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Fiscal adjustment in a panel of countries 1870–2016

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ABSTRACT

The financial crisis from 2007 and, even more so, the Covid-19 pandemic caused large increases in public sector deficits and debts in many countries and prompted concern about fiscal adjustment. This paper examines fiscal adjustment to debt and deficits for a panel of 17 countries over 1870–2016 using the Jordà–Schularick–Taylor Macrohistory Database. This long span panel is informative since it contains many examples of large fiscal shocks similar to those recently experienced. The results from reduced-form models suggest that large deficits or surpluses tend to prompt stabilising feedbacks, mainly through changes in revenue, and there is greater pressure to adjust on countries running a deficit versus those running a surplus. However, the debt–GDP ratio prompts much less stabilising feedback by expenditure or revenue.

1. Introduction

The financial crisis from 2007 and, even more so, the Covid-19 pandemic increased government expenditure and reduced revenue by large amounts in many countries. This rapid growth in public sector deficits and debts prompted concern about the sustainability of public finances, the solvency of national governments and the likely fiscal adjustments.

Solvency conditions have been analysed by performing unit root and cointegration tests on fiscal and external deficit time series (Ahmed and Rogers, 1995; Trehan and Walsh, 1988; Quintos, 1995). These papers use tests for stationarity and cointegration to check whether the intertemporal budget constraint (IBC), which guarantees that the debt is backed by the expected present value of future primary surpluses, is satisfied. The issue however, is that the intertemporal budget constraint is a weak condition as it can be satisfied for series of any order of integration (Bohn, 2005, 2007). Hence, Bohn argues that the standard time series tests are fairly useless for analysing fiscal sustainability, because since higher order of integration can never be completely ruled out, these tests can never credibly reject the consistency of data with the IBC (i.e. sustainability).

Bohn (2007, 2016) also argues that solvency is an economic rather than statistical issue, a question of whether the lenders believe the borrowing government is solvent and capable of repaying its debt. Hence, governments with credibility have been able to run large deficits and accumulated large debt to GDP ratios, for instance to pay for wars without significantly changing interest rates.

Bohn (2007) concluded that from the empirical side, the most credible evidence in favour of fiscal sustainability is the robust positive response of primary surpluses to increase in debt–GDP ratio. He explained that if the fiscal policy is sufficiently “responsive” to accumulation of debt, meaning the government takes corrective actions by increasing surplus to meet increasing interest payments, then it can be concluded that the primary surplus has an error-correction representation (Bohn, 2007). This paper uses an error-correction model to examine not only how surpluses (deficits) adjust to debt, but how they respond to their own lagged values.

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The analysis uses data for 17 countries for 1870–2016, from the Jordà–Schularick–Taylor, JST, Macrowhistory Database, to examine the adjustment of surplus, revenue and expenditure to changes in the lagged surplus and lagged debt. The patterns of adjustment are estimated for the whole period and then for three shorter sub-periods: 1870–1914, 1915–1950 and 1951–2016.

Overall, it appears that large deficits do tend to adjust to shocks in a stabilising way, mainly through revenue, not expenditure. However, there does not seem to be a significant feedback to debt, suggesting that there might not be an equilibrium level of debt–GDP. This is not surprising, since different countries do maintain very different debt–GDP ratios. It is also consistent with the idea emphasised by Bohn (2007, 2016) that solvency of government debt depends on the government’s ability to refinance it by assuring the lenders that its fiscal policy is sustainable. Inclusion of additional macroeconomic variables, such as GDP growth, long-term interest rate and inflation rate, does not substantially alter these results. Moreover, there seems to be more pressure to adjust on countries running deficits versus those running surpluses. Finally the paper discusses the twin-deficits hypothesis that links balance of payments and fiscal sustainability together. Nonetheless, the results presented here show no evidence of such cross-deficit adjustment.

While the true solvency condition might be of an economic nature, depending on expectations, the statistical analysis of fiscal adjustment is still of some interest, particularly in the light of the effects of the 2020 pandemic. Hence, this paper analyses the long-run statistical properties of the public sector surplus (deficit) and debt.

Section 2 reviews the literature. The data are discussed in Section 3. Section 4 describes the basic theory and the empirical model. The pooled estimates are discussed in Section 5, and the country-specific estimates are presented in Section 6. Asymmetric adjustment is covered in Section 7. Section 8 contains some concluding comments.

2. Literature review

A large portion of the literature on fiscal sustainability is concerned with the contribution of the primary deficit, the growth-interest rate differential and stock-flow adjustment to changes in the debt–GDP ratio. In contrast, the main question addressed in this paper is whether fiscal budget adjusts to debt and deficits. The data used in this paper are on the total, rather than primary, surplus.

There is no consensus on how dangerous large government deficits and debts are. On one side, increase in government expenditure and taxes often have a crowding out effect on investment (Mountford and Uhlig, 2009). In most extreme cases, expectation of increase in interest rates and inflation rate may lead to capital flight and depreciation which might end with a crisis (Boskin, 2020). Meanwhile, Smith (2020), also using the JST data set, found that it is the change in debt–GDP ratio, not necessarily the level of debt, that has a small but significant positive effect on the nominal long interest rate. Chudik et al. (2017) emphasised that the government’s refinancing opportunities largely depend on its ability to assure potential lenders that any noticeable rises in debt–GDP ratio are of temporary nature. In contrast, Mountford and Uhlig (2009) argued that, contrary to the traditional view, deficit spending does not seem to cause increase in interest rates or in the real wages.

Hence, there are some who argue that large debt and deficit are sources of major economic uncertainties and likely to lead to higher taxes, lower income and raise in intergenerational inequality in the future (Boskin, 2020; Uhlig, 2013). While others suggest that expansionary fiscal policy and tax smoothing might provide a useful boost to the economy, especially in time of a recession (Mountford and Uhlig, 2009; Blanchard, 2019).

There are many factors that affect fiscal sustainability. For instance, Cochrane (2019) found that market value of debt and hence refinancing opportunities, depend on predictability of future primary surpluses and variation in discount rates, while effect of future growth rate is insignificant. On the contrary, Bohn (2005) found that the nominal growth term has historically covered the entire interest bill on the US debt and kept the debt–GDP bounded. Bohn (1998) also argued that as long as interest rate is near or below the GDP growth rate, then debt can be kept bounded by adjusting fiscal policy (Bohn, 1998). He claimed that the most credible evidence of government debt solvency is a positive response coefficient of primary surplus to increase in debt–GDP ratio. In addition, Bohn et al. (2016) claimed that the level of debt–GDP a government can maintain depends on its credibility. Hence, there might not be a natural equilibrium level of debt, and debt ceiling in fact depends on economic costs of servicing debt and political acceptability (Wyplosz et al., 2007; Chudik et al., 2017). In that sense, debt distress can be a self-fulfilling process.

There are many ways to analyse fiscal sustainability. Arnone et al. (2005) and Wyplosz et al. (2007) critically reviewed different approaches on the analysis of solvency. This paper adopts Bohn’s (2005, 2007) empirical approach to the analysis of fiscal sustainability. There is strong support for his theoretical framework in the literature (Schoder, 2014; Greiner et al., 2007). Schoder (2014) found evidence of fiscal sustainability for eight out of 15 countries, although in the long run only. Meanwhile, Greiner et al. (2007) confirmed sustainability for four out of five OECD countries they considered, but in case of Germany the responsiveness of fiscal policy to accumulation of debt seems to have been decreasing since 1980s.

An alternative, or addition, to expenditure cuts and conventional taxes as a means of debt reduction is inflation, which works as a hidden tax on money balances when inflation rises above interest rates. Lerner (1955) argued that to avoid punishment by voters for the painful austerity involved in reducing deficits and debt, many democratic politicians opt for reducing real debt through the inflation tax. This form of financial repression proved effective in reducing post-World War-II debt burdens in many countries, including the United Kingdom and the United States, which kept their interest rates on fiscal debt below GDP growth rate (Mayer and Schnabl, 2021; Reinhart et al., 2011). With new record-high debts consequent on Covid-19, the question of whether inflation will be used to reduce debt is back on the table. But while inflation erodes the real value of government’s liabilities and can reduce fiscal deficit, there is the risk of that it may lead to persistent inflation (Bleaney, 2000).
In addition, financial crises can contribute to augmentation of debt and significant increases in deficits. Sufi and Taylor (2021) emphasise that the downturns after crises are greater than from a typical recession and at 6 year horizon, real GDP per capita is lower by about 4% after the crisis when aligning event using business cycle peaks as in Jordà et al. (2013). Sufi and Taylor (2021) also emphasise that crises are quite common and in the JST data advanced economies have experienced roughly fifty peacetime recessions since 1870 associated with financial crises. Financial crises are substantially more common than wars and pandemics, and can hit the economy hard. Sufi and Taylor (2021) survey the literature on financial crises which indicates that financial crises cause a sharp decline in real economic activity irrespective of the technique used to measure such an effect. While the historical evidence does not suggest that a cyclical rise in government debt–GDP ratios predict a subsequent decline in economic growth, the danger of high debt is that it can limit government ability to make direct fiscal interventions when needed, such as for Covid-19, and can limit its ability to do what is necessary to repair a damaged financial sector if such necessity arises.

Building on the rich literature, this paper presents a version of Bohn’s (2005, 2007) model that allows for feedback from both, debt and surplus (deficit). The analysis uses a long-span large panel of data, which has the advantage of providing evidence on the effect of large fiscal shocks and of fiscal sustainability in response to them.

3. Data

The analysis in this paper uses data for a sample of 17 OECD countries for 1870–2016 from the Jordà–Schularick–Taylor (JST) Macrohistory Database. The sample includes Australia, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the UK and US. The highest jumps in debt–GDP ratios over 1870–2016 were recorded in the UK, Japan and France (Figs. 1 and 2). In case of France it was after the end of World War I, in the UK — in the 1940s, while Japan has been running high debt–GDP ratio since 1990s. In contrast, Sweden and Switzerland maintained relatively low debt–GDP ratios over 1870–2016.

The JST dataset has a number of limitations. It uses official deficit and national debt measures, which differ across countries, and do not fully account for inflation or intangible investments in R&D and education (Boskin, 2020). Nonetheless, these measures are simple and widely used in the literature on fiscal sustainability. While the fact that the JST dataset covers nearly 150 years of data provides a lot of variation in debt and deficit, the use of long-span heterogeneous panels comes with measurement issues, such as data sources and definitions vary among countries and across estimation periods. There are some missing values in the dataset, which restrict estimations for some countries and sub-periods. For instance, Finland’s data for debt–GDP are missing for 1870–1913 and for revenue and expenditure—from 1870 to 1881. Hence, there is an insufficient number of observations to estimate equations for Finland for the first sub-period, 1870–1914. Other data gaps are less wide and mostly include years for World War I and World War II.

Descriptive statistics for the four focus variables, revenue, expenditure, surplus and debt, are presented in Table 1. In the JST database revenue, expenditure and surplus are given in nominal terms and local currency, while debt is a ratio of GDP. In Table 1, all variables are expressed as shares of GDP to allow for comparison among the countries (nominal GDP in local currency from the JST dataset was used to calculate shares of revenue, expenditure, surplus).

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The data that support the findings of this study come from Jordà, Ò. Schularick, M., and Taylor, A. M. (2017). Macrofinancial History and the New Business Cycle Facts. *NBER Macroeconomics Annual*, 31(1): 213–263, edited by M. Eichenbaum and J. A. Parker. These data are openly available at [http://www.macrohistory.net/data](http://www.macrohistory.net/data).
Most countries, 12 out of 17, run an average deficit, while fiscal balances of Germany, Japan, Switzerland and the UK, averaged zero, and Norway had an average surplus. It appears that most countries, including France, the UK and US, have periods of exceptionally high government surpluses followed by periods of running large deficits. However, some countries, such as Switzerland, Portugal and Spain, maintain more or less stable government revenue and spending.

4. Modelling

The analysis of fiscal sustainability in this paper follows Bohn’s (2005) proposal to model surplus-GDP ratio as a linear function of the debt–GDP ratio to check whether response coefficient is positive. The budget identity links the deficit to revenue, spending and public debt:

\[ DEF_t = E_t^i - R_t + i_t B_{t-1}. \]  

(1)

where \( DEF_t \) is the fiscal or total deficit (with-interest deficit) in year \( t \), \( E_t^i \) is non-interest spending (then \( E_t \) is the total expenditure), \( R_t \) is the government revenue, \( B_{t-1} \) is the debt at the end of year \( t - 1 \) (all in nominal terms) and \( i_t \) is the interest charge.

The second budget identity is:

\[ DEF_t = B_t - B_{t-1}. \]  

(2)

Table 1
Descriptive Statistics (Shares of GDP; 1870–2016).

| Country   | Revenue Mean | Revenue SD | Revenue Max | Revenue Min | Expenditure Mean | Expenditure SD | Expenditure Max | Expenditure Min | Surplus Mean | Surplus SD | Surplus Max | Surplus Min | Debt Mean | Debt SD | Debt Max | Debt Min |
|-----------|--------------|------------|-------------|-------------|------------------|----------------|----------------|----------------|--------------|-----------|------------|------------|-----------|---------|---------|---------|---------|
| Australia | 0.17         | 0.08       | 0.29        | 0.04        | 0.20             | 0.10           | 0.46           | 0.01           | -0.03        | 0.05      | 0.03       | -0.32      | 0.40      | 0.21    | 0.98    | 0.10    |
| Belgium   | 0.18         | 0.09       | 0.32        | 0.04        | 0.22             | 0.11           | 0.43           | 0.05           | -0.04        | 0.04      | 0.02       | -0.25      | 0.71      | 0.35    | 1.41    | 0.13    |
| Canada    | 0.12         | 0.06       | 0.25        | 0.04        | 0.14             | 0.08           | 0.45           | 0.04           | -0.02        | 0.04      | 0.04       | -0.22      | 0.63      | 0.28    | 1.55    | 0.18    |
| Denmark   | 0.19         | 0.14       | 0.42        | 0.04        | 0.19             | 0.14           | 0.44           | 0.05           | -0.01        | 0.02      | 0.05       | -0.10      | 0.27      | 0.18    | 0.72    | 0.04    |
| Finland   | 0.18         | 0.07       | 0.30        | 0.06        | 0.21             | 0.10           | 0.58           | 0.06           | -0.03        | 0.06      | 0.04       | -0.37      | 0.25      | 0.18    | 0.71    | 0.06    |
| France    | 0.17         | 0.05       | 0.25        | 0.07        | 0.21             | 0.09           | 0.63           | 0.10           | -0.04        | 0.08      | 0.05       | -0.52      | 0.76      | 0.50    | 2.37    | 0.14    |
| Germany   | 0.10         | 0.06       | 0.60        | 0.03        | 0.10             | 0.05           | 0.32           | 0.03           | 0.00         | 0.02      | 0.06       | -0.12      | 0.42      | 0.23    | 1.74    | 0.15    |
| Italy     | 0.18         | 0.06       | 0.33        | 0.08        | 0.23             | 0.10           | 0.44           | 0.10           | -0.05        | 0.07      | 0.02       | -0.36      | 0.86      | 0.32    | 1.54    | 0.25    |
| Japan     | 0.13         | 0.03       | 0.28        | 0.07        | 0.13             | 0.04           | 0.27           | 0.06           | 0.00         | 0.03      | 0.06       | -0.08      | 0.61      | 0.59    | 2.39    | 0.04    |
| Netherlands| 0.20        | 0.09       | 0.46        | 0.09        | 0.22             | 0.12           | 1.06           | 0.09           | -0.02        | 0.07      | 0.09       | -0.75      | 0.79      | 0.29    | 2.23    | 0.38    |
| Norway    | 0.21         | 0.16       | 0.53        | 0.02        | 0.20             | 0.13           | 0.41           | 0.03           | 0.01         | 0.05      | 0.20       | -0.05      | 0.28      | 0.09    | 0.53    | 0.10    |
| Portugal  | 0.11         | 0.06       | 0.25        | 0.04        | 0.13             | 0.08           | 0.29           | 0.04           | -0.02        | 0.03      | 0.01       | -0.09      | 0.51      | 0.25    | 1.30    | 0.13    |
| Spain     | 0.12         | 0.04       | 0.21        | 0.06        | 0.13             | 0.05           | 0.26           | 0.08           | -0.01        | 0.02      | 0.02       | -0.09      | 0.60      | 0.30    | 1.52    | 0.13    |
| Sweden    | 0.16         | 0.10       | 0.42        | 0.06        | 0.18             | 0.11           | 0.44           | 0.05           | -0.02        | 0.03      | 0.07       | -0.14      | 0.28      | 0.16    | 0.73    | 0.09    |
| Switzerland| 0.06        | 0.04       | 0.13        | 0.01        | 0.06             | 0.04           | 0.19           | 0.01           | 0.00         | 0.02      | 0.02       | -0.08      | 0.32      | 0.21    | 0.87    | 0.02    |
| UK        | 0.24         | 0.13       | 0.44        | 0.06        | 0.25             | 0.15           | 0.64           | 0.06           | 0.00         | 0.10      | 0.13       | -0.45      | 0.90      | 0.60    | 2.70    | 0.27    |
| US        | 0.10         | 0.07       | 0.20        | 0.02        | 0.12             | 0.09           | 0.41           | 0.01           | -0.02        | 0.04      | 0.04       | -0.27      | 0.40      | 0.29    | 1.19    | 0.02    |

Notes:

*a* standard deviation.

*b* maximum.

*c* minimum.

Fig. 2. Debt to GDP ratios (Sub-Sample 2, 1870–2016).
In order to separate the stock of debt, $B_t$, from the flows of government expenditures and revenues, it is useful to define the primary deficit, $DEFI_t^0$, as the non-interest spending minus revenue ($DEFI_t^0 = E_t^0 - R_t$). Then by putting (1) and (2) together, the nominal budget equation can be defined as:

$$B_t = E_t^0 - R_t + (1 + i_t)B_{t-1} = DEFI_t^0 + (1 + i_t)B_{t-1}. \quad (3)$$

Then the GDP-ratio version of the (3) is:

$$\frac{B_t}{Y_t} = \frac{DEFI_t^0}{Y_t} + \left(\frac{1 + i_t}{1 + \gamma_t}\right)\frac{B_{t-1}}{Y_{t-1}}, \quad (4)$$

where $\gamma_t = \left(\frac{Y_t}{Y_{t-1}} - 1\right)$ is nominal GDP growth rate. The first right hand side (RHS) term is the primary deficit, and the second RHS term is the previous period’s debt multiplied by a propagation factor.

As Bohn (2005) noted, both the nominal equation, (3), and the corresponding GDP-ratio version of it, (4), express period-t debt as the sum of a flow variable (the primary deficit) and a stock variable (debt from the previous period multiplied by a propagation factor). Bohn (2005) then derived an equation for a ‘generic’ (scaled) version of debt, $b_t$ (which can be expressed in nominal terms, $B_t$, or as a ratio, $B_t/Y_t$, if needed). If the corresponding version of the primary surplus is $s_t$ ($s_t = -DEFI_t^0$ or $s_t = -DEFI_t^0/Y_t$) and $r_t$ is the “return” on debt ($r_t = i_t$ in the nominal equation or $r_t \approx i_t - \gamma_t$ in the GDP-ratio version), then we can describe the dynamics of public debt as:

$$b_t = (1 + r_t)b_{t-1} - s_t, \quad (5)$$

Bohn (2005) emphasised that, as follows from (5), if one uses the appropriate propagation factor, budget accounting is scale-invariant. From (5), fiscal decisions that affect tax and spending have impact on debt accumulation through their effect on primary deficit (surplus) and interest rate, $r_t$.

One of the influential papers on the topic, Trehan and Walsh (1991), confirmed presence of cointegration between debt and primary surpluses. Building on this result, Bohn (2005) emphasised that it implies a strictly positive linkage between the two. Hence, Bohn (2005, 2007) proposed to model the relationship between primary surplus and debt-GDP using an error-correction-type policy reaction function, and he proved that this approach does not require stationarity driving processes.

Bohn (2007) presents the sufficient condition as an error-correction relationship between surplus-GDP ratio, $s_t$, and lagged debt-GDP ratio, $b_{t-1}$:

$$(s_t - a b_{t-1}) = z_t \sim I(m), \quad (6)$$

for some $a \in (0, 1 + r_t)$, and where $z_t$ is of any order of integration.

Hence, if surplus-GDP ratio is a positive linear function of debt–GDP ratio, then it suggests that a government takes adjusting actions in response to accumulation of debt. In this case the debt–GDP ratio remains bounded, and fiscal policy can be considered sustainable.

In this paper an augmented version of (6) is used allowing for feedback not only from the previous debt–GDP ratio, but also from the lagged surplus (deficits). The JST data for debt come as a ratio of GDP, while surplus is calculated using nominal revenue and expenditure. The following model is estimated for surplus:

$$\Delta S_{it} = a^i + \beta_i S_{it-1} + \gamma^i lnb_{it-1} + \epsilon_{it}^i, \quad (7)$$

where $S_{it} = \ln R_{it} - \ln E_{it}$ ($R_{it}$ is the revenue and $E_{it}$ is the total expenditure in nominal values, local currency), hence $S_{it}$ is the log of a ratio, meaning scale invariant; and $lnb_{it}$ is the log of debt-to-GDP ratio. The coefficients $\beta_i$ and $\gamma^i$ in (7) measure feedbacks from previous surplus and debt, respectively.

Eq. (5) is an accounting identity, the government budget constraint, and it is in levels (not logarithms), though it can be scaled by GDP if needed. Here we are aiming to estimate an equation describing government behaviour, where the government is responding proportionately to changes in flows of debt (deficits/surpluses) and stock of debt (debt-GDP ratio), adjusting the growth rates of expenditure and revenue in a self-corrective manner, which is what determines the left-hand side, hence the use of logs.

As a robustness check, a more general version of (7), was estimated, including: lagged income, $Y_{it-1}$, to allow for the cyclical effects and the lagged expenditure, $E_{it-1}$, to allow for differential feedbacks from the surplus components (appendix, A). However, the coefficients on these variables were small, suggesting that the cyclical effects are minor and that the difference between revenue and expenditure is what matters, not their individual effects. Hence, the simpler model, (7), was used.

To allow for asymmetric adjustment between the components of the surplus, (7) was also split into the equation for revenue:

$$\Delta \ln R_{it} = a^r + \beta^r S_{it-1} + \gamma^r lnb_{it-1} + \epsilon_{it}^r, \quad (8)$$

and the equation for expenditure:

$$\Delta \ln E_{it} = a^x + \beta^x S_{it-1} + \gamma^x lnb_{it-1} + \epsilon_{it}^x. \quad (9)$$

A glossary with the description of the variables (including calculations and units of measure) is presented in the appendix, Table 7.
where \( \alpha' = \alpha' - \alpha \), \( \beta' = \beta' - \beta \) and \( \gamma' = \gamma' - \gamma \). Here \( \ln R_t \) and \( \ln E_t \) are logs of the nominal revenue and expenditure (local currency), correspondingly, \( \ln b_{t-1} \) is the log of debt–GDP ratio and \( S_t = \ln R_t - \ln E_t \) as in (7).

There is evidence of fiscal sustainability if in (7) \( \beta' < 0 \) and \( \gamma' > 0 \), as these signs of the coefficients would suggest that a government increases current surplus (by increasing revenue or decreasing expenditure) to balance out deficits and meet increasing debt payments. It follows that in (8) the expected signs are \( \beta' < 0 \) and \( \gamma' > 0 \), and in (9), \( \beta' > 0 \) and \( \gamma' < 0 \).

In addition, we consider a possibility that the response of government revenue and expenditure to fiscal deficit is non-linear. Reinhart and Rogoff (2010) suggest there is a negative effect on economic growth once a country’s level of debt exceeds 90% of GDP. Cecchetti et al. (2011) also found there to be a threshold for debt–GDP ratio after which its adverse effect on economic growth becomes stronger. Their estimate for a panel of 18 OECD countries for a period of 1980–2010 came to 86% debt–GDP.

To see if the relationships between revenue and deficit and expenditure and deficit are in fact non-linear, we approximate the non-linearity by a quadratic and add \( S_{t-1}^2, \ln b_{t-1}^2 \) and \( S_{t-1} \times \ln b_{t-1} \) to the pooled regressions for (8) and (9) and estimate the following equations for revenue and expenditure:

\[
\Delta \ln R_t = \alpha' + \beta'S_{t-1} + \gamma' \ln b_{t-1} + \nu' S_{t-1}^2 + \mu' \ln b_{t-1}^2 + \rho' \ln R_{t-1} + \epsilon_t.
\]

(10)

\[
\Delta \ln E_t = \alpha' + \beta'S_{t-1} + \gamma' \ln b_{t-1} + \nu' S_{t-1}^2 + \mu' \ln b_{t-1}^2 + \rho' \ln E_{t-1} + \epsilon_t.
\]

(11)

In line with (8) and (9) we also estimate a similar equation for inflation to analyse the role of inflation tax in reducing deficit and debt. To calculate inflation we use consumer price index which is also available from the JST data set. Hence, we estimate the following equation for inflation for pooled data with country fixed effects:

\[
\Delta \pi_t = \alpha' + \beta' S_{t-1} + \gamma' \ln b_{t-1} + \nu' S_{t-1}^2 + \mu' \ln b_{t-1}^2 + \epsilon_t.
\]

(12)

where \( \pi = \ln (CPI_t) - \ln (CPI_{t-1}) \) and CPI is consumer prices (index, 1990=100).

The variables are trend-stationary for some countries and difference-stationary for others (the Augmented Dickey–Fuller unit root test results are presented in the appendix, Table 5). It does not raise an issue since here we analyse fiscal sustainability by simply checking whether the government is responding proportionately to changes in deficits (surpluses) and debt–GDP in self-corrective way or it does not.

As a further robustness check two augmented models, variations of (7), are estimated that include additional key macroeconomic variables, nominal GDP growth, \( g_{it} \), long-term interest rate, \( r_{it} \), and inflation, \( \pi_{it} \). Here \( g_{it} \) is the growth rate calculated using nominal GDP in local currency, \( r_{it} \) is the nominal long-term interest rate expressed as percent per year, and inflation, \( \pi_{it} \), is calculated using consumer prices index (1990=100). All data for these three variables and their calculations also come from the JST database (appendix, Table 7).

Two versions of the extended model are considered, the log one and the level (ratios) version. The log version uses surplus and debt–GDP as in the main model for surplus, (7), but includes three additional variables mentioned above. The log version is:

\[
\Delta S_t = a + \beta' S_{t-1} + \gamma' \ln b_{t-1} + \mu' g_{it} + \nu' r_{it} + \eta' \pi_{it} + \epsilon_{2t}.
\]

(13)

For the log version, (13), income growth, long-term interest rate and inflation rate are already in proportionate form, hence, there is no need to take logarithmic transformations of these three variables. However, in contrast to (7) the level version of the extended model uses both surplus and debt expressed as shares of GDP to see if it significantly alters the feedback coming from flows and stock of debt. The level version is:

\[
\Delta S_t = a + \beta' S_{t-1} + \gamma' b_{t-1} + \mu' g_{it} + \nu' r_{it} + \eta' \pi_{it} + \epsilon_{1t}.
\]

(14)

In addition, government surplus adjustment might be linked to the adjustment of the balance of payments. There is a theory, known as the twin-deficit hypothesis, which suggests that fiscal shocks that have negative effect on the government budget also deteriorate the current account (Corsetti and Müller, 2006). Hence, the last part of the analysis considers whether fiscal sustainability and balance of payments solvency are related.

The identity that links the balance of payments, \( BOT_{it} \), and government surplus, \( S_{it} \), together can be derived from the GDP equation by subtracting the government revenue, \( R \), from both sides and rearranging the terms to get:

\[
(Y_t - R_t - C_t) - I_t = (E_t - R_t) + (X_t - M_t).
\]

(15)

where \( Y_t \) is GDP, \( C_t \) is consumption, \( I_t \) is investment, \( E_t \) is government expenditure, \( X_t \) is exports, \( M_t \) is imports and, by definition, \( (Y_t - R_t - C_t) \) equals private savings, \( PS_{it} \).

Then from (15) it follows that the net private savings, government surplus and current account (balance of trade) deficit sum to zero. From empirical side, to analyse the link between balance of payments and fiscal sustainability, the following equations for the government surplus:

\[
\Delta S_{it} = a_{10} + a_{11} S_{it-1} + a_{12} BOT_{it-1} + \nu_{1t},
\]

(16)

and for the balance of trade:

\[
\Delta BOT_{it} = a_{20} + a_{21} S_{it-1} + a_{22} BOT_{it-1} + \nu_{2t},
\]

(17)
are estimated, where $BOT_{it} = \ln X_{it} - \ln M_{it}$ ($X_{it}$ are exports and $M_{it}$ are imports), and $a_{12}$ and $a_{21}$ measure cross-surplus adjustments.

In addition, episodes of very large fiscal deficits are often associated with wartime spending and this in turn can lead to more severe trade deficits. Since our estimation period covers two world wars and numerous other military conflicts, we create a dummy variable, $DW$, to account for when a country was at war. To do that we use the Correlates of War dataset which includes both, inter-state and intra-state war data for 1816–2007 for all countries in our sample. Hence, a dummy variable for war, $DW$, takes value of one for years of financial turmoil and zero otherwise. Hence, we estimate the following equations:

$$\Delta S_{it} = a_{10} + a_{11} S_{it-1} + a_{12} B(O_{it-1} + a_{13}(S_{it-1} \ast DW_{it}) + \nu_{it},$$

(18)

$$\Delta B(O)_{it} = a_{20} + a_{21} S_{it-1} + a_{22} B(O)_{it-1} + a_{23}(S_{it-1} \ast DW_{it}) + \nu_{2it}.$$  

(19)

The residuals for surplus equation, (7), suggests that many cases of high deficits and debt are recorded during financial turmoil. Hence, we use a dummy variable for crisis which is also available from the JST dataset to further analyse debt and deficits. We augment equations for surplus, (7), revenue, (8), expenditure, (9), and inflation, (12), with a dummy variable for war, $DW$, and crisis, $DC$, as well as their lagged versions, $DW_{it-1}$ and $DC_{it-1}$. $DC_{it}$ is a crisisjst variable from the JST dataset for systemic financial crises, which takes value of one for years of financial turmoil and zero otherwise. Hence, we estimate the following equations:

$$\Delta S_{it} = a^x + b^x S_{it-1} + \gamma^x \ln b_{it-1} + e^x DW_{it} + \kappa^x DW_{it-1} + \mu^x DC_{it-1} + \nu^x DC_{it-1} + \epsilon^x_{it},$$

(20)

$$\Delta \ln R_{it} = a^r + b^r S_{it-1} + \gamma^r \ln b_{it-1} + e^r DW_{it} + \kappa^r DW_{it-1} + \mu^r DC_{it-1} + \nu^r DC_{it-1} + \epsilon^r_{it},$$

(21)

$$\Delta \ln E_{it} = a^e + b^e S_{it-1} + \gamma^e \ln b_{it-1} + e^e DW_{it} + \kappa^e DW_{it-1} + \mu^e DC_{it-1} + \nu^e DC_{it-1} + \epsilon^e_{it},$$

(22)

$$\Delta \pi_{it} = a^\pi + b^\pi S_{it-1} + \gamma^\pi \ln b_{it-1} + \epsilon^\pi DW_{it} + \kappa^\pi DW_{it-1} + \mu^\pi DC_{it-1} + \nu^\pi DC_{it-1} + \epsilon^\pi_{it},$$

(23)

Finally, it is possible that when a government is running a deficit it may be under more pressure to adjust it than when the government is running a surplus. The analysis for asymmetric adjustment is performed by checking whether surplus responds differently to lagged surplus and previous deficit. Hence, a new variable $\Delta defpos_{it}$ is created, which is a product of the dummy defdum (that equals one when surplus is negative and zero otherwise) and $S_{it}$. Then $\Delta defpos_{it}$ is added to (7):

$$\Delta S_{it} = a + b S_{it-1} + \gamma \ln b_{it-1} + \mu \Delta defpos_{it-1} + \epsilon_{it},$$

(24)

If the coefficient of this new variable, $\Delta defpos_{it-1}$, is significant, then the government adjusts its budget to the lagged deficit differently than to the lagged surplus, suggesting that there is evidence of asymmetric adjustment.

5. Pooled estimations

Starting from the surplus equation, the estimates (standard errors) for (7) using pooled data with country fixed effects are:

$$\Delta S_{it} = -0.007 - 0.191 S_{it-1} + 0.014 \ln b_{it-1} + \epsilon_{it}, \quad R^2 = 0.107, \quad SER = 0.128$$

It appears that the fiscal surplus (deficit) significantly adjusts in a stabilising way to lagged surplus and debt. The lagged surplus coefficient suggests that if previous surplus increases by 1%, the government tends to decrease the current surplus by 0.19%. The coefficient of the lagged debt–GDP ratio is small and suggests that as debt–GDP increases by one 1%, the government raises the surplus by 0.01% perhaps to meet increasing interest payments on debt.

The residuals from the surplus equations were examined to identify outliers, which were mainly associated with wars and economic crises. The largest outliers are for Germany in the inter-war period, with the hyperinflation of 1923, and when German deficits and debt were at their historic highs. There are spikes in the residuals for Australia in early 1930s when it defaulted on its domestic debt and in 1992 which coincides with early 1990s recession when Australian GDP fell by 1.7% and the unemployment rate rose to 10.8%. Another outlier is for Belgium where debt rose from under 50% of GDP in 1979 to over 100% of GDP in 1982 during the 1980–82 recession that shook the Belgium economy to the core. The outlier for Spain occurred around early 1930s, time of the Revolution when Primo de Rivera was forced to resign. In addition, there is an outlier for the US in 1972, associated with the Nixon Shock of 1971, which ended Bretton Woods. There are also spikes in residuals during the interwar period and in the years following the World War II for many countries in the sample.

The fixed effects estimates for the components of surplus, revenue, (8), and expenditure, (9) are:

$$\Delta \ln R_{it} = 0.031 - 0.195 S_{it-1} - 0.024 \ln b_{it-1} + \epsilon_{it}, \quad R^2 = 0.141, \quad SER = 0.116$$

(0.004) (0.011) (0.004)

$$\Delta \ln E_{it} = 0.037 - 0.004 S_{it-1} - 0.038 \ln b_{it-1} + \epsilon_{it}, \quad R^2 = 0.040, \quad SER = 0.150$$

(0.006) (0.015) (0.005)
While the coefficients on the surplus equation were as expected for stabilising behaviour, the effect of surplus on expenditure has the wrong, though insignificant, sign, as does the coefficient of debt on revenue. The stabilising effects are of surplus on revenue and debt on expenditure. Hence, the net behaviour shows stabilisation.

When we estimate a non-linear equation for revenue, (10), for fixed cross-country effects pooled data, all coefficients are significant at 1% significance level (appendix, C). However, the coefficients of lagged surplus and debt as well as lagged debt squared are negative. We get the sign we would expect for lagged surplus, but not for coefficients of debt. As for estimates for expenditure equation, (11), all coefficients are significant but the lagged debt squared coefficient is significant at 5%, and the product of lagged surplus and debt is only significant at 10% level. Therefore, the results of the non-linear model are difficult to give an economic interpretation to, and it is unlikely to be a case of a simple threshold effect. However, this may be worth investigating in the future research.

In addition, estimation of the equation for inflation, (12), yielded the following results:

\[
\Delta \pi_t = 0.708 + 1.711 S_{t-1} + 0.538 \ln b_{t-1} + \epsilon_t, \quad R^2 = 0.004
\]

\[
S_E = 8.706
\]

The coefficient of lagged surplus is just significant at 5% level, but that of lagged debt only at 10%. Overall, it seems there is a positive relationship between lagged debt coefficients and inflation growth which provides some support that increasing debt can be partially financed through inflation. However, neither coefficient is significant for any of the countries when considering heterogeneous estimates. Thus while inflation may on occasion be a response to high debts and deficits it does not seem a systematic pattern.

Overall, pooled fixed-effect estimations suggest that governments tend to correct deficits by adjusting revenues. Mountford and Uhlig (2009) claimed that deficit-financed tax cuts do indeed have better effect on growth than alternative fiscal policy tools, such as deficit-spending or balanced budget spending expansion, and are less costly. Mountford and Uhlig (2009), however, calculated that a 2% government spending increase would eventually translate into an over 2% increase in taxes and more than 7% decrease in GDP. Hence, they concluded that the long-run costs of the deficit-financed expansionary fiscal policy were likely to outweigh the benefits of its initial stimulating effect on the economy.

As for the extended models that include GDP growth, \(g_{it}\), long-term interest rate, \(lr_{it}\), and inflation, \(\pi_{it}\), the level version, (14), is closer to the theory, but the log version, (13), fits the data better (appendix, D). The GDP growth rate has a positive effect on the change in surplus, while increase in inflation rate reduces the change in surplus. When the data for 17 countries are pooled together, there is a significant feedback coming from surplus and debt–GDP ratio in both, level and log versions. When considering heterogeneous estimates over the whole period deficits mostly adjust themselves, but surplus is stabilising on debt only in case of four countries in the level version, (14), and for two countries in the log version, (13). Overall, there does not seem to be a natural equilibrium level of debt. Moreover, use of surplus expressed as a ratio of GDP (as in (14)) also does not alter results in terms of significance of the feedback coming from the lagged surplus (deficit) and lagged debt–GDP.

Estimates for the mutual adjustment of fiscal balance and balance of trade (Eqs. (16) and (17)) provide little empirical support for the twin-deficit hypothesis. Both, pooled (appendix, E) and heterogeneous (appendix, Table 6) estimates, suggest very little cross-surplus adjustment. The coefficients that measure cross-surplus effects are mostly insignificant. For instance, for (16), \(a_{12}\), coefficient, which measures the effect of an increase in the balance of trade on the government surplus, is only significant in six countries and only in three has the expected negative sign. As for Eq. (17), the effect of government surplus on the balance of trade, \(a_{21}\), is significant in seven countries and has the expected negative sign in two of them. Hence, there does not appear to be much evidence in support of the twin-deficit adjustment.

Moreover, it appears surplus and its components as well as inflation are strongly influenced by wartime spending and financial turmoil that often lead to higher spending, lower revenues and spikes in inflation, which ultimately leads to higher deficits and increase stock of debt. When we estimate (18) and (19) to analyse the effect of wartime spending on deficits, the dummy variable is significant in both cases although in (18) the coefficient that measures a twin-deficit adjustment is still insignificant and has the wrong sign (appendix, F). Hence, there is evidence that large fiscal deficits are associated with wartime spending, but the link between government budget and balance of trade is much weaker during time of smaller fiscal deficits.

When we consider (20), (21), (22) and (23), lagged war and crisis dummy are significant for surplus and revenue (in case of revenue, current values of dummy variables are significant as well), but only war has significant impact on expenditure and inflation is strongly affected by current war dummy variable (appendix, G). There are no obvious country-specific differences, but it is clear from surplus equation estimates that financial crises, to lesser extent than wartime spending, but nonetheless causes large deteriorations to economic activity. We also try to identify any country-specific characteristics using heterogeneous estimates for surplus and its components. For Germany, Finland, France, Italy and Japan estimates for 1915–1950 are insignificant but this is inter-war period, and there are quite a few observations missing for these countries. This in turn might have caused, for instance, estimates for surplus for the whole period, 1870–2016, for Japan and for revenue and expenditure for Germany to also be insignificant.

6. Country-specific estimates

The fixed effect estimates on the pooled data assume that, apart from the intercept, the parameters are the same in each country and are constant over time. In this section these assumptions are relaxed. We estimate country-specific models for surplus, (7), for revenue, (8), and for expenditure, (9) for the whole period and then for three sub-periods: 1870–1914, 1915–1950 and 1951–2016.
suggest corrective actions by a government are:

estimates for (7), for 1870–2016 and three sub-periods are summarised in Table 2. In the surplus equation, (7), signs that would

6.1. Surplus

The data are split roughly around the major historical breaks: World War I and World War II. Hence, first sub-period is a pre-World War I period, third one is a post-World War II period, while second sub-period encompasses highly disturbed time with two world wars and depression in-between. This split gives three sub-periods of roughly equal sizes with sufficient data points in each sub-period. Finland is the only country for which there is an insufficient number of observations for one of the periods (first sub-period, 1870–1914). All other estimates are presented and discussed below.

6.1. Surplus

Estimates for individual countries and sub-periods look quite different from the pooled fixed-effect results. The heterogeneous estimates for (7), for 1870–2016 and three sub-periods are summarised in Table 2. In the surplus equation, (7), signs that would suggest corrective actions by a government are: $\beta^s < 0$ and $\gamma^s > 0$.

Over the whole period only for Norway and the UK the surplus is stabilising on both, its lagged value and lagged debt–GDP, with both coefficients ({$\beta^s$ and $\gamma^s$}) being significant and having correct (expected) signs. For all countries, except Japan, surpluses ($\gamma^s$ coefficient is insignificant for all countries but these two.

Considering three sub-periods, there is an insufficient number of observations for Finland for the first sub-period, hence, the sample size for 1870–1914 is 16 not 17. In the first sub-period fiscal sustainability is confirmed for three countries, the Netherlands, Spain and Sweden. Overall, government budget is stabilising on lagged surplus for 12 out of 16 countries and on the lagged debt–GDP ratio for five economies.

There is also evidence of fiscal sustainability for two countries in the second and third sub-periods. There are no other countries for which lagged debt–GDP is significant for these two sub-periods. However, the deficits adjust themselves for 12 out of 17 countries in the second sub-period and in 14 for the third one.

Overall, heterogeneous estimates suggest that while deficits tend to adjust themselves, there is not much feedback coming from debt–GDP on current surplus.

6.2. Revenue

The equations for the components of surplus, revenue and expenditure, are also considered for each country individually. In the revenue model, (8), a stabilising process would imply $\beta^r < 0$ and $\gamma^r > 0$. The results are presented in Table 3.

Over the whole period, revenue responds to changes in surpluses for all but four countries (Denmark, Germany, Japan and Norway). However, debt does not stabilise for any of the countries, as all lagged debt–GDP coefficients for all countries are either insignificant or have the wrong sign.

For the first sub-period most coefficients are insignificant. Revenue adjusts in the right way to both, surplus and debt, for two out of 16 countries, Germany and Spain. but not on the lagged debt–GDP ratio.

Notes: Significant coefficients are in bold (5% level);

$t$-statistic; X - insufficient number of observations.
6.3. Expenditure

Finally, the expenditure model, (9), is estimated for each country over the whole period and three sub-periods (Table 4). The expected signs are $\beta^r > 0$ and $\gamma^r < 0$. The estimates for the whole period show that expenditure adjusts in the right way in response to changes in surplus and debt for three countries, namely Denmark, Norway and Spain. Overall, there is evidence of stabilisation for debt for nine countries and for surplus for five countries.

Heterogeneous estimates suggest that expenditure responds in the right way to surplus and debt for three countries in the first sub-period, for two economies in the second and for five countries in the third sub-period. Moreover, the lagged debt–GDP ratio is stabilising for 16 out of 17 countries in the third sub-period, although it does so only for five economies in the first sub-period and for four in the second one. Meanwhile, expenditure is adjusting correctly to surplus for seven countries in 1870–1914, for six economies in 1915–1950 and for five countries in 1951–2016.

Overall, it seems that the adjustment to the lagged surplus is mainly done through revenue and, when there is in fact an adjustment to the lagged debt–GDP, it is mainly done through expenditure.

7. Asymmetric adjustment

There might be more pressure on governments running deficits to adjust than on those running surpluses. Hence, to test for asymmetric adjustment (24) is estimated. The estimates for pooled data for the whole period are:
The adjustments in case of surplus versus deficit are significantly different. If a government is running a surplus ($S_{it-1} > 0$) then the speed of adjustment is 10%. However, if a government is running a deficit ($S_{it-1} < 0$), then the speed of adjustment is about twice higher, 20% (from $-0.101 + (-0.100)) = -0.201$. Hence, there is indeed evidence of asymmetric adjustment.

Nonetheless, there is little evidence of asymmetric adjustment if the estimation period is shortened or if the countries are considered individually. In fact if this model, (24), is estimated for the whole period for individual countries, it appears that the coefficient of $ldefpos_{it-1}$ is only significantly different from zero in Portugal. This might be majorly due to the fact that the data are noisy and the effect of this becomes substantially more apparent when we consider individual countries and shorter estimation periods. Overall, the conclusion that there is evidence of asymmetric adjustment is based on the pooled data estimations for the whole period.

8. Conclusion

This paper analyses fiscal sustainability for 17 countries for 1870–2016. Here the sustainability analysis is performed by estimating equations for surplus and its components, revenue and expenditure, to check whether the government is responding proportionately to changes in flows of debt (deficits/surpluses) and stock of debt (debt–GDP ratio) in a self-corrective way by adjusting the growth rates of expenditure and revenue.

Over the whole period with fixed cross-country effects, surplus is stabilising on its own lagged values and on debt–GDP. Deficits mainly adjust themselves through revenue, and the adjustment to the lagged debt–GDP is achieved through expenditure.

Meanwhile, heterogeneous estimates confirm stabilisation of deficits, but fiscal policy appears to be unresponsive to the accumulation of debt. This suggests that there does not seem to be an equilibrium level of debt, which is consistent with Bohn’s (2007, 2016) argument that any debt–GDP ratio can be sustainable as long as lenders believe that the government can meet its debt payments, in which case they continue to lend to it, effectively ensuring its solvency. This result is also consistent with the large variation in debt–GDP ratios we observe. For instance, a number of countries, including the UK and Japan, have had no difficulty borrowing even when their debt–GDP ratios were over 200%. Hence, the results of this paper suggest that the stabilising force lies at the level of the surplus (deficit) not at the level of debt.

However, Bohn’s (2007, 2016) argument also brings attention to the main issue with the empirical analysis of fiscal sustainability. Since solvency depends on the rational expectations, then it is a question of economic nature, meaning true condition for solvency cannot be tested empirically. This also means that it is difficult to make any forward-looking conclusions from the empirical analysis of fiscal sustainability as it is based on past trends and rational expectations that may change in the future. Hence, this paper approaches the question of fiscal sustainability by simply looking at the feedback processes and checking whether the government adjusts its spending and revenue to changes in flows and stock of debt in a self-corrective manner.

In addition, pooled data estimates suggest that, on average, the speed of adjustment for governments running budget deficits is about twice higher (20%) than for those running surpluses (10%). Hence, it appears there is evidence of asymmetric adjustment with there being significantly more pressure to adjust on governments running deficits versus those running surpluses.

Overall, there is strong evidence of fiscal sustainability when averaging over the whole sample and a sufficiently long estimation period. The adjustment of surplus to debt appears to be very slow, and there is less evidence of fiscal sustainability over shorter periods. The traditional economic theory suggest that fiscal sustainability is often achieved through the interest rate adjustments.

8. Appendix A. General model

To check what is the optimal functional form of (6), the following public sector equivalent of (6) was considered:

$$\Delta S_t = \mu + \lambda_1 S_{it-1} + \lambda_2 \ln b_{it-1} + \lambda_3 \ln E_{it-1} + \lambda_4 \ln Y_{it-1} + \epsilon_t,$$

(25)

where $S_t$ is the total surplus ($S_t = \ln R_{it} - \ln E_{it}$, where $R_{it}$ is the revenue and $E_{it}$ is the total expenditure), $\ln b_{it}$ is the debt–GDP ratio and $Y_{it-1}$ is GDP.

The coefficients $\lambda_1$ and $\lambda_2$ in (25) measure feedbacks from previous debt and surplus, respectively. The lagged income, $Y_{it-1}$, is included to allow for the cyclical effects and the lagged expenditure, $E_{it-1}$ is added to allow for differential effects of surplus components. If feedbacks from expenditure and revenue are similar, then $\lambda_1 = \lambda_2 \approx 0$, and if cyclical effects are small, then $\lambda_4 \approx 0$.

The pooled fixed effects estimates (standard errors) for (25) are:

$$\Delta S_t = 0.040 - 0.182 S_{it-1} + 0.008 \ln b_{it-1} + 0.018 \ln E_{it-1} - 0.020 \ln Y_{it-1} + \epsilon_t, \quad R^2 = 0.110$$

(0.016) (0.013) (0.005) (0.007) (0.007) $SER = 0.127$

Lagged income and expenditure coefficients are quite small, suggesting that the cyclical effects and individual effects of surplus components are minor, and it is the difference between expenditure and revenue is what might be of importance.
Table 5
Augmented Dickey–Fuller unit root test.

| Country   | Surplus Log (debt–GDP) | Log (debt–GDP) |
|-----------|-------------------------|----------------|
|           | p-value I(0) | p-value I(1) | p-value I(0) | p-value I(1) |
| Australia | 0.014         | 0.000         | 0.267        | 0.000         |
| Belgium   | 0.000         | 0.002         |             |               |
| Canada    | 0.001         | 0.316         |             |               |
| Denmark   | 0.007         | 0.641         |             |               |
| Finland   | 0.000         | 0.287         |             |               |
| France    | 0.000         | 0.292         |             |               |
| Germany   | 0.007         | 0.696         |             |               |
| Italy     | 0.540         | 0.439         |             |               |
| Japan     | 0.337         | 0.866         |             |               |
| Netherlands | 0.024     | 0.045         |             |               |
| Norway    | 0.078         | 0.230         |             |               |
| Portugal  | 0.151         | 0.843         |             |               |
| Spain     | 0.240         | 0.479         |             |               |
| Sweden    | 0.000         | 0.263         |             |               |
| Switzerland | 0.192     | 0.104         |             |               |
| UK        | 0.016         | 0.248         |             |               |
| US        | 0.000         | 0.706         |             |               |

Notes: Maximum lag length selection by the Schwarz Info Criterion.

Appendix B. Augmented Dickey–Fuller unit root test

See Table 5.

Appendix C. Non-linear models

When we estimate non-linear models for revenue, (10), and expenditure, (11), using pooled data for the whole period, we obtain the following results:

\[
\Delta \ln R_t = 0.025 - 0.079 S_{t-1} - 0.040 \ln b_{t-1} + 0.173 S^2_{t-1} - 0.007 \ln b^2_{t-1} + 0.043 (S_{t-1} \times \ln b_{t-1}) + \epsilon_t \quad R^2 = 0.180
\]
\[
RER = 0.019
\]

\[
\Delta \ln E_t = 0.033 + 0.065 S_{t-1} - 0.054 \ln b_{t-1} + 0.090 S^2_{t-1} - 0.007 \ln b^2_{t-1} + 0.036 (S_{t-1} \times \ln b_{t-1}) + \epsilon_t \quad R^2 = 0.050
\]
\[
RER = 0.025
\]

Appendix D. Extensions of the surplus model

The coefficients (standard errors) for the log version of the augmented model, (13), are:

\[
\Delta S_t = -0.013 - 0.199 S_{t-1} + 0.014 \ln b_{t-1} + 0.004 g_{t-1} + 0.001 I_{r-1} - 0.001 \hat{v}_t + \epsilon^2_t \quad R^2 = 0.128
\]
\[
RER = 0.012
\]

For the level version of the augmented model, (14), the coefficients (standard errors) are:

\[
\Delta s_t = -0.006 - 0.174 s_{t-1} + 0.006 h_{t-1} + 0.001 g_{t-1} + 0.000 I_{r-1} - 0.001 \hat{v}_t + \epsilon^1_t \quad R^2 = 0.109
\]
\[
RER = 0.014
\]

Appendix E. Cross-surplus effects

To see how balance of trade and government surplus adjust to each other, Eq. (16) is estimated for change in government surplus, \(\Delta S_{it}\), and Eq. (17) for change in the balance of trade, \(\Delta BOT_{it}\):

\[
\Delta S_{it} = -0.021 - 0.193 S_{t-1} - 0.003 BOT_{t-1} + v_{1t} \quad R^2 = 0.104
\]
\[
RER = 0.012
\]

\[
\Delta BOT_{it} = -0.015 + 0.066 S_{t-1} - 0.221 BOT_{t-1} + v_{2t} \quad R^2 = 0.116
\]
\[
RER = 0.013
\]

The equations were also estimated for 17 countries individually for 1870–2016. Both effects, own and cross-surplus, are expected to be negative. If an economy is running a balance of trade deficit, it wants to increase the government surplus. Meanwhile, if there is a balance of trade surplus, a government can choose an expansionary fiscal policy which leads to fiscal surplus going down, hence, the inverse relationship between balance of trade and government surpluses.
Table 6
Cross-surplus effects (Eqs. (16) and (17); 1870–2016).

| Country       | $S_{t-1}$ | $\Delta S_{t-1}$ | $\Delta BO T_{t-1}$ | $B O T_{t-1}$ | $\Delta S_{t-1}$ | $\Delta BO T_{t-1}$ |
|---------------|-----------|------------------|---------------------|--------------|------------------|---------------------|
|               | $a_{11}$  | $t$-stat.$^a$    | $a_{12}$            | $t$-stat.    | $a_{21}$         | $t$-stat.           |
| 17 countries  | -0.19     | -16.13           | 0.00                | -0.27        | 0.07             | 4.61                |
| Australia     | -0.11     | -3.56            | -0.05               | -0.53        | 0.12             | 2.77                |
| Belgium       | -0.43     | -6.25            | 0.00                | -0.03        | 0.17             | 1.87                |
| Canada        | -0.26     | -4.48            | -0.04               | -0.70        | 0.02             | 0.44                |
| Denmark       | -0.53     | -6.83            | 0.12                | 1.94         | 0.09             | 1.34                |
| Finland       | -0.33     | -4.79            | 0.01                | 0.15         | 0.05             | 0.68                |
| France        | -0.04     | -0.78            | -0.17               | -3.01        | 0.48             | 6.40                |
| Germany       | -0.23     | -3.38            | -0.03               | -0.62        | -0.23            | -1.63               |
| Italy         | -0.06     | -1.58            | -0.16               | -4.22        | 0.31             | 4.54                |
| Japan         | -0.07     | -2.08            | -0.01               | -0.22        | -0.16            | -2.45               |
| Netherlands   | -0.22     | -3.62            | -0.09               | -2.03        | -0.09            | -1.88               |
| Norway        | -0.31     | -5.95            | 0.13                | 4.68         | 0.01             | 0.18                |
| Portugal      | -0.20     | -4.11            | 0.01                | 0.19         | 0.10             | 1.46                |
| Spain         | -0.31     | -5.58            | 0.01                | 0.30         | 0.05             | 0.49                |
| Sweden        | -0.35     | -5.66            | 0.11                | 2.12         | -0.06            | 0.98                |
| Switzerland   | -0.19     | -3.49            | 0.16                | 2.23         | -0.08            | -2.38               |
| UK            | -0.14     | -2.58            | 0.03                | 0.39         | 0.13             | 2.56                |
| US            | -0.21     | -4.07            | 0.00                | 0.06         | -0.01            | -0.33               |
| Average       | -0.234    | 0.001            | 0.068               | -0.271       |

Note: the significant coefficients are in bold; $^a$t-statistic. Expected signs: all coefficients are expected to be negative.

Table 7
Variables and data (glossary).

| Variable     | Label | Description |
|--------------|-------|-------------|
| Revenue      | R     | Government revenue (nominal, local currency) |
| Expenditure  | E     | Government expenditure (nominal, local currency) |
| Debt−GDP     | b     | Public debt-to-GDP ratio |
| Surplus      | S     | Surplus as the log of a ratio [formula: $S = \ln R - \ln E$] |
| Surplus−GDP  | s     | Surplus-to-GDP ratio [formula: $s = (R - E)/Y$] |
| Long Interest Rate | lr | Long-term interest rate (nominal, percent per year) |
| Growth       | g     | Growth of GDP (calculated using GDP, $Y$) [formula: $g = 100 \times (\ln Y_t - \ln Y_{t-1})/T$] |
| GDP          | Y     | GDP (nominal, local currency) |
| Inflation    | z     | Inflation rate (calculated using CPI, $cpi$) [formula: $z = 100 \times (\ln cpi_t - \ln cpi_{t-1})$] |
| CPI          | cpi   | Consumer prices index (1990=100) |
| Balance of Trade | BOT | Balance of Trade (calculated using exports, $X$, and imports, $M$) [formula: $BOT = \ln X - \ln M$] |
| Exports      | X     | Exports (nominal, local currency) |
| Imports      | M     | Imports (nominal, local currency) |

Note: Data are from Jordà, Ò., Schularick, M., and Taylor, A. M., 2017. Macroeconomic and the New Business Cycle Facts. *NBER Macroeconomics Annual*, 31(1), 213-263, edited by M. Eichenbaum and J. A. Parker. These data are openly available at [http://www.macrohistory.net/data/](http://www.macrohistory.net/data/).

Appendix F. Wartime spending and deficits

When we estimate (18) and (19) to account for the military spending, we obtain the following estimates:

$$\Delta S_t = -0.025 - 0.318 S_{t-1} - 0.015 \ln b_{t-1} + 0.404 (S_t \ast DW_t) + \nu_{1t} \quad R^2 = 0.249 \quad SER = 0.121$$

$$\Delta BO T_t = -0.017 + 0.006 S_{t-1} - 0.226 \ln b_{t-1} + 0.195 (S_t \ast DW_t) + \nu_{2t} \quad R^2 = 0.139 \quad SER = 0.155$$

Appendix G. Financial turmoil, debt and deficit

When we analyse the effect of financial turmoil on deficits and debt and estimate (20), (21), (22) and (23), we obtain the following estimates for pooled data for the whole period:
Appendix H. Glossary

See Table 7.

Appendix I. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.jce.2021.12.003.

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