof and Malinen, 2014).

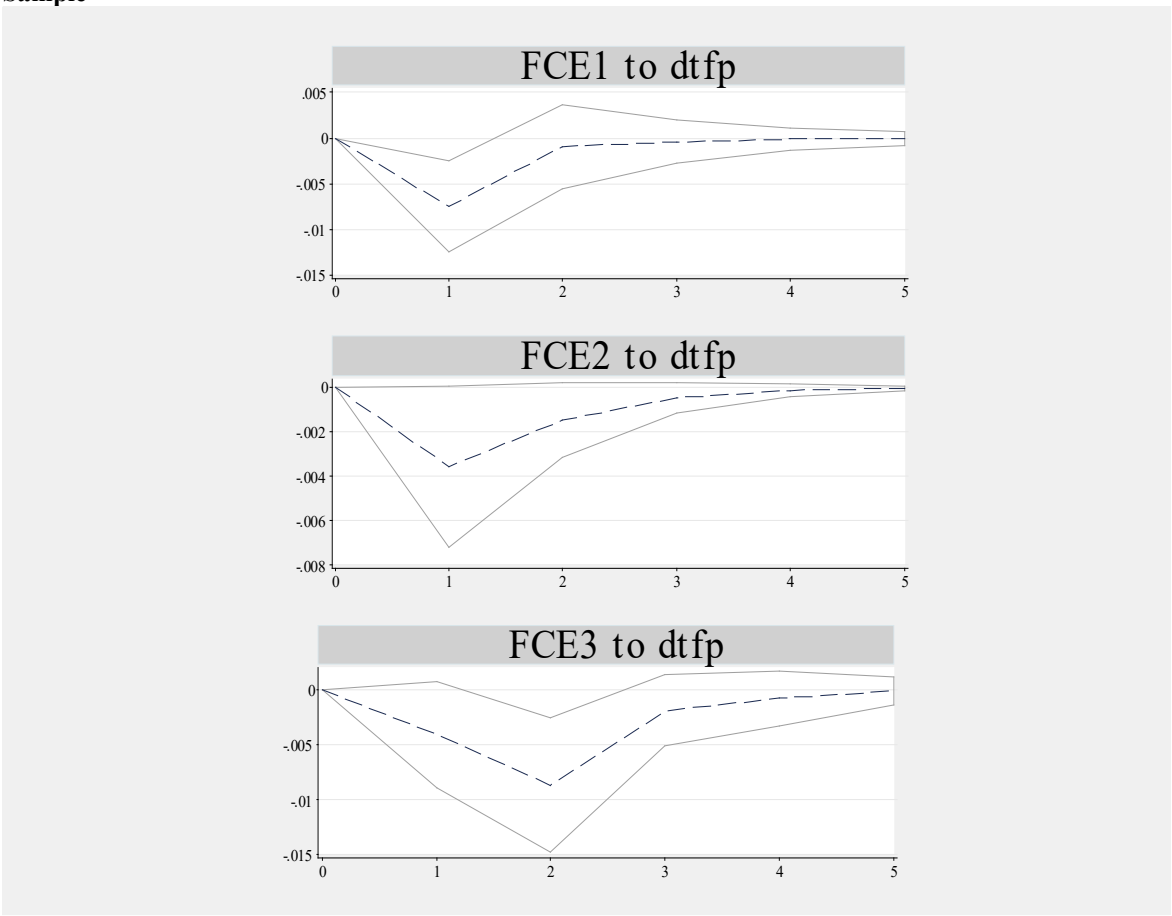
To identify the system, we use the recursive VAR structure (Hamilton, 1994) in which the order of endogenous variables matters. In our set-up, we use the convention that there is a delay between political action and actual spending (Caldara and Kamps, 2008; Lof et al., 2015). This is to say that current shocks in Δ*tfp* have an effect on current fiscal policy, while fiscal policy actions impact on Δ*tfp* with a lag. Intuitively, this assumption is plausible as government budget is determined once a year, so any decisions that impact on economic activities will take effect in the forthcoming year while it is common to assume that a government usually responds instantaneously to a productivity shock. We test empirically the above assumption applying the panel Granger causality test of Dumitrescu and Hurlin (2012) on whether TFP can Granger-cause changes in CAPB. We follow the estimation routine of Lopez and Weber (2017) in selecting the optimal number of lags of the model. Under the null hypothesis there is no Granger causality for any units in the panel with the average statistic associated with the null hypothesis to be distributed independently and identically in infinite samples. Appendix B2 shows the estimates from the Granger causality test, accordingly, we were not able to reject the null hypothesis that TFP does not Granger-cause CAPB for two alternative measures of the latter variable. Therefore, for our identification strategy in the PVAR estimation, we have sufficient evidence to argue that fiscal consolidation episodes (*FCE*) should be placed before Δ*tfp*.

Turning to the measure of *FCE*, all three definitions represent large consolidation attempts. *FCE1* and *FCE2* refer to cumulative effects over a number of years while *FCE3* identifies improvements in a single year and it is widely regarded as an episode of severe austerity (Alesina and Perotti, 1997; Alesina and Ardagna, 2010). Precisely, *FCE1* takes the value one if country *i* has achieved cumulatively a *dcapb*>1% for two consecutive years with at least 0.5% in the first year and zero otherwise, (Ahrend et al., 2006); *FCE2* takes the value one if country *i* has achieved cumulatively a *dcapb*>1.5% for three years with a *dcapb* no less than 0.5% for any of the years and zero otherwise (European Commission, 2007 and Barrios et al., 2010); *FCE3* takes the value one if country *i* has achieved a *dcapb* >1.5 in year *t* and zero otherwise (Alesina and Perotti, 1997; Alesina and Ardagna, 2010; de Cos and Moral-Benito, 2013). Appendix D2 displays the years of fiscal consolidation episodes for each country using definition *FCE3*.

PVAR results are presented in the form of IRFs that show the impact of a fiscal consolidation episode on the evolution of current TFP growth for a period of five years after

the realisation of the episode. Figure 2 displays three IRFs, one for each definition of *FCE*. These estimates suggest a negative impact of fiscal consolidation on TFP with the effect to last from one to two years depending on the definition considered. For *FCE1*, the impact of the episode is significant for one year while it dies afterwards. The size of this effect is 0.8 percent. Given that Δ*tfp* is differences in log TFP, the above coefficient can be interpreted as an episode of fiscal consolidation to decelerate the growth rate of TFP by 0.8 percent. When, fiscal consolidation is defined as *dcapb*>1.5 over a 3 years' period, *FCE2*, the negative effect on *Δtfp* dies out again after one year and the decrease in TFP growth rate is equal to 0.48 percent. The strongest effect on TFP is found with *FCE3*, which is regarded as a measure of severe austerity. The duration of the effect in this case dies out after two years with TFP to be decreased cumulatively by 1 percent.

Figure 2: Impulse Responses from PVAR with 2 Lags of Fiscal Consolidation Episodes and *Δtfp* -Full Sample

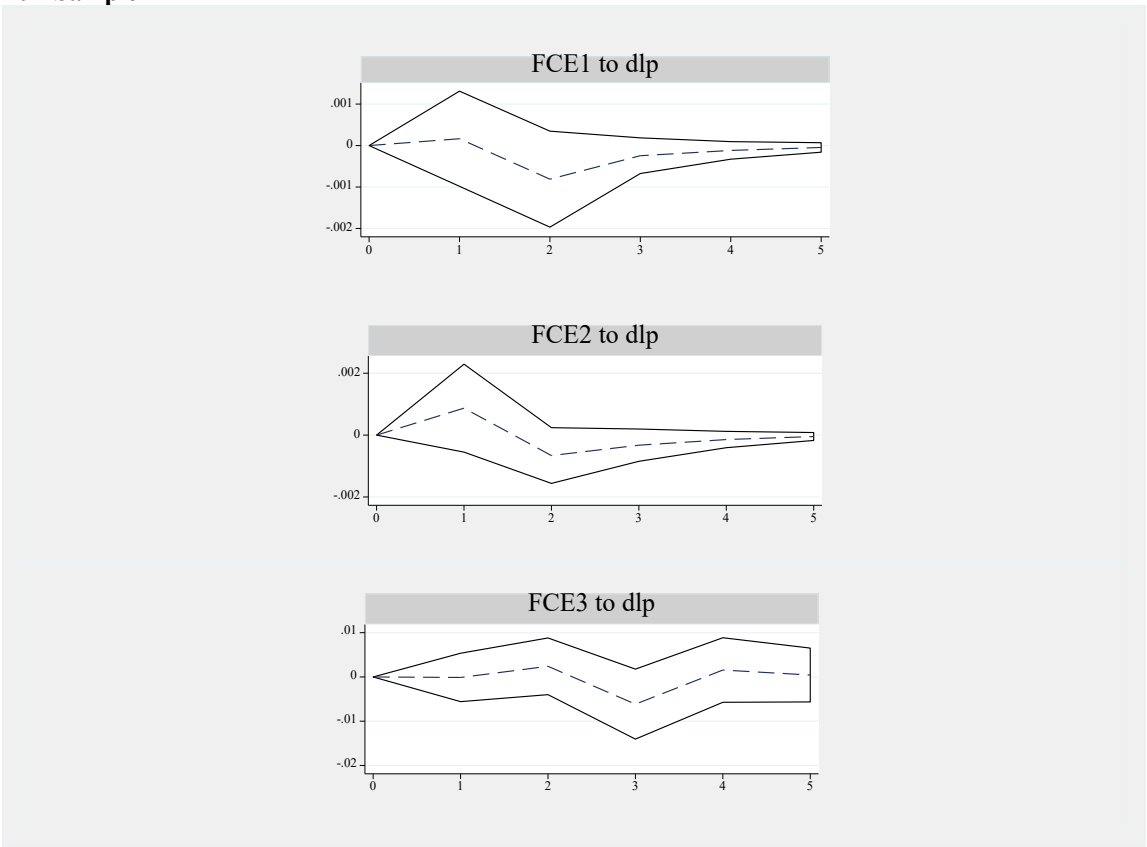


Notes: The impulse response functions IRF (dashed line) are derived from a PVAR (2) with *h*=2 and shows the change in *Δtfp* five years after a fiscal consolidation episode (FCE). *FCE1* takes the value 1 if country *i* has achieved *dcapb*>1% cumulatively for two consecutive years and zero otherwise; *FCE2* takes the value 1 if country *i* has achieved *dcapb*>1.5% cumulatively for three consecutive years and zero otherwise; *FCE3* takes the value 1 if country *i* has achieved *dcapb*>1.5% in a single year and zero otherwise.

Overall, Impulse-Response diagrams show that the negative shock of a fiscal consolidation episode on TFP can be persistent up to two years in cases of severe austerity. Quantitatively,

the negative effect of *FCE* on TFP is smaller than estimates found in Guajardo et al. (2014) and Jordà and Taylor (2016) for the effect of austerity on an array of domestic demand variables. Replicating the same PVAR specification for LP, we observe that the response of LP to a negative impulse from FCE1 and FCE2 now lasts two years with the deceleration in LP not exceeding 0.1 percent. In the case of a severe austerity as per FCE3 definition, the effect lasts up to three years. Overall, evidence in Figures 2 and 3 confirm the existence of contractionary short-run effects of austerity in both productivity measures. Differences in the responses between TFP and LP exist mainly in the duration of the effect and to a lesser extent in the strength of it. The detrimental effects of austerity on LP seem to last at least for two years with the economy reverting back to the pre-episode condition after three years while if TFP is considered the economy seems to recover slightly faster. We now proceed with analysing whether the short run effects of TFP after FCE varies across with different debt-to-GDP profiles. The estimation of a cointegrating relationship in the next section will signify whether the tightening or loosening of fiscal policy can also induce substantial long-run effects on productivity.

Figure 3: Impulse Responses from PVAR with 2 Lags of Fiscal Consolidation Episodes and Δ*lp* - Full Sample



Notes: The impulse response functions IRF (dashed line) are derived from a PVAR(2) with h=2 and shows the change in Δlp five years after a fiscal consolidation episode (FCE). Definitions of *FCE* are identical to IRFs in Figure 2.

3.2.1 PVAR Estimates for High Debt-Low Debt Countries

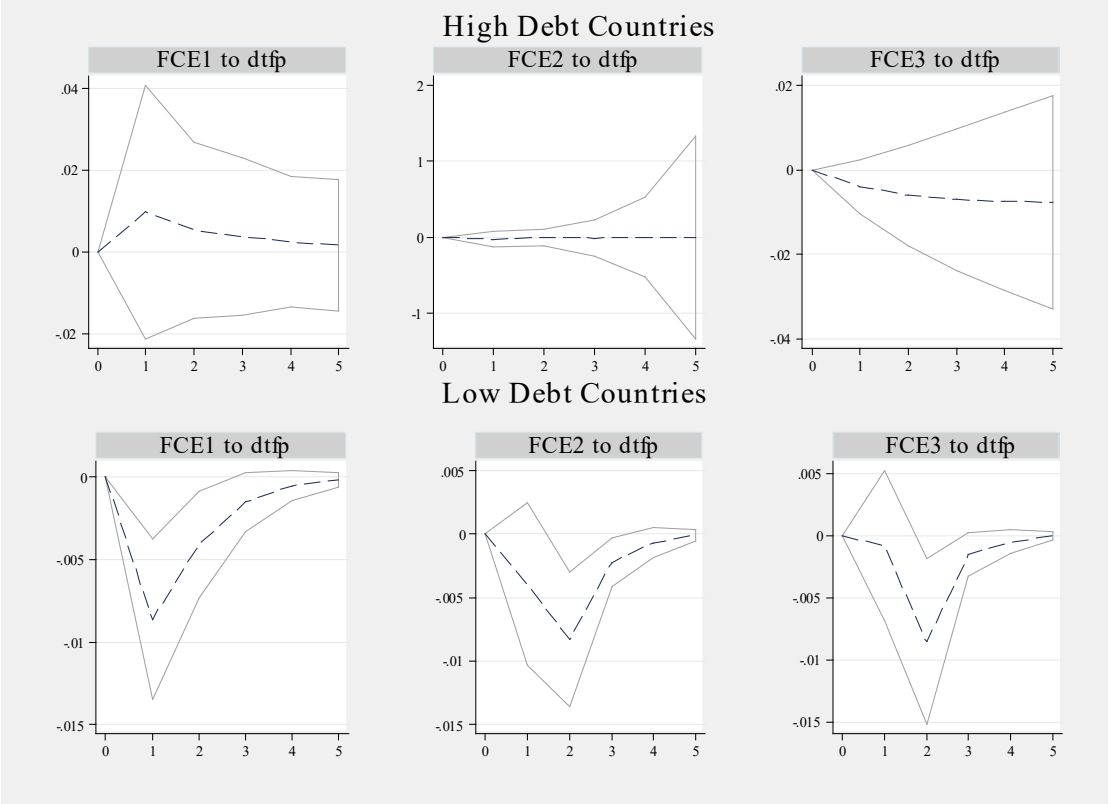
In addition to the full sample analysis, we replicate PVARs estimates separately for high and low debt countries. The rationale behind this exercise is to unveil whether the benefits of productivity enhancing austerity are more relevant in countries with substantial burden of public debt. Productivity-enhancing austerity might be more effective when the country exceeds a critical threshold of debt and must call for fiscal adjustment in order to maintain a stable private business environment with low inflation and default risks. Corsetti et al. (2010) argue that prospective spending cuts stimulate anticipation of low inflation and in association with a zero bounded interest rate the economy can enhance private investment. Efforts to reduce the share of debt to GDP can also reduce future policy intervention for tax increases, which promote crowding-in effects alongside with an efficient use of resources that stimulate capital accumulation, thus a higher level of productivity (Dar and AmirKhalkhali, 2002). Analogously, austerity measures can harm disproportionately countries with low level of public debt, which can potentially cause adverse effects on the productive capacity of the economy. To explore how Δtfp responds to FCE in countries with different levels of debt, we split our sample into "High Debt" and "Low Debt" countries using as threshold the sample median of debt-to-GDP ratio (Eberhardt and Presbitero, 2015).[11] Appendix B3 shows average values of debt-to-GDP ratio.

Graphs from IRFs and 5% error bands for the three alternative definitions of FCE are shown in Figure 4. The optimal number of lags for the PVAR associated with the IRFs is specified at two. Graphs in the upper panel of Figure 4 show no evidence for a significant impact of FCE on Δtfp for High debt countries. A fiscal consolidation episode does however affect Δtfp in low debt countries persistently regardless the definition of FCE. The negative effects from FCE die out after two years when *FCE2* and *FCE3* are used. The cumulative coefficient for all three different definitions of *FCE* is close to 0.8 for the group of low debt countries, which implies that the shock induced from a fiscal consolidation episode reduces TFP growth by 0.8 percent. These results suggest that the negative effects of fiscal consolidation tend to be stronger in countries with low debt ratios while the detrimental effect of austerity on productivity is non-existent in countries with high levels of debt. This finding

[11] The sample median is 57%, very close to the 60% Maastricht rule for the Eurozone countries. Appendix B3 displays the average value of debt-to-GDP ratio over the period 1980-2016 for all countries. Using the "canonical" rule of 90% debt-to-GDP ratio leaves us only with four countries in the "high debt" group, Belgium, Greece, Italy and Japan. With this small number of observations, the covariance matrix becomes singular, so it becomes infeasible to estimate a PVAR.

can be interpreted as evidence in favour of non-Keynesian effects of expansionary austerity, at least when debt to GDP is approximately above 60%. It is also true that the impact of austerity on TFP growth in the short-run is not always homogenous, rather depends on structural characteristics in each country such as debt profile (Afonso and Jalles, 2011).

Figure 4: Impulse Responses from PVAR with 2 Lags of Fiscal Consolidation Episodes and *Δtfp* - High and Low Debt countries (Threshold 60.2%)



Notes: The impulse response functions IRF (dashed line) are derived from a PVAR(2) with *h*=2 showing the change in *Δtfp* five years after a fiscal consolidation episode (FCE). Definitions of *FCE* are identical to IRFs in Figure 2.

3.3 Results from Estimating Panel Cointegration Models

3.3.1 Empirical Methodology

Next, we employ panel cointegration methods to study the relationship between fiscal consolidation and TFP. We have chosen to use three techniques, the dynamic ordinary least squares (DOLS) estimator of Kao and Chiang (2000), the pooled mean group (PMG) estimator of Pesaran et al. (1999) and in order of completeness we also apply the common correlated effects (CCE) estimator of Pesaran (2006). The panel cointegration methodology addresses endogeneity and serial correlation problems that are present in ordinary least square (OLS) estimation. The DOLS and PMG estimators pool data across countries to obtain a unique stable long-run vector assuming homogeneity while the short-run dynamics are flexible and unrestricted across panel units (Demetriades and Law, 2006).[12] A long-run relationship is estimated taking into account the dynamic nature of the data: (i) distinguishing between long-run and short-run behaviour (ii) using error-correction to estimate the speed of adjustment to the long-run equilibrium relationship. In the CCE estimation we augment the model with cross-section averages of all variables and estimate with OLS. The following log-linear specification is considered:

$$tfp_{it} = \alpha_0 + \alpha_B \Lambda_{it} + \mathbf{x}'_{it}\boldsymbol{\alpha}_{\mathbf{X}} + u_{it} \qquad (2)$$

where *tfp* is a measure of total factor productivity in country *i* at year *t,* and variable Λ stands for *capb* (cyclically adjustment primary balance). We use interchangeably two definitions, $CAPB^{O}$ (own estimations) and $CAPB^{E}$ (estimations obtained from OECD Economic Outlook (2018), Models 1a and 1b, respectively); **x**, is a vector of other covariates that drive *tfp* consistent with recent evidence (Mc Morrow et al., 2010; Bjørnskov and Méon, 2015). This vector includes R&D stock (RD), trade openness (*openness*) both measured as a share of GDP and interest rate of government bonds (*i*). $\boldsymbol{\alpha}$ is a vector of parameters to be estimated.[13]

3.3.2 Panel Unit Root and Panel Cointegration and Tests of Cross-Sectional Dependence

Before estimating the cointegrating relationship, we test for the order of integration of the variables included in the long-run equation using the panel unit root tests LLC, Breitung and

[12] See appendix C1 for a full representation of the DOLS specification.

[13] R&D stock is calculated using the perpetual inventory method. R&D investment data in 2010 USD refer to total Business R&D (BERD) and they are taken from OECD (Main Science and Technology Indicators). Trade openness is the ratio of imports and exports over GDP (OECD-Economic Outlook). Interest rate is the long-term interest on government bonds (OECD-Economic outlook). Appendix D1 displays a table of summary statistics.

IPS of Levin, Lin and Chu (2002), Breitung (2000) and Im et al. (2003).[14] As shown in Table 1, based on the three tests the null hypothesis of non-stationarity (otherwise the existence of a unit root) cannot be rejected uniformly regarding all the series. Accordingly, all variables in first differences reject the null of a unit root and become stationary I(0). Thus, the series examined are first-order integrated I(1).

Table 1: Panel Unit Root Tests, 1980-2016

Variables in Level			
	LLC	**Breitung**	**IPS**
tfp	1.524	-1.849	-0.358
	(0.936)	(0.032)	(0.360)
$CAPB^O$	-2.0244*	-1.868	-5.310**
	(0.022)	(0.031)	(0.000)
$CAPB^E$	-0.307	-4.147**	-4.047**
	(0.379)	(0.000)	(0.000)
RD	0.894	3.973**	2.436*
	(0.814)	(1.000)	(0.993)
i	2.3325*	0.404	-0.722
	(0.990)	(0.656)	(0.235)
openness	2.363*	1.978*	0.857
	(0.991)	(0.976)	(0.804)
Variables in First Differences			
tfp	-13.97**	-9.635**	-16.09**
	(0.000)	(0.000)	(0.000)
$CAPB^O$	-3.700**	-8.492**	13.277**
	(0.000)	(0.000)	(0.000)
$CAPB^E$	-9.130**	-12.76**	-19.06**
	(0.000)	(0.000)	(0.000)
RD	-4.842**	-6.845**	-9.835**
	(0.000)	(0.000)	(0.000)
i	-9.101**	-11.17**	-12.69**
	(0.000)	(0.000)	(0.000)
openness	--2.662**	-7.248**	-10.734**
	(0.004)	(0.000)	(0.000)

Note: LLC is Levin et al. (2002), Breitung is Breitung(2000) and IPS is Im et al. (2003). The tests reported use a constant term and a trend. All test statistics follow the normal distribution. ** and * denote the rejection of the null hypothesis of non-stationarity at 1 and 5 percent levels of significance, respectively. Numbers in parentheses are p-values.

The recent panel-data literature places emphasis on the substantial cross-sectional dependence in the errors that panel data may exhibit, which may arise because of the presence

[14] The IPS test estimates a separate ADF regression for each individual cross-section to allow for separate unit root processes assuming heterogeneous cross-sections (the known between dimension), while the Breitung test is a panel version of an Augmented Dickey Fuller test (ADF) considering homogeneity in the coefficient of the variables in levels but allowing the lag order for the first differenced terms to vary across cross sectional units introducing some heterogeneity in the panel. The LLC test, on the other hand, considers a homogeneous panel. Each of the tests is performed assuming an intercept and a linear trend.

of common shocks and unobserved components that ultimately become part of the error term.[15]This can be attributed-for example- to the experience of the increasing economic and financial integration across countries and financial entities, which implies strong interdependencies between the cross-sectional units. Taking the above into consideration, we implement a test of cross-sectional dependence in the panel structure of our data. We first use Pesaran's (2004) CD test and we also run Frees (1995, 2004) test. Both tests are performed after estimating a fixed effects (FE) model. Pesaran's CD test (15.7 and 16.9 for Models 1a and 1b respectively, with p-values 0.000 in both cases) strongly rejects the null hypothesis of no cross-sectional dependence for both specifications. Frees test (5.717 for Model 1a and 5.341 for Model 1b) also rejects the null hypothesis of no cross-sectional dependence at 1% level.

We next consider the issues of the existence of long-run relationships in our data. In order to do so we need to establish whether cointegration is present among the variables. Table 2 reports the panel cointegration tests of Kao (1999), Pedroni (1999) and the Johansen-Fisher test (Maddala and Wu, 1999). The Pedroni test refers to the null hypothesis of no cointegration with alternative hypotheses allowing for heterogeneity among countries. The first four of the Pedroni tests are within-group statistics and compute the unit root tests of the residuals pooling the autoregressive coefficients across countries. The between-group statistics compute the tests by allowing the first-order autoregressive term to vary across countries and then averaging individual estimates across countries. With the exception of the v-statistic, panel and group statistics reject the null hypothesis of no cointegration for both specifications. Similar results are produced from Kao[16] and Johansen-Fisher tests. The persistence in rejecting the null hypothesis suggests the existence of a homogeneous relationship that is in line with the use of the PMG estimator. A similar result is also indicated from the Kao test, which assumes panel homogeneity. Consequently, there is strong evidence that TFP, CAPB and control variables across the 26 countries in both specifications are cointegrated and two long-run homogeneous relationships could possibly be derived.

[15]See, for example, Pesaran (2004).

[16] The Kao test imposes homogeneity on cointegrating vectors. It is essentially a generalization of the DF (Dickey-Fuller) and the ADF (Augmented Dickey Fuller) tests.

Table 2: Panel Cointegration Tests

Pedroni Tests	**Model 1**		**Model 2**	
H_o:There is no cointegration				
H_1:Common AR coefficients				
Panel v	-0.743		-1.425	
Panel ρ	1.216		1.967*	
Panel PP	-4.039**		-3.286**	
Panel ADF	-4.144**		-2.646**	
H_1:Idividual AR coefficients				
Group ρ	3.339**		3.798**	
Group PP	-7.592**		-6.989**	
Group ADF	-5.049**		-3.243**	
Kao ADF	-2.228 (0.013)		-2.666 (0.003)	
Johansen Fisher test	From Trace Test	From max Eigen test	From Trace Test	From max Eigen test
H_o:No cointegrating vector	303.3 0.000)	209.8 (0.000)	315.4 (0.000)	235.4 (0.000)
H_1:At most 1 cointegrating vector	192.3 (0.000)	896.6 (0.000)	183.5 (0.000)	902.6 (0.000)
H_1:At most 2 cointegrating vectors	102.8 (0.000)	102.2 (0.000)	93.09 (0.000)	94.21 (0.000)
H_1:At most 3 cointegrating vectors	31.64 (0.947)	32.22 (0.938)	29.73 (0.969)	26.71 (0.989)

Notes: * and ** indicate rejection of the null hypothesis of no cointegration at 5 and 1 percent based on the 1.644 and 2.326 critical values, respectively. Numbers in parentheses are p-values. The Kao and Pedroni tests follow the normal distribution, while probabilities in the Johansen Fisher test are computed following asymptotically the chi-squared distribution.

3.3.3 Panel cointegration estimation

To provide a sense of robustness, we present results from specification (2) using three different estimators, PMG, DOLS and CCE.[17] We have more trust in the CCE estimator as it is the one that corrects for cross-sectional dependence in the panel structure of the data, thus we treat CCE as the preferred specification. The two CAPB definitions, $CAPB^O$ and $CAPB^E$ (Models 1a and 1b, respectively) are used interchangeably as a check that results are robust to the methodology used to calculate the fiscal adjustment variable.

Table 3 presents the long-run coefficients along with the error-correction coefficient from the PMG estimator. Our results highlight a strong long-run relationship between TFP and fiscal balance for OECD countries that are uniform and comparable across methods and specifications. Fiscal tightening has a negative and significant effect on TFP with the

[17] The use of the CCE estimator is considered important since the performed CD tests indicate the existence of cross-sectional dependence.

magnitude of the relevant coefficient being larger when the OECD Economic Outlook definition of $CAPB^E$ is used. Among the three estimators CCE produces the largest coefficient for CAPB. Interestingly, accounting for cross-sectional dependence strengthens the claim of a negative TFP–CAPB relationship. In addition, the CCE estimator exhibits improved performance in terms of standard errors relative to PMG and DOLS estimators. Regarding the rest of the variables, *openness* has the strongest impact on TFP with the size of this coefficient in DOLS and PMG to be twice or three times as much the size in the CCE estimator. The remaining coefficients are statistically significant with the expected signs. Our findings support the argument that fiscal consolidation has detrimental effects in long-run productivity. The magnitude of the long-run CAPB coefficient varies between -0.046 and -0.01 (i.e. 0.021 on average) across the six different specifications shown in Table 3. Taking the highest value among the six, our estimates suggest that a 10% fiscal tightening leads to a 0.46% decrease in long-run productivity. It should be noted that the negative impact of this effect is smaller from the gain that R&D and trade openness generate.

In the dynamic specification of the PMG estimator, the short-run error correction coefficient is negative and significant indicating a relatively fast adjustment to equilibrium. In a year about 40% has reverted back to the long-run cointegrating relationship, while full equilibrium is attained in almost two years. Error correction is an important feature of the TFP-CAPB relationship expressed uniformly across the 26 countries of the sample.

The main conclusion from the estimates in Table 3 is the sufficient evidence of a negative long-run relationship between discretionary fiscal policy, and TFP. This finding raises an issue that overlooked in the current literature of expansionary austerity; that is contractionary fiscal policy hurts productivity in a more lasting fashion. Our findings could be proved useful in several contexts, as for instance, it could help explain recent evidence contrasting the post- 2007/8 crisis adjustment in the Eurozone and the US. The slump in real activity in the post-2009 period was markedly more protracted in the Eurozone and this, according to Kollmann et al. (2016) reflects largely negative shocks to TFP growth, which were not so severe in the US. Our results would provide direct support to this view and in fact attribute the lower productivity growth in the euro area, among other factors, to differentials in fiscal policy, as between 2009 and 2016 the CAPB stood on average at 0.2% of potential GDP in the euro area, compared to -3.7% in the US.[18] As already discussed in Section 2, austerity is more likely to impede productivity through the supply side of the economy, namely by limiting

[18] US has adopted a much more loose fiscal policy in the post crisis period while EU has adopted in general a very tight fiscal budget.

public spending on sectors like public infrastructure, education and investment in new technologies. Empirically, verifying more precisely this mechanism is a promising avenue for future research and our study takes the first step towards this direction by further examining in the next section whether revenue-or expenditure-based fiscal consolidation is more damaging to the productive capacity of the economy. The expansionary austerity thesis argues in favor of spending-based consolidations, but the line of reasoning presented here would point to exactly the opposite conclusion.

Table 3: The Determinants of TFP, Long-Run estimates from PMG, DOLS and CCE

	PMG (1)	DOLS (2)	CCE (3)
Model 1a			
$CAPB_t^O$	-0.007***	-0.010*	-0.004***
	(0.002)	(0.006)	(0.000)
RD_t	0.073***	0.021***	0.053***
	(0.006)	(0.324)	(0.001)
i_t	-0.006***	-0.019***	-0.010***
	(0.000)	(0.003)	(0.001)
$openness_t$	0.911***	1.863***	0.431***
	(0.123)	(0.298)	(0.038)
gfc_i	-0.019***	-0.125**	-0.274***
	(0.004)	(0.07)	(0.016)
Observations	697	745	745
R^2		0.12	0.97
SE		1.386	0.859
Log likelihood	1230		
F test	$2.05*10^{13}$		
Model 1b			
$CAPB_t^E$	-0.015***	-0.045***	-0.046***
	(0.003)	(0.007)	(0.001)
RD_t	0.076***	0.021***	0.050***
	(0.005)	(0.327)	(0.001)
i_t	-0.011***	-0.017***	-0,008***
	(0.001)	(0.003)	(0.001)
$openness_t$	0.962***	1.381***	0.415***
	(0.088)	(0.188)	(0.059)
gfc_i	-0.008***	-0.09**	-0.237***
	(0.000)	(0.07)	(0.027)
Observations	682	727	727
R^2		0.13	0.97
SE		1.387	0.813
Log likelihood	1215		
F test	$5*10^{12}$		
Error Correction Coefficient			
Model 1a	-0.409***		
	(0.075)		
Model 1b	-0.396***		
	(0.064)		

Notes: The dependent variable in PMG is *Δtfp* and in DOLS and CCE is *tfp.* In PMG, estimates refer to long-run elasticities with respect to relevant regressors, short-run coefficients are not reported here but they are available from the authors upon request. Numbers in parentheses are standard errors. *gfc* is a dummy variable that accounts for the effect of a global financial crisis. The variable takes value one in the year of crisis, which is country specific and zero otherwise (Atkinson and Morelli, 2011). The lag order in PMG is 2 for the dependent variable and 1 for each of the independent variables. Model selection was based on the Schwartz criterion. F-test refers to the null hypothesis that coefficients of all independent variables included are zero, standard errors are in parentheses, *, ** and *** indicate significance at 10, 5 and 1 percent, respectively.

3.4 Tax versus spending driven consolidation

In this last section, we extend our analysis by decomposing fiscal consolidation into spending cuts and tax hikes. For this exercise, we use the data set of Devries et al. (2011) that reports policy actions for fiscal consolidation in 17 OECD countries over a shorter time span and smaller country coverage than those used so far for our previous estimates. We replicate the PMG and CCE estimates of Table 3 using spending cuts and tax hikes (both expressed as shares to GDP), separately. We first report in column (1) of Table 4 estimates from a total consolidation variable as reported in Devries et al. (2011). Columns (1) and (3) in Table 4 can be viewed as an additional robustness check of the estimates shown in Table 3, nonetheless these estimates are not directly comparable as the data sample is now smaller both in time dimension and cross-sectional coverage. The *consolidation* variable is insignificant when PMG is used, while it remains negative and statistically significant with CCE. More crucially, results in columns (2) and (4) indicate that tax hike driven consolidation has a positive effect on TFP, while the opposite is true for spending cuts. The size of estimated coefficients changes noticeably between PMG and CCE in Table 4, but more importantly the sign of the coefficients remains consistent between estimators. This pattern of results is rather intriguing as it points towards two crucial implications, first, the type of consolidation matters and second, arguments in favour of productivity enhancing austerity mainly work through taxation hikes. This is to say that any uncertainty associated with expansionary fiscal policy can be more effectively corrected with an increase in taxes rather than spending cuts.[19] Our findings do not comply with the common wisdom that government spending is essentially unproductive (transfers and social benefits etc.); to the contrary, government consumption plays a central role in shaping national productive capacity in terms of fixed assets that are more likely complementary to private investment. The result that spending driven consolidation has a negative impact on TFP also suggests that government is in charge of sectors such as education, health and justice for which underfunding can have crucial negative consequences in the long-run. Castro also (2017) presents evidence in support of this claim based on evidence from 15 European Union countries during the period 1990-2012, concluding that during fiscal consolidation episodes governments significantly cut spending related to safety, health assistance, and investment in human capital.

[19] For further evidence against expenditure-driven fiscal consolidation, see Kaplanoglou et al.(2015) for industrialised countries and Schaltegger and Weder (2015) for developing countries. In the case of tax hikes, there is evidence that certain kinds of taxes are themselves harmful for TFP. Bournakis and Mallick (2017, 2018), for example, show that corporate tax negatively affects TFP growth at a firm-level based on data from the UK.

Table 4: The Determinants of TFP, Long-Run estimates from PMG and CCE.
Historical Data of Fiscal Consolidation (Devries et al., 2011), 1980-2009, 17 OECD Countries

	PMG (1)	PMG (2)	CCE (3)	CCE (4)
Main				
consolidation	-0.045		-0.039**	
	(0.14)		(0.02)	
Tax		0.811**		0.441***
		(0.36)		(0.04)
Spending		-1.133**		-0.251***
		(0.48)		(0.03)
RD	2.512***	3.235*	0.965***	0.975***
	(0.93)	(1.69)	(0.09)	(0.09)
i	-0.061	-0.150	-0.023***	-0.026***
	(0.04)	(0.10)	(0.01)	(0.01)
Openness	2.682*	0.882	0.516***	0.593***
	(1.38)	(1.58)	(0.20)	(0.20)
Observations	475	475	416	416
R^2			0.12	0.12
Error Correction Coefficient				
	0.19 (0.085)*	0.12 (0.1)*		

Notes: The dependent variable in PMG is Δ*tfp* and in CCE is *tfp*. In PMG, estimates refer to long-run elasticities with respect to relevant regressors, short-run coefficients are not reported here but they are available from the authors upon request. Robust standard errors in parentheses clustered by country with *, ** and *** indicating significance at 10, 5 and 1 percent, respectively.

4 Concluding Remarks

The present paper evaluates the role of fiscal consolidation on productivity. The existing literature is mainly focused on the role of short-run effects without considering if austerity has long-run effects on economic activity through the supply side of the economy. The main goal of our paper is to shed light on this rather unexplored area of the expansionary austerity literature. Our empirical methodology is split into two parts, first, we run a PVAR model to identify the short-run effects of fiscal consolidation episodes on TFP growth and second, we employ panel cointegration as well as other estimation techniques to establish the long-run relationship between fiscal consolidation and TFP. We found that the negative impact of a fiscal consolidation episode lasts for about two years and it is disproportionately more damaging in low debt countries, where probably issues of debt sustainability are not so severe thus, contractionary fiscal action causes adverse effects in productivity. This result holds even if we use labour productivity instead of TFP. Using three different estimators (PMG, DOLS and CCE), we also establish a negative long-run relationship between TFP and fiscal adjustments. The size of this effect is smaller relative to other traditional TFP drivers but not negligible in statistical terms. Our findings thus, highlight yet another channel through which

austerity impairs long-run growth prospects, namely via its detrimental effect in decelerating aggregate productivity.

This has serious policy implications not only with regard to the validity of the expansionary fiscal contraction thesis, but also in the context of the debt-sustainability debate, where austerity can prove self-defeating. On a more general front, our findings could also contribute to the currently heated debate on better understanding hysteresis mechanisms, or what Stiglitz (2015) called the missing "dark matter", following economic crises like the global recent one which affect economies' productive capacity (Ball, 2014). Having established contractionary fiscal policy as a one of the long-run determinants of such capacity, highlights an additional cost of austerity and calls for a more in-depth analysis of its design on the policy front.

Our results also cast doubt on the claim regarding the superiority of spending-based fiscal consolidations, which has been central in the policy debate when austerity programmes are designed worldwide. Distinguishing between taxes and expenditure, we reveal that tax based austerity is more appropriate for TFP while spending driven fiscal consolidation undermines capacity, due to the important role of government in financing investments related to the productive capital of the economy. Public expenditure on infrastructure projects, technology, innovation, education and health builds the necessary physical, human and social capital that enhances the productive capacity of the economy and such expenditure often bears a large share of the burden of fiscal consolidation.

Some caveats are in order regarding our analysis, while there are further interesting dimensions worth exploring to expand our understanding of this rich research topic. First we need a more thorough classification of what really represents productive government spending. This requires the construction of a CAPB measure that will explicitly distinguish between productive and non-productive government spending. Additionally, our analysis does not investigate whether non-linearities and asymmetries are present in the sample. Although we have split our sample into low and high debt countries, it remains of interest to explore whether the TFP-fiscal consolidation nexus changes above or below critical thresholds of austerity. Within a panel of heterogeneous countries, it will be also of relevance to identify country specific thresholds in the TFP austerity nexus. Finally, it would also be worth to explore the effect of austerity on different components of gross fixed capital formation, especially investment in intangible assets which has been steadily growing over time (Van Ark et al., 2008). All these matters call for further research on the topic.

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Appendices

A1. TFP Measurement

We consider the following aggregate production function with parameter *A* to represent Hicks neutral technical change:

$$Y_{it} = A_{it} L_{it}^{a_L} K_{it}^{1-a_L} \tag{A1}$$

Y is value added, *L* is labour and *K* is capital stock; *i* and *t* index country and year, respectively. The share of labour to value added is denoted by $a_L < 1$. Labour input is measured in hours worked per employee in the total economy (OECD, Economic Outlook) and capital stock is constructed with the perpetual inventory method as follows: $K_{it} = K_{it-1} - \delta K_{it-1} + I_{it-1}$, where δ is the physical depreciation rate defined at a constant rate of 10% for all countries. *I* is investment in Gross Fixed Capital Formation (OECD, Economic Outlook). We initiate the series of capital stock from the following steady state condition: $K_{it=0} \equiv \frac{I_{it=0}}{\overline{g}_i + \delta}$, where $\overline{g}$ is the sample mean of investment growth rate for each country. Value added and investment are deflated using GDP and GFCF deflators (2010=100) (OECD, Economic Outlook). Labour share is the ratio of real wages to real GDP. Wages are deflated using the consumer price index (CPI). To make values comparable across countries, we express all data into PPP constant USD (2010=100). To measure TFP, the empirical counterpart of *A*, we use the Tornqvist index number (Caves et al., 1982; Good et al., 1996), which is superlative as its components can be derived from an underlying translog production function. Accordingly, output and input units in each country are expressed relative to a hypothetical reference point. After taking logs of (A1) and re-arranging we get:

$$TFP_{it} = \left(\log Y_{it} - \log \overline{Y}\right) - \tilde{a}_{it}^{L}\left(\log L_{it} - \log \overline{L}\right) - (1 - \tilde{a}_{it}^{L})\left(\log K_{it} - \log \overline{K}\right) \tag{A2}$$

The hypothetical points for *Y*, *L* and *K* are denoted with a bar and defined as sample geometric means of each variable. Analogously, we express the adjusted labor shares as: $\tilde{a}_{it} = \frac{a_{it} + \overline{a}}{2}$ with the waved bar above a to represent the sample arithmetic mean. We also experiment by measuring TFP using data from Penn World Table (9.1) (PWT). This data source allows adjusting labour input for human capital, so the labour input is the defined as: $\widetilde{L} = HL$, with *H*

denoting the average human capital index in the economy. The degree of correlation in the TFP series constructed from Economic Outlook (EO) and PWT (adjusted for labour quality) is 0.86. Appendix A2 shows the sample means of TFP from each source. Two points merit highlighting from Appendix A2, the ranking of countries based on TFP does not change substantially between the two data sources and second TFP_PWT tends to be downward biased more likely reflecting the fact that accounting for human capital reduces the source of technological progress that is unexplained as it is now attributed to the quality of labour.

Appendix A2: Total Factor Productivity Means, 1980-2016

TFP_EO		TFP_PWT	
United States	6.931	United States	4.540
Japan	4.426	United Kingdom	2.549
Germany	3.186	Germany	2.310
France	2.649	France	2.037
Italy	2.275	Switzerland	1.979
United Kingdom	2.032	Japan	1.646
Spain	1.784	Netherlands	1.557
Canada	1.644	Canada	1.456
Poland	1.225	Australia	1.453
Netherlands	1.149	Spain	1.425
Australia	1.114	Italy	1.422
Switzerland	0.947	Sweden	1.160
Korea	0.871	Belgium	1.124
Norway	0.844	Denmark	1.085
Belgium	0.808	Norway	0.998
Sweden	0.807	Ireland	0.965
Austria	0.671	Austria	0.961
Portugal	0.666	Poland	0.863
Denmark	0.641	New Zealand	0.805
Greece	0.614	Korea	0.743
Hungary	0.516	Czech Republic	0.689
Czech Republic	0.472	Portugal	0.688
Finland	0.460	Finland	0.678
New Zealand	0.428	Greece	0.534
Ireland	0.412	Hungary	0.197
Iceland	0.063	Iceland	0.018

Notes: TFP_EO is the TFP series constructed from Economic outlook-OECD (2018); TFP_PWT is TFP series constructed from Penn World Tables (9.1). The TFP_PWT is adjusted for labour quality as per explanation in Appendix A1.

B1. Panel Var (PVAR) Specification

The specific PVAR model used to derive the Impulse Response Functions (IRFs) is the following:

$$\Delta tfp_{it} = \gamma_i + \sum_{t-h}^{H} \beta_{1t-h} \Delta tfp_{it-h} + \sum_{t-h}^{H} \beta_{2t-h} FC_{it-h} + \upsilon_{it} \qquad \text{with } h \geq 1$$

Parameter γ_i controls for country heterogeneity and h specifies the number of lags. The optimal number of lags is chosen from the Bayesian information criterion (BIC) reported in the table below.

Lag Selection for PVAR

Numbers of lags	BIC
	FCE1
1	-25.48344
2	**-67.34058**
3	-43.86729
4	-5.628352
	FCE2
1	-31.84603
2	**-65.15207**
3	-52.55787
4	-11.52538
	FCE3
1	-31.7996
2	**-70.48421**
3	-55.57539
4	-12.65899

Notes: BIC Bayesian Information criteria for a PVAR(2) with *h* initially specified from 1-4. Minimum BIC in each model is specified in bold.

B2: Results from Panel Granger Causality Tests

Hypothesis	Z statistic	Critical value	Outcome
TFP does not cause $CAPB^O$	2.619/p-value=0.10	3.304	reject
TFP does not cause $CAPB^E$	0.408/p-value=0.82	4.501	Reject

Notes: The p-values are computed from 1000 bootstrap replications. The optimal lag is 1 as indicated by the BIC criterion.

B3: Average Values of Debt-to-GDP ratio, 1980-2016, Sample Median: 57%

Country	Mean	Group
Australia	26.54	Low
Austria	63.74	High
Belgium	109.74	High
Canada	75.71	High
Czech Republic	28.17	Low
Denmark	54.82	Low
Finland	37.15	Low
France	56.53	Low
Germany	62.79	High
Greece	98.02	High
Hungary	68.24	High
Iceland	56.11	Low
Ireland	73.05	High
Italy	100.76	High
Japan	135.25	High
Korea	25.77	Low
Netherlands	61.36	High
New Zealand	27.15	Low
Norway	36.73	Low
Poland	46.47	Low
Portugal	67.68	High
Spain	52.98	Low
Sweden	50.59	Low
Switzerland	48.14	Low
United Kingdom	49.45	Low
United States	68.59	High
	60.82	

C. DOLS specification

DOLS takes account of the endogeneity bias that is inherent in static OLS by augmenting specification (1) with leads, lags and contemporaneous values of all regressors. DOLS estimates the following version of (1):

$$tfp_{it} = \alpha_{\Lambda}\Lambda_{it-1} + \mathbf{x}'_{it-1}\boldsymbol{\alpha}_{\mathbf{x}} + \sum_{j=-p_1}^{j=p_2} c_{ij}\Delta\mathbf{x}_{it+j} + \sum_{j=-p_1}^{j=p_2} c_{ij}\Delta\Lambda_{it+j} + u_{it} \qquad \text{(C1)}$$

where c_{ij} is the coefficient of a lag or a lead of the first differences of the variables.

D. Definition of CAPB and Descriptive Statistics

Two alternative definitions of cyclical adjustment of government budget balances that determine fiscal consolidation have been used in the estimation of the relationship between TFP and fiscal consolidation. The first, $CAPB^E$ is obtained from the OECD Economic Outlook No 102 of November 2017 and it is given as a percentage of potential GDP. Data from Economic Outlook of previous years were used to obtain a continuous series. The OECD uses a disaggregated approach with respect to the calculation of the CAPB where it first adjusts individual tax and spending categories for the cycle, and then aggregates the resulting cyclically adjusted items into a CAPB (for details, see OECD, 2018).

The second definition of cyclically adjusted government balances namely $CAPB^O$ is derived from own calculations and it is based on the European Commission's method using trend GDP from a Hodrick-Prescott filter. The method involves two main steps. In the first step, the output trend is estimated by means of the Hodrick-Prescott filter and the output gap between the trend GDP level and the actual output is calculated. In the second step, cyclical components of budget balances are calculated by applying the output gaps to the marginal rates of change of revenue and expenditure with respect to GDP. More specifically, the cyclical component of the primary balance is obtained by multiplying the output gap with the budgetary sensitivity to GDP (European Commission, 2017). Budgetary elasticities have been calculated by OECD in "Measuring cyclically adjusted budget balances for OECD countries" by Nathalie Girouard and Christophe Andre in OECD Economics Department Working Paper No 434, 2005.[20] Finally, the cyclically adjusted budget balances are obtained by deducting the cyclical component from the actual government budget balances.

[20] It should be noted that in our calculations we have used the elasticities for the Total Balance choosing not to break down in revenue and expenditure.

D1: Descriptive Statistics

Panel A

Variables in levels

Variable	Mean	Median	Sd	Min	Max
tfp_t	1.44	0.85	1.49	0.06	6.93
$CAPB_t^E$	-0.15	0.10	3.12	-26.12	14.48
$CAPB_t^O$	-0.20	-0.00	4.14	-31.10	14.85
RD_t	7.72	7.19	4.99	0.24	21.73
i_t	6.82	5.61	4.17	-0.07	29.74
$openness_t$	-0.00	-0.01	0.09	-0.44	0.39

Panel B

Variables in first differences

Variable	Mean	Median	Sd	Min	Max
Δtfp_{t-1}	-0.00	-0.00	0.09	-0.44	0.68
$\Delta CAPB_t^E$	0.09	0.08	2.04	-18.33	18.05
$\Delta CAPB_t^O$	0.16	0.07	2.55	-17.80	19.69
ΔRD_t	0.16	0.11	0.28	-1.14	2.58
Δi_t	-0.37	-0.29	1.20	-12.45	6.75
$\Delta openness_t$	0.00	-0.00	0.03	-0.16	0.17

Notes: We present descriptive statistics for an unbalanced sample of 936 observations. Panel A shows averages for the level variables, while panel B presents descriptive statistics of first difference transformations of the same variables.

D2: Consolidation Episodes per Country According to Criterion FCE3

Country	Years of Fiscal consolidation Episodes
Australia	1986, 1987, 2011, 2013
Austria	1984, 1986, 1997, 2001, 2005, 2015
Belgium	1993, 2006
Canada	1986, 1987, 1995, 1996, 1997, 2012
Czech Republic	1999, 2004, 2013, 2016
Denmark	1983, 1984, 1986, 2005, 2013, 2014
Finland	1981, 1984, 1988, 1994, 1996, 1998, 2000
France	1996
Germany	1992, 1996, 2000, 2011
Greece	2005. 2010, 2011, 2012,2014, 2016
Hungary	1996, 1999,2003,2007,2008, 2009, 2012
Iceland	1984, 1988, 1990, 1992, 1995, 1999, 2005, 2009, 2010, 2011, 2012, 2014, 2016
Ireland	1983, 1984, 1987, 1988, 2003, 2011, 2012, 2013
Italy	1982, 1983, 1991, 1992, 1993, 1997, 2007, 2012
Japan	1984. 1985, 1997, 1999, 2001, 2004, 2014, 2015
Korea	2000, 2004, 2010
Netherlands	1983, 1991, 1993, 1996, 2013, 2016
New Zealand	1987, 1989, 1991, 2000, 2011, 2012
Norway	1983, 1995
Poland	2011, 2012
Portugal	1983, 1984, 1988, 1992, 2002, 2006, 2011, 2012, 2013, 2015
Spain	1992, 1996, 2010, 2012, 2013
Sweden	1983, 1986, 1987, 1996, 2010
Switzerland	
UK	1982, 1998, 2010, 2011, 2013, 2016
US	2011, 2013

Note: FCE3 takes the value one if country *i* has achieved a d*capb* >1.5 in year *t* and zero otherwise.