Public Debt Sustainability:
From roots to regressions

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Preface

Writing a thesis on public debt sustainability in times like these - with the financial and debt crisis troubling the world - has been an exciting and fascinating task. Essentially, it has meant paying attention to all kinds of public debt and budget or deficit news. Also, even almost exactly 300 years after its introduction, the concept of sustainability has lost none of its contemporary relevance. So the work on this topic is as alluring as ever.

Furthermore, I currently found out that an early personal connection, at least in a geographical sense, to sustainability arose - unconsciously! - from my high school exchange year in Glendale, Arizona, USA. Because as Ross (2011) recently pointed out, Phoenix metropolitan area, which includes Glendale, is a strong candidate for 'the world's least sustainable' region. Who would have known thirteen years ago that I would now write a thesis that is concerned with sustainability?

During the course of preparing this work I received a lot of encouragement from many different persons and I would like to use the opportunity to thank them. First, very special thanks goes to my supervisor Prof. Dr. Alfred Greiner for his guidance. He has supported all my ideas and suggestions with patience and provided professional advice along the way. For his step by step introduction to academic tasks and for the (scientific) freedom that I was able to enjoy I am deeply grateful. Also, I thank Prof. Dr. Herbert Dawid, who agreed to be my second advisor. With their expertise, both professors have especially shaped my economics education at Bielefeld University.

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Of course, potentially remaining discrepancies and errors are my own.

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Chapter 1

Introduction

"Sustainability is basically
about good housekeeping."

Blanchard et al. (1990),
The sustainability of fiscal
policy: new answers to an old
question, p. 8.

While public finance aspects have always enjoyed great attention in economics literature, the recent developments of the financial crisis and subsequent debt crisis have extended the audience far beyond the academic world. This also holds true for the concept of sustainability. It is not only employed in the different academic disciplines - sometimes even as a separate science - but the term is used more frequently throughout everyday life or in the media for example. Thus, statements like the one above receive additional awareness in debt-troubled times like these.

At the moment Europe is especially affected by the public debt crisis. But in particular for European Monetary Union (EMU) member countries - with a single monetary policy - sustainable fiscal positions are important. The institutional setting with the Treaty on the European Union (Maastricht Treaty) and the Stability and Growth Pact requires sound fiscal policies. For instance, Article 121 of European Union (1997)'s Consolidated Version of the Treaty on European Union calls for realization of "the sustainability of the government financial position". However, the recent developments with persistent deficits and deteriorating fiscal conditions may leave room for doubts whether governments have

actually implemented sustainable debt policies. Therefore, the central research question of this thesis asks:

- Have governments of selected economies pursued sustainable debt policies?

To answer this subject several possible approaches can be pursued. For this thesis, the essential concept has been introduced by Bohn (1998): Does the government undertake corrective actions in response to an increasing public debt ratio? Meaning, does it utilize its main fiscal variable, which it can influence - the primary surplus, to stabilize or decrease its debt ratio? This idea is closely related to the aspect of whether there is a certain level at which the debt ratio stabilizes in accordance with the previous behavior. And going further: is it possible to calculate (a proxy for) a critical value or benchmark of the debt ratio beyond which achievement of fiscal sustainability is impossible? These more specified objects of study are relevant for fiscal policy decisions, particularly in these times.

From the economics perspective, the past couple of years have been significantly shaped by public debt matters. Starting with the severe fiscal problems of the Greek government in spring 2010, huge financial rescue programs have been organized to meet the acute difficulties in Europe and the Eurozone. The European Financial Stabilisation Mechanism (EFSM) and the European Financial Stability Facility (EFSF), both temporary instruments, are supposed to be replaced by a permanent European Stability Mechanism (ESM) soon.[1] Currently, the financial assistance programs, also including International Monetary Fund (IMF) shares, cover the volumes of 130 billion Euros for Greece,[2] 78 billion Euros for Portugal and 85 billion Euros for Ireland, cf. for instance EFSF (2012).[3] In return the recipients commit to implementing rigorous austerity programs with tough fiscal retrenchments. Likewise other highly indebted economies enforce such measures in order to avoid application for financial assistance and the involved requirements. The cutbacks have not been without social, economic and political problems. Thus, as these examples show, public debt, deficits and (sound) fiscal positions are an urgent topic at the moment. And by proceeding towards a deeper integration in Europe these aspects will remain important for the future as well. Moreover, these debt matters are not limited on

[1] An initially planned start in July 2012 had to be delayed.

[2] This regards the second program. Earlier, a first bilateral and IMF involved package summed up to 110 billion Euros in 2010.

[3] Recently, also Cyprus applied for financial support as well as Spain for its banking sector.

Europe but concern economies throughout the world as well. Within this context, debt sustainability analysis can provide auxiliary information. Therefore, a profound (empirical) study on public debt sustainability is especially relevant nowadays.

The focus in this thesis is set on central European economies, which are represented by Austria, France and Germany, as well as on southern European countries, here corresponding to Greece, Italy and Portugal. For a meaningful comparison, this analysis has been extended and additionally includes two large industrialized economies from abroad: Japan and the USA. As discussed above, the severe public finance circumstances in Europe warrant the inclusion of the first two groups. This especially holds true for Greece and Portugal since they have received international financial support, starting in May 2010 for Greece and in April 2011 for Portugal. Japan has been subject to one of the world's highest debt ratios and, thus, is of particular interest for a debt sustainability study. Finally, the USA is the biggest industrialized economy that has also been exposed to a high and an increasing debt ratio recently.

But before beginning with the analysis, a demarcation of the term *sustainability* is essential because there exists no precise definition of it yet. Generally the concept is quite versatile and may be applied to a broad range of aspects. Thus, in a first step, this thesis reflects on the roots and selected stages of development of the term and concept of *sustainability* in order to find common characteristics and its relevance for public debt. These conceptual and terminological considerations are followed by a literature review on different approaches of fiscal sustainability. It concentrates on empirical contributions. Generally, two main directions can be distinguished: on the one hand there are sustainability signaling indicators and on the other hand, there are time series analysis. The first signifies a more practical assessment and presents sustainability information, which is summarized in one number. For this direction an influential contribution has been the formative paper introduced by Blanchard (1990). The latter are implemented for example via regressions, stationarity tests or cointegration studies in order to suggest for sustainability. Bohn (1995, 1998) for instance has introduced a fiscal response mechanism that studies whether governments react to increasing debt ratios by enhancing their primary surplus ratios. For this thesis, both literature branches are discussed shortly.

The theoretical basis of the debt sustainability approach is characterized by the government's budget equation. Central analytical terms in this context are the inter-temporal budget constraint and the No-Ponzi-Game (NPG) condition. They claim that the existing amount of public debt has to be compensated by the sum of discounted future primary surpluses in order to assure that the present value of public debt converges to zero asymptotically. Additionally, the aspect of Bohn (1998)'s fiscal response mechanism is included in that theory. This allows to derive conditions for sustainability and suggests an applicable sustainability analysis with less restrictive or demanding assumptions than common approaches. Further, some considerations on a stabilized debt ratio are discussed as suggested by Burger (2012). Accordingly, such a non-changing debt ratio can be calculated by using the coefficients from Bohn (1998)'s fiscal reaction idea. Additionally, limits of Bohn (1998)'s test are addressed. In line with Fincke and Greiner (2011c), it is possible to show that this reaction concept only works under certain conditions. It is demonstrated that an effective operation of the mechanism depends on the initial debt ratio situation of an economy. Once a certain benchmark has been passed, sustainability of public debt is no longer possible. These critical debt ratio benchmarks can be calculated theoretically with relatively few assumptions. Especially for economies with rising public debt ratios, this is a very crucial finding. If they continue with their prevailing fiscal behavior, they run the risk of no longer being able to establish sustainable policies. This holds true despite of their reform programs and austerity measures.

For the empirical part, the recent fiscal development in Europe shows that the role of government and in particular its ability and efficiency to counteract debt expansion is especially relevant. This idea has been implemented in Bohn (1998)'s test that explicitly studies whether the primary surplus ratio increases in response to a rise in the public debt ratio with a regression equation. Accordingly, sustainability is signaled by a significantly positive reaction coefficient. This thesis resorts to that approach and amends it. First, in terms of methodology: this study utilizes the semi-parametric regression technique of splines instead of the traditional ordinary least squares (OLS) regression method. By further including an interaction in terms of time-varying coefficients, the development of the fiscal reaction over time can be displayed. This estimation design allows to identify

periods in which the government has put more emphasis on debt stabilization and recognizes possible changes over time. It enables to show country specific policy decisions and effects of influences such as the upcoming Maastricht Treaty in the 1990s requiring sound fiscal performance. Such information may be particularly instructive for policy decision making. Secondly, the theoretical reflections have pointed out limits of the fiscal reaction mechanism to signal sustainability. Therefore, Bohn (1998)'s regression should be complemented by additional testing for a more sound sustainability decision. Here, the stationarity test approach introduced by Trehan and Walsh (1991) has been chosen. It addresses the stationarity properties of the budget deficit series and indicates sustainability if the hypothesis of nonstationarity is rejected. In a third step, the stabilized debt ratios for the selected economies are calculated. Ahead of that computation a different sustainability criterion is investigated, which is based on the comparison of the size of the reaction coefficient from the regression and the difference between the interest rate and the growth rate. It denotes sustainability if the reaction coefficient exceeds the interest rate/ growth rate gap. Finally, the critical sustainable debt ratio is computed. These calculations, especially the latter two, strongly depend on assumptions and the available data. Further, it should be noted that country specific characteristics shape the outcomes. Nevertheless, this study provides a general impression of the debt sustainability conditions in the selected countries in central and southern Europe and abroad. It reveals public finance information that may then be interpreted from an economic perspective for policy purposes.

This thesis compiles a demarcation of public debt sustainability and literature contributions in order to classify this approach into the broad range of sustainability aspects and the appropriate economic perspective. Moreover, theoretically it is reasoned why solely Bohn (1998)'s test may not be evidence enough to indicate public debt sustainability and under which conditions his mechanism might not work appropriately anymore. Plus, empirically this thesis goes beyond the common OLS regression to test for sustainability by applying the more flexible spline estimation. By accounting for interactions this method allows for the coefficients to vary over time. The empirical results for the selected eight countries in Europe and overseas are then interpreted in the context of public debt sustainability and economic policy. From the public finance policy perspective this permits

insight in a government's fiscal policy decisions over time and facilitates to identify periods with more and less emphasis on debt stabilization and fiscal sustainability. Moreover, it allows to allocate particular changes in this behavior over time.

The rest of this thesis is structured as follows. Chapter 2 elaborates on a demarcation of public debt and presents a literature overview. It further discusses a classification of public debt. Chapter 3 introduces the theoretical background. This incorporates the government's inter-temporal budget constraint and also Bohn (1998)'s fiscal response idea. Moreover, it specifies the theoretical reflections on the stabilized debt ratio and critical debt ratio benchmark. The centerpiece of this thesis is chapter 4 which presents the empirical evidence. First, a short introduction into the methodology of both approaches, spline estimation and stationarity tests, is given. Then, the data set is described and subsequently, the sustainability outcomes are displayed. For the regression estimation the findings are presented for each cluster (i.e. central Europe, southern Europe and overseas) by country, each including a description and portrayal of the fiscal situation in the individual economy over the considered time period. Then, the stationarity test results as well as the stabilized debt ratios and the critical debt ratio benchmarks are presented separately. Finally, chapter 5 summarizes the central aspects of this thesis.

Chapter 2

Sustainability of public debt

> [There is a] "remarkable number of books, chapters and papers that even use 'sustainable' or 'sustainability' in the title but do not define either term."
>
> Spedding (1996), *Agriculture and the Citizen*, p. 151.

The term 'sustainability' has become a very popular expression and the concept is versatile and applicable to a large variety of aspects and disciplines. However, sustainability is not precisely defined and this vagueness calls for a closer study. The ambiguity usually requires an appropriate, and possibly implementable, characterization according to the aspect considered, cf. for example SVR (2003), p. 270. Thus, to avoid the problem mentioned in the quote, a demarcation is essential for utilization and discussion. The subsequent section briefly reflects on the beginnings and some stages of the expansion of the term sustainability in order to find common traits and to transfer their application to public finance. Then, some considerations on denoting public debt indicate details for the subsequent analysis because there are different approaches for assessing and measuring public debt. For example, gross or net public debt could be taken into account.

2.1 A demarcation of sustainability

2.1.1 Definition and derivation

As discussed above there is neither no clear-cut definition of sustainability in general nor universal fiscal sustainability instruments in the economic perspective. Thus, for a demarcation and a gradual approach to an applicable concept, first a derivation of *sustainability* is regarded. Further, *sustainable development* is considered and eventually *fiscal sustainability* will be taken into account.

As a starting point, the verb *to sustain* embodies the Latin verb 'sustinere', meaning 'to bear' (in terms of 'to endure' or 'to maintain'), see for example Jüdes (1997, p. 26) or Grober (2010, pp. 19f.). Therefore, according to Jüdes (1997), sustainability can be understood as a characteristic of relations, such as a state or a process, that can be maintained for the long-term.

Concerning the term *sustainability*, the roots can be traced back to forestry and it was shaped in the German-speaking area - with 'Nachhaltigkeit' for the German translation of sustainability, see for example Pittel (2002, pp. 9f.) and Grober (2010, p. 104). In the 18th century the Saxon mining administrator ('Oberberghauptmann') Hannß Carl von Carlowitz employed the expression "...nachhaltende Nutzung..."[1] (translation: sustainable use) in his science of forestry work "Sylvicultura oeconomica", that was published in 1713, cf. for instance Mathé (2001) or Von Hauff and Kleine (2009, pp. 2f.). According to Pittel (2002) the work can be interpreted as one of the earliest approaches to sustainability and was applied to forest management. It generally addresses a central economic problem: resource scarcity, here in terms of expected decline of wood supply, cf. Grober (2007, p. 7). Accordingly, sustainable management tries to find a balance between depletion and restoration in order to keep the stock stable and thus to assure continuous yields.[2]

To get an idea of the importance of forests and wood around that time, a brief selected review of the historical economic situation in Europe (Germany) in the early 18th century

[1] See Von Carlowitz (2000) p.105.

[2] Cf. Wiss. Beirat (2001) p.5 (with 'nachhaltiges Wirtschaften' as the German translation for sustainable management) or Pittel (2002) p.9.

might be helpful. When Von Carlowitz published his Sylvicultura oeconomica in 1713, the general prevalent conditions were shaped by the end of the Thirty Years' War (1618-1648) and the reign of Louis XIV. in France (1643-1715). Furthermore, Europe stood on the eve of the Industrial Revolution. This pre-industrial-revolution time set the conditions for the following industrialization in Europe, cf. Buchheim (1997, p. 15). Wood was of economic relevance because of two main purposes: (production) material and energy, i.e. fuel. Thus, occasionally that period is referred to as "Wood Civilization".[3] During the 18th century Saxony, where Von Carlowitz worked in the administration, became one of the regions with the most numerous crafts and businesses in Germany. Moreover, the German uplands were considerably affected by metal production which was also true for the Ore Mountains (Erzgebirge) in Saxony, cf. Buchheim (1997, p. 50). In general the usage of wood was relatively inefficient due to simple equipment. Thus, unsurprisingly wood availability became scarce around the 17th to 19th century in Europe, which was also expressed through a remarkable increase in prices.[4] Then, within the educated elites, improvement of agriculture became a fashionable issue during the 18th century. This led to the foundation of agricultural societies, an increasing number of related literature and to studies of the example of English agriculture.[5] Here, Von Carlowitz's Sylvicultura oeconomica fits in.

The idea of assurance of wood supply had already been of concern earlier, although the term sustainability was not employed directly. For example, in the high-medieval period in regions of today's Switzerland, provisions and regulations regarding the protection forest in the mountains and wood utilization considered a long-run horizon and an usage on a continuous basis. This type of sustainability consideration goes beyond the pure economic view and along with the protective function, also regards ecological aspects, perhaps unintentionally, see Schuler (2000, p. 498) and Grober (2010, pp. 199-204).

Thus, in the German-speaking area the adjective 'nachhaltig' has been employed since

[3] Cf. Malanima (2009) esp. p56.

[4] Cf. Malanima (2009) pp. 57-60, which also includes two descriptive graphs of declining forest and increasing wood and charcoal prices.

[5] Cf. for example Buchheim (1997) pp. 72f. This has also been pointed out by Grober (2007) esp. in sec. 3, emphasizing the earlier English approach.

the 18th century while the noun 'Nachhaltigkeit' has been used starting in the 19th century. Both are closely connected to forestry and established as an expression of that discipline, see Kehr (1993, p. 597). Also pointed out by Kehr (1993), even though sustainability is a technical term from forestry, there is no binding definition for that term. It is not determined for all times but rather is a central expression that has altered and adapted to changes since its introduction. This note as well as the following reflections actually point to a dynamic perspective when considering sustainability.

Geographically this was not limited to the German-speaking area as, for example, a similar idea was also of interest in Britain around that time. That arose due to the high demand by the fleet, by transforming forests into farmland and by an upcoming early industrialization, cf. Grober (2010, pp. 87-97) or Grober (2007, p. 8). There, for instance, studies analyzed in which way the growing population could be sustained given a limited quantity of land, as mentioned for example by Pezzey and Toman (2002) or Von Hauff and Kleine (2009) referring to *Malthus*. Moreover, in France king Louis XIV. signed a forest reform regulation in 1669. It included the general idea of proper forest management:"...il était nécessaire de faire un bon ménage des bois" besides the aspects of generating revenues, eliminating fear of wood shortage and promoting shipbuilding.[6] And going beyond, this idea was not only restricted to Europe: as for example pointed out by Grober (2010), according to whom similar concepts had been developed in Japan as well.

Such a resource oriented approach leads to the concept of *sustainable development*, which considers especially environmental and economic links and later also social aspects.[7] Early advances in the 1970s reflected the increasing awareness and importance of environmental aspects. The examples of Meadows et al. (1972)'s 'Limits to Growth' a report for the Club of Rome or the 1972 United Nations Conference on the Human Environment in Stockholm reveal this, see Von Hauff and Kleine (2009, pp. 4f.). The idea of sustainable development emerged in the 1980s with many applications and different definitions of sus-

[6] Cf. Grober (2010) pp.97-104, or Grober (2007) sec. 4, esp. pp.12-13, citation quoted from Grober (2010) p.100.

[7] See for example Von Hauff and Kleine (2009) p.5. According to Grober (2007) these three aspects can also be found already in Von Carlowitz (2000), cf. Grober (2007) pp.19-20.

tainability concepts.[8] Among them, branches can be found that distinguish between weak and strong sustainability regarding the interpretation of maintenance of resources for the future. Basically, the two types vary in the view on the ability of resource substitution, cf. Pittel (2002, p. 11). On the one hand, preserving the sum of resources allows for substitution of resource types and is considered as weak sustainability. This can be related to neoclassical economic analysis.[9] On the other hand, a conservation of each type and element regarded as nonexchangeable resources are reflected by strong sustainability. That can be interpreted as ecologic sustainability. As a mixture of both types a limited replaceability could be possible or some required critical minimum limits of natural resources, see Grunwald and Kopfmüller (2006, pp. 37-39) or Pittel (2002, pp. 11-14;22) for instance.

However, among the more well-known descriptions is the one published in the 'Brundtland report', that is by the World Commission on Environment and Development (WCED), which states sustainable development in the following way:

> "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."
> WCED (1987), page 43.

Having enhanced the public awareness and attention on sustainability and sustainable development, it was followed by the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992. There a number of documents were approved, among them Agenda 21: a plan of action for several aims. Later on they were concretized by protocols. In 2002, the World Summit on Sustainable Development in Johannesburg adopted amongst others a substantiated environmental protection program, see Von Hauff and Kleine (2009, sec. 1.4) or Grunwald and Kopfmüller (2006, sec. 2.4).

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8 For a survey see for example Pezzey (1992b) especially section 3 and appendix 1.

9 The aspect is closely linked to the economic idea of different types of capital. These are natural resources such as land or commodities and man-made resources for instance knowledge or machinery and equipment, cf. Grunwald and Kopfmüller (2006, pp. 37-38). As they are inputs in production, this is of importance for the idea of sustainable development as non-declining utility and sustainable growth as non-declining consumption, which is applied by Pezzey (1992b) for example.

Beyond these concerns of environmental aspects, the economic perspective with focus on the public sector and especially the public budget is interested in *fiscal sustainability*. For this idea the central concern is public debt, which is the development of debt in level and deficits over time. However, due to mutual effects it cannot be disconnected from the government's revenue and expenditure pattern.[10] According to Burger (2005), albeit fiscal sustainability is rather a new term coming up by the 1970s and 1980s, the idea of a government's solvency and the effects on the economy are considerably older. Also, from a historical perspective the economics' awareness of governmental solvency increased in times of large public indebtedness or accelerated debt growth. Burger (2003, 2005) generally distinguishes the development of the fiscal sustainability discussion into three stages: that is an early episode, then a Keynesian phase and finally a modern perspective. First, in the 18^{th} and 19^{th} century for classical economists, mainly skepticism prevailed towards public debt.[11] With the beginning of the Great Depression, deficit financing of governments in the 1930s led to debt accumulation. For countries involved in World War II it rose even further. Then, the economics perspective switched and worries concerning public debt eased some. With the economic prosperity of the 1950s until 1970s less notice of fiscal sustainability prevailed, however, that situation reversed beginning with the 1980s. Now, modern approaches basically follow-up on the matters of the classical perspective with concerns about debt, deficits and solvency, cf. Burger (2005, sec. 4) for these points.

Furthermore, some fiscal sustainability concepts also discriminate between solvency and sustainability: accordingly, whereas sustainability can be considered as a sufficient condition for solvency, necessity must not hold. As a currently unsustainable policy (for instance in terms of rising debt) may still lead to solvency if the government is able to invert policy in the upcoming future, cf. Burger (2005, p. 19) and Horne (1991, pp. 1f. and sec. II). Therefore, the refined perspective of the fiscal sustainability concept involves the governmental commitment and the ability to reverse current fiscal policy in the future, see also Horne (1991, p. 6).

As only these few considerations show, the approaches to sustainability are manifold

[10] See Burger (2005) p.3. Also, dissaving aspects could be considered, cf. Burger (2005) section 2.2.

[11] A point of Ricardo has also been indicated by Balassone and Franco (2000) sec. 2, especially pp.23-24, for example.

and addressed in many fields. For example Pezzey (1992a) regards reflections on sustainability by various disciplines, for instance from a social or psychological point of view. This can be illustrated by figure 2.1:[12]

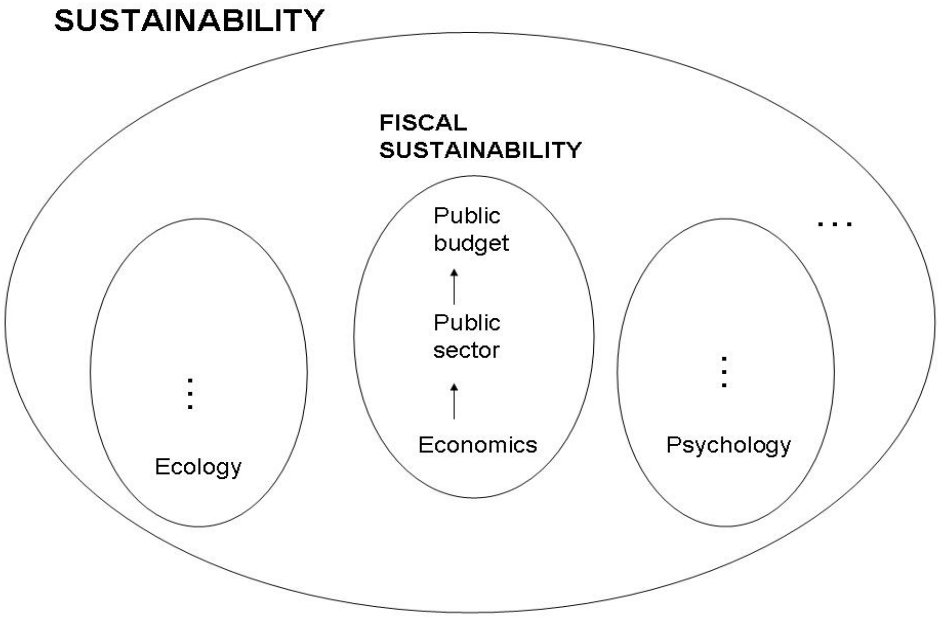

Figure 2.1: Assessing a characterization of the term *sustainability*.

In the following chapters the analysis concentrates on fiscal sustainability, that is the economic perspective regarding the public budget of the public sector. Further, within that specification the focus is mainly set on studying public indebtedness, which, however, is interconnected with expenditures and (non-debt) revenues of the public sector.

Summing up the previous findings and reflections, some common traits and characterizations relating to sustainability can be distinguished. Even though an implementable criterion depends on the precise context under consideration, according to Pezzey (1992b) several sustainability definitions share the following features:

i) sustainability regards a long-term horizon (inter-temporal aspect)

[12] This graphical classification is also in accordance with SVR (2003)'s description, who employ the German term 'Tragfähigkeit' for the narrow interpretation of sustainability for considering the public budget ('Öffentliche Haushalte'). Cf. SVR (2003) paragraph 439, p. 270.

ii) it considers a form of generational equity, that is inter- and/ or intragenerational (distributional perspective)

iii) sustainability is understood as a constraint (not -necessarily- optimality)

Additionally, from a legal perspective, Buscher (2010) points to a territorial aspect of sustainability. As it often goes beyond (national) borders it might well be of global relevance.[13] With the focus set on fiscal sustainability and especially the dimension of public debt, the characteristics listed above can be interpreted and related to that demarcation as

i) the inter-temporal aspect is obviously contained, since the theoretical instruments for fiscal sustainability analysis require the debt to be balanced or paid off over the considered time horizon. That is usually long-term and often even infinite.

ii) the distributional aspect, especially intergenerational fairness, is indirectly included also in the inter-temporal perspective. Future generations as well as current generations participate in balancing or paying off public debt. Moreover, relations with the constraint trait below can be connected for example to constitutional aspects. A 'golden rule' is contained in some legislations: through debt financing, contributions of future generations are included in the payment stream for public investments. This is of relevance because they also benefit from it.[14]

iii) fiscal sustainability and the mentioned analysis instruments are an additional requirement for budget policy. It constrains policy makers in their decisions on public duties, in the resulting expenditures and in revenue funding, cf. Horne (1991, p. 2 or sec. II.4). Also possible are constitutional constraints, for example a 'debt brake' or fulfilling "the sustainability of the government financial position" in Art. 121 European Union (1997) Consolidated Version of the Treaty on European Union (or ex-Article 109j in European Union (1992) Treaty on European Union, p.20) or the convergence criteria.[15]

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[13] Cf. Buscher (2010) part 3 sec. C.I.2, especially p. 339. Pezzey (1992b) also points at a geographical context for sustainability, cf. Pezzey (1992b) p. xi.

[14] Concerning the golden rule, see also Balassone and Franco (2000), sec. 2, p. 25 for example.

[15] The role of EMU regulations for addressing fiscal sustainability has for instance been pointed out by Balassone and Franco (2000).

For public debt, the territorial trait might be of importance regarding for example the structure of bonds or bond holders (domestic or external). There are also manifold ties and an integration of international markets, as illustrated by the current crisis. Sustainability strategies such as the mentioned Agenda 21 or the Treaty on European Union constraint are discussed in an international context. International coordination is common as illustrated by the Greek support starting in 2010. But sustainability studies (and often plan or action implementation) of public debt are analyzed (done) in a country by country or national manner.

Certainly, such a demarcation does not come without problems. For this contribution sustainability is regarded from the public finance economics perspective which may not be compatible with the holistic comprehension of sustainability in ecological economics. Such an approach would require fiscal policy with respect to an entire perspective: reconciling the economic view with the ecological and social dimension. This could mean a design of economic policy that contributes to an improved responsible development for all economic, societal and (eco-) system participants. It may be implemented through its instruments of public responsibilities and functions as well as revenues and expenditures for example, see Lang (2007, pp. 174f.) for these points. Noteworthy, this idea is not pursued here. As the previous reflections have shown, the public finance economics understanding of public debt sustainability possesses the central characteristics of general sustainability concepts. Thus, the subsequent analysis can appropriately resort to it. Plus, as claimed by Buiter (2004, p. 1), fiscal sustainability is just as essential as the other dimensions because the government must be and remain in a position to be able to finance the environmental and social targets and programs.

Like many general principles or overall concepts, the already mentioned broad scope of the idea of sustainability makes it more easily acceptable but also quite vulnerable for emphasis and interpretation towards a required purpose, see also Spedding (1996), pp. 149-151. However, another characteristic directly interconnected with that broad range of the approach is its dynamic. It allows for adjustment and extension of the idea over time according to the current situation (and society).[16] For sustainability this be-

[16] This point is similar to the reasoning by Kehr (1993) from above regarding a dynamic trait of the

came apparent both with the incorporation of the ecologic perspective beyond the mere economic focus as well as including the social component somewhat later.

To see how the concept of fiscal sustainability has been assessed by the economics literature, the following subsection reflects on directions of literature and regards different approaches. The focus is set on empirical research.

2.1.2 Approaches in economics literature

This subsection reviews on the economics literature on public debt sustainability and concentrates on empirical approaches. Before addressing directions of literature, some selected approaches and applications in relation to the term discussion from above are assessed. They show the various possibilities of emphasis and interpretation of sustainability in debt analysis, even though most of them have a common basic idea.

For example, an intuitive specification is pointed out by Langenus (2006) who generally considers fiscal sustainability in terms of policies which can (theoretically) be pursued indefinitely without necessity of adjustment or change. Among other things, in his survey on empirical approaches Afonso (2005) reflects Keynes' reasoning. He mentions that sustainability can be questioned once the relative amount of, or relationship between, liabilities and income of a nation, which can be understood as the debt to GDP ratio, approaches an excessive amount. By combining both ideas of policy continuance and regarding the debt accumulation, Blanchard (1990) addresses sustainability as maintenance of the present policy without future adjustment while debt is neither exploding nor imploding. In accordance with that, Wilcox (1989) considers sustainability as a fiscal policy:"...that would be expected to generate a sequence of debt and deficits such that the present-value borrowing constraint would hold"[17] while later on he also mentions to leave that policy unchanged indefinitely. A more practical perspective, as proposed by Perotti et al. (1997) for instance, concentrates especially on the ability to control public finances, 'controllability', as a central aspect for sustainability. While regarding the EMU rules, that is the criteria implemented in the Maastricht Treaty and the Stability and

forestry term.

[17] Cf. Wilcox (1989) p. 294. For assessment of the present-value borrowing constraint see section 3.1.

Growth Pact, Balassone and Franco (2000) state that sustainability can be considered by "non-violation of arbitrarily predefined parametric standards".[18] As only these few particular applications show, there is a variety of options to focus on when considering debt sustainability. In addition, they mainly all share a similar idea and starting point. Subsequently, that base is presented more technically.

Like any economic agent, the government has to balance its budget, that is public expenditures G must be financed by revenues T, which are mainly attained via taxation. Here, a closed economy with an independent central bank is assumed. Thus, the government cannot rely on external sources or seignorage for funding. But if the expenses exceed the tax revenues, the government is able to equalize the budget by debt financing, that is issuing government bonds B. At this point decisions concerning the tasks and functions of the government are assumed to be made and the associated costs for them are the expenditures considered here. Therefore, the government's budget constraint can be described by:[19]

$$\begin{aligned} T(t) + \frac{dB(t)}{dt} &= G(t) + r(t)B(t) \\ \frac{dB(t)}{dt} = r(t)B(t) + G(t) - T(t) &= r(t)B(t) - S(t) \end{aligned} \tag{2.1}$$

with t indicating time, r the interest rate and S describing the primary surplus, which is calculated by the difference in revenues less primary expenditures for goods and services, that is without interest payments. All variables are expressed in real terms. Thus, the first line in equation (2.1) means that revenues in the form of tax revenues and newly issued debt are to be equal to the expenditures of the government. They consist of primary expenditures and interest payments on already existing debt. Reorganization of that first line gives the second line of (2.1), stating that the deficit, which shows the change in debt, is equal to the sum of interest payments on already existing debt and the primary deficit.[20] Accordingly, with this basis the empirical literature can be assessed.

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[18] Cf. Balassone and Franco (2000), quote cited from p. 30.

[19] See for example Blanchard (1990) sec. IV A or Fincke and Greiner (2011b). Here, the interest rate is allowed to vary over time.

[20] As pointed out by Burger (2003) pp.36-38 or Blanchard (1990) sec. IV A for example, the (intertemporal) budget constraint will be fulfilled ex post. See also sec. 3.1.

Concerning directions of empirical literature, in accordance with Chalk and Hemming (2000)'s distinction the focus can be set on two branches of study: *indicators* and *debt sustainability tests*. Of course both strands have several specifications and extensions and each has its benefits and disadvantages. Selected ideas are presented below.

Starting with *indicators*, the focus is set on composed indicators instead of simple numbers such as the debt ratio or deficit. Those must not reveal meaningful sustainability information, as Bohn (1995) pointed out. Since the rather theoretical (test) concepts often regard long-term linkages and infinite horizons which could be difficult to implement and use in actual political decision making, composed indicators generally represent a more practical sustainability approach, cf. Burger (2003, sec. 2.4, esp. pp. 35f.). Relating to indicators, sustainability information is summarized in one device or measure, which enlightens policy decisions and allows for judgment regarding potential adjustment, cf. Blanchard et al. (1990). Overall, indicators are relatively easy to calculate and quite suitable for comparing different economies but they also strongly depend on their strict assumptions.[21]

Among the most formative contributions of this direction is the paper by Blanchard (1990). He suggests calculating (forward looking) sustainability indicators starting from the budget constraint in equation (2.1) while considering ratios to GDP:

$$\frac{d\left(\frac{B(t)}{Y(t)}\right)}{dt} = (\bar{r} - \bar{\gamma})b(t) - s(t) \tag{2.2}$$

with small letters indicating ratios to GDP and γ for the growth rate of GDP.[22] For a set of fiscal policy variables, a given future spending ratio pattern g (by projections) and starting value of the debt ratio in $t = 0$, a sustainable debt policy in terms of a constant

[21] See Horne (1991) for a discussion on sustainability indicators.

[22] Cf. Blanchard (1990) sec. IV A or Blanchard et al. (1990) sec I.A and I.B. The presentation in (2.2) - (2.5) slightly differs from the previous ones regarding the variables in order to stay close to Blanchard's reasoning, especially concerning the interest rate and growth rate, which are assumed to be constant here. They might be interpreted as average values at this point, thus the bars indicate average values. Blanchard (1990) suggests using 10 year averages for $\bar{r}$ and $\bar{\gamma}$ for computing the primary gap $s(t) - (\bar{r} - \bar{\gamma})b(t)$ for example, cf. ibid. p.14.

tax rate τ can be obtained from (2.2) by:[23]

$$\int_0^\infty e^{-(\bar{r}-\bar{\gamma})\mu}(s(\mu))d\mu = \int_0^\infty e^{-(\bar{r}-\bar{\gamma})\mu}(\tau - g(\mu))d\mu = b(0). \tag{2.3}$$

From (2.3) the sustainability indicating tax rate τ^* is then given by:

$$\tau^* = (\bar{r} - \bar{\gamma}) \left(b(0) + \int_0^\infty e^{-(\bar{r}-\bar{\gamma})\mu}(g(\mu))d\mu \right), \tag{2.4}$$

which is indicating potentially necessary policy changes if compared to the actual tax rate τ. Then $\tau - \tau^*$ is the 'tax gap' and negative values signal adjustment needs.[24] This can be calculated for different horizons, e.g. especially medium term or long term goals, cf. Blanchard (1990, sec. IV). Suggesting that the debt ratio is back on its initial level $b(0)$ in k years according to Blanchard et al. (1990) or Blanchard (1990) the sustainability indicating tax rate can be approximated by:

$$\tau_k^* \approx \textit{average primary spending ratio } g \textit{ over next } k \textit{ years } + \ (\bar{r} - \bar{\gamma})b(0). \tag{2.5}$$

For example, with the long term perspective it is possible to regard population ageing expenditure changes as well.[25] All in all, indicators such as the tax gap allow for transparent sustainability statements on the basis of relatively few information. But as pointed out above, they assess sustainability quite arbitrarily with regards to the benchmark of $b(0)$, or point of origin, and they must adhere to strict assumptions, so that their simplicity and intuitiveness do not come without costs.

The other direction of literature deals with *debt sustainability tests*. In an early approach Hamilton and Flavin (1986) assess the fiscal sustainability idea by applying time series test methods. They suggest empirical testing for limitations of government deficit financing by directly addressing the present value budget constraint (PVBC). They are interested in whether the public budget is inter-temporally balanced, i.e. the PVBC holds. Concretely, they apply stationarity tests on the series of debt and the primary surplus.

[23] As noted by Blanchard (1990) p. 13, a central assumption in this context is whether $r > \gamma$ holds, e.g. if the interest rate is larger than the growth rate. Cf. also Excursus I in sec 3.2. For empirical evidence regarding that point for the USA, Germany and Japan see Fincke and Greiner (2011c) sec. 4.1.4, indicating that this relationship is fulfilled since the 1980s.

[24] See for example Balassone and Franco (2000) sec 5.2, Chalk and Hemming (2000) sec II.C or Horne (1991) sec III for a discussion of Blanchard's tax gap indicators.

[25] See Blanchard (1990) p. 15. This has also been recognized by Balassone and Franco (2000) p. 44.

If the surplus is stationary (and a regression error term as well), stationarity of the debt series implies that the PVBC holds while an unstationary debt series indicates violation of the PVBC. As also noted by Chalk and Hemming (2000) this is only a sufficient condition for sustainability. Hamilton and Flavin (1986) conclude that for US data the budget constraint can be considered to be fulfilled, thus, signaling sustainability.

Also testing for stationarity properties, Trehan and Walsh (1991) utilize the budget deficit DEF, inclusive of interest payments to analyze debt or fiscal policy sustainability. Requiring a variable but positive real interest rate, stationarity of the deficit can be considered sufficient for fulfilling the present value budget constraint and for sustainability. Stationarity analyses of time series can be implemented by unit root tests. Stationarity can be addressed by a regression given for instance in (2.6). In that context a coefficient, here denoted by π, indicates whether stationarity may be present. Applying exemplarily an Augmented Dickey Fuller (ADF) Test it distinguishes the hypothesis H_0: unstationary series and H_1: stationarity[26]

$$H_0 : \pi = 0 \quad \text{versus} \quad H_1 : \pi < 0.$$

A possible test model then analyzes:[27]

$$\Delta DEF(t) = \pi DEF(t-1) + \sum_{l=1}^{m} \psi_l \Delta DEF(t-l) + \epsilon(t). \tag{2.6}$$

The ψ_l are additional coefficients for lagged variables and ϵ indicates errors in (2.6). The empirical results of Trehan and Walsh (1991) point to stationarity of the budget deficit and, therefore, suggest sustainability for US data, too.

There have been several other related attempts in the empirical economics literature.[28] However, most of them involve relatively strong assumptions especially central to the interest rate which is quite a demanding requirement as pointed out and criticized by Bohn (1995, 1998). Instead, he suggests analyzing whether there is a systematic (positive) relationship between the primary surplus to GDP ratio $s(t)$ and the public debt to

[26] See for example Enders (1995) chapter 4, especially sec 2, pages 221-224.

[27] See Fincke and Greiner (2011c) sec 4.2 for instance, also for more model types. In sec. 4.1.2 below a more detailed description of the ADF test is presented.

[28] For a review see Afonso (2005) for instance.

GDP ratio $b(t)$. Such a reaction can be interpreted as mean reversion. Meaning, as the public debt ratio rises, a government actively increases the primary surplus. This could be implemented by reducing public expenditures or enhancing revenues. Bohn (1998) introduces the regression:

$$s(t) = \upsilon\, b(t) + \mathbf{Z}(\mathbf{t})\alpha + \epsilon(t), \tag{2.7}$$

The reaction coefficient υ is of interest and $\epsilon(t)$ is a regression error term. It is assumed to be i.i.d. $N(0, \sigma^2)$. $\mathbf{Z}(\mathbf{t})$ includes other variables that can have an effect on the primary surplus ratio (some of them may not even be entirely under the control of the government, such as the business cycle for example) and α is a vector of coefficients. Thus, sustainability is indicated by a positive and statistically significant reaction coefficient υ in this analysis. In comparison with the few selected studies above, a key advantage of Bohn (1998)'s sustainability approach is the direct testing of the primary surplus and public debt link, which does not need explicitly strict interest rate assumptions.[29] Bohn (1998)'s test results for the USA reveal a positive reaction, thus also signifying debt sustainability. This is the central technical concept for the subsequent empirical analysis.

As noted above, there are several other studies and many new advances analyzing debt sustainability empirically and each sets a different emphasis. To mention just a few, Hakkio and Rush (1991) regard the development of public revenues and expenditures in the USA and their relationship. They test for cointegration and conclude that such a development cannot be characterized as sustainable because revenues appear to increase not as quickly than expenditures. Or Chalk (2001) additionally considers non-renewable resources with the debt sustainability context.

But, whenever studying empirical approaches, measurement and approximation of variables and data is a central and important aspect. Therefore, the next section reflects on these issues and focuses on public debt.

[29] However, if Bohn (1998)'s test is considered in combination with the theoretical reflections, there may be additional requirements regarding the reaction coefficient and guaranteeing sustainability, cf. Fincke and Greiner (2011c) sec.2.

2.2 Forms of public debt

The measurement of public liabilities faces several difficulties regarding both a determination of 'public' as well as concerning 'liabilities'. This section briefly elaborates on those classification problems for central aspects of these topics.

Especially if it is organized federally, a country may consist of different levels of government, for instance of a local or municipal unit, states and a central or national level. Thus, when evaluating 'public' the regarded level or combination of levels of government should be pointed out. Especially for comparisons it is quite common to look at the general government classification. That includes all government tiers, e.g. central, regional (state) and/or local governments and social security funds.[30] Therefore, referring to 'public' broadly regards general government in this study. However, as pointed out by Balassone and Franco (2000), in practice difficulties arise concerning the definition of public sector units. They mention especially public companies.

Concerning liabilities, a distinction for example between explicit and implicit debt as well as gross and net debt may be discussed. Gross debt is defined by Chalk and Hemming (2000) as "the total stock of outstanding government financial liabilities".[31] Such a current countable debt can be regarded as explicit debt while implicit debt also considers future government benefit payments. As pointed out by Hamilton and Flavin (1986) such upcoming program outcomes do not denote a presently existing charge which could be put into an actual liability amount, as they depend on "an uncertain political process".[32] Thus, future pension payments for example may be adjusted through reforms. To avoid such uncertainties for this contribution only explicit debt is of concern.

Then, gross and net debt measurement differ with regard to assets. Net debt is determined by adjusting gross debt for asset values. But, as noted by Hamilton and Flavin (1986), the question whether to correct debt for assets concerns credibility and commit-

[30] For a definition of general government see for example European Union (1992) Protocol on the excessive deficit procedure, Art.2, p. 84 or OECD (2011); but attention must be paid to the particular system classifications.

[31] Cf. Chalk and Hemming (2000) quote cited from p. 15.

[32] Cf. Hamilton and Flavin (1986) sec. II.B, quote cited from p. 813.

ment of the government to liquidate assets in order to repay debt.[33] Liquidity is an important feature regarding assets and if net debt is considered, financial assets are commonly taken into account. As pointed out by Chalk and Hemming (2000) or studied by Fincke and Greiner (2011c), the difference in gross or net debt matters noticeably for example for Japan. But Balassone and Franco (2000) mention that information on assets must not always be considered as reliable. Thus, they suggest a gross debt approach. Another distinction may concern the time structure or maturity of debt or bonds. A common assessment of debt sustainability relates to long run government debt (usually 10 year bonds). However, also short-term debt has gained attention which is recently observable more often especially for lower government levels.[34]

2.3 Summary

This section has considered the development of public debt sustainability. Almost exactly 300 years after the first reference, the concept is as relevant as ever. Selected stages of advancement have been reflected such as utilization in forestry in the 18th century with early reference by Von Carlowitz (2000) in 1713. The accentuated relation between economic and environmental positions revived in the 1970s and has been taken into account. Now sustainable development concepts usually contain a social dimension as well. So, the idea itself is not permanently fixed but incorporates a dynamic trait that allows for adjustment and changes over time.

Focusing on the public finance perspective, the idea of solvency of a government can be shown to be quite an old feature. Thus, with respect to sustainability of the public budget, three main common characteristics can be separated. From an inter-temporal perspective generally a long-term horizon is considered, for some analyses even infinity. Further, usually a distributional aspect is contained regarding generational equity. Moreover, debt sustainability commonly is of a constraining nature. That means it is an additional requirement to be considered in governmental decision making as for example adhering to constitutional rules. The territorial trait reveals international linkages even

[33] See Hamilton and Flavin (1986) sec II.D. They note the exception of gold, p. 814.

[34] Cf. Fincke and Greiner (2011a) p. 240, mentioning for example increasing importance of Kassenverstärkungskredite for German federal states lately.

though (budget related) policy decisions are mainly done in a national manner because they are one of the most essential government decisions.

Against this background, approaches in the empirical economics literature show that there are mainly two directions on which to focus: on the one hand indicators and on the other hand sustainability tests. The first summarize information in one measure or device. The latter analyze properties or estimate relationships of series of variables. Of course, both strands have several specifications. Among the indicators, one of the most well-known approaches is the tax-gap by Blanchard (1990). He suggests calculating the difference between the actual and the tax rates required for sustainability thus indicating potentially necessary adjustment. Starting with a key paper by Hamilton and Flavin (1986), promising test approaches can for instance focus on stationarity properties of relevant data series. Or they may test for the relationship between the primary surplus and the public debt ratio, as proposed by Bohn (1998). However, all of these advances have benefits and drawbacks, such as relating to explanatory power and feasibility of data availability, for example. But they provide tools to analyze current economic situations and can support economic policy decision making that allows for public debt sustainability, even though upcoming challenges are difficult to account for.

Also, some difficulties concerning the measurement of the relevant variables have been discussed. Here, the focus has been set on the classification of 'public', that is, what level of the public sector should be regarded, and 'liabilities', meaning what type or category of debt should be considered. These determinations are relevant for the empirical analysis. The general government classification and long term debt are commonly applied in sustainability analyses.

Chapter 3

Theoretical Considerations

> "Theory without empirics is empty. Empirics without theory is blind."
>
> Immanuel Kant (1724-1804)

Just like the idea of sustainability Kant was also born in the early 18th century. The quote[1] indicates that before public debt sustainability is addressed empirically it should be regarded theoretically as well. A suitable starting point for that might be the government's budget, which has already been introduced in section 2.1.2. This chapter briefly elaborates on essential theoretical reflections for the empirical study. First, the central relationship in a government's budget position is discussed and theoretical conditions for sustainability are determined. This idea is then related to Bohn (1998)'s test and additionally limitations of it are considered. Finally, some calculations on a stabilized debt ratio and a possible benchmark of an upper sustainable debt ratio limit are implemented.

3.1 Theoretical assessment of debt sustainability

For an analysis of public finances an appropriate beginning might be the budget of a government. Again, this perspective assumes that decisions on governmental tasks and the associated public expenditures and tax revenue settings are given. Thus, for balancing

[1] This translation of Kant's dictum has been found at `http://www.wiwi.uni-bielefeld.de/cemm.html` (Access: December 14th, 2011). In Kant (1998) a translation says "Thoughts without content are empty, intuitions without concepts are blind." pp.193-194.

the budget the government's revenues are supposed to be (at least) equal to its spending. This is expressed in the familiar equation

$$\begin{aligned} T(t) + \frac{dB(t)}{dt} &= G(t) + r(t)B(t) \\ \frac{dB(t)}{dt} &= r(t)B(t) + G(t) - T(t) = r(t)B(t) - S(t) \end{aligned} \tag{3.1}$$

which has already been discussed in section 2.1.2.

Solving equation (3.1) for $B(t)$ and discounting it leads to:

$$B(t)\, e^{-\int_0^t r(\mu)d\mu} = \left(B(0) - \int_0^t e^{-\int_0^\mu r(\phi)d\phi} S(\mu)d\mu \right), \tag{3.2}$$

with $B(0)$ indicating the debt level at $t = 0$. The result is given in present value description. In accordance with the sustainability requirements of not exploding debt from above, equation (3.2) points at the following two conditions, see also for example Fincke and Greiner (2011b, sec. 2) or Greiner et al. (2007, sec. 2):

$$\lim_{t\to\infty} B(t)\, e^{-\int_0^t r(\mu)d\mu} = 0 \quad \Leftrightarrow \quad B(0) = \int_0^\infty e^{-\int_0^\mu r(\phi)d\phi} S(\mu)d\mu \ . \tag{3.3}$$

The first part of equation (3.3), often referred to as the No-Ponzi-Game condition, states that the present value of public debt converges to zero asymptotically, cf. for example Blanchard and Fischer (1989, ch. 2). This is equivalent to the second part of (3.3) which is the inter-temporal budget constraint. It requires that the already existing debt at time $t = 0$ is paid off by the sum of the discounted future primary surpluses.[2] Strictly speaking, it is expected future primary surpluses. Thus, often an expectation operator is included. Then, each side of equation (3.2) and (3.3) leads to the conditions:

$$\begin{aligned} E\ B(t)\, e^{-\int_0^t r(\mu)d\mu} &= E\left(B(0) - \int_0^t e^{-\int_0^\mu r(\phi)d\phi} S(\mu)d\mu \right), \\ \lim_{t\to\infty}\ E\ B(t)\, e^{-\int_0^t r(\mu)d\mu} = 0 \quad &\Leftrightarrow \quad B(0) = E \int_0^\infty e^{-\int_0^\mu r(\phi)d\phi} S(\mu)d\mu \end{aligned} \tag{3.4}$$

with E for expectation as it actually considers future values. Thus, from a theoretical point of view, a debt policy that fulfills these conditions may be considered as sustainable.

The next section details on a link between this general theoretical assessment of debt sustainability and Bohn (1998)'s approach of the reaction mechanism between the primary surplus to GDP ratio and the debt to GDP ratio.

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[2] Please note that this idea well allows for temporary primary deficits, but in the long run these have to be compensated, cf. for instance Wilcox (1989) p. 294.

3.2 Bohn's sustainability test

As for instance pointed out by Bohn (1995), addressing the theoretical sustainability access from above involves tight assumptions and suitable discounting must be considered. In order to avoid that problem, Bohn (1998) supposes to check on a possible existing positive linear relationship between the primary surplus ratio and the public debt ratio. If a government behaves in this way, it will implement corrective actions in times of increasing debt ratios by enhancing its primary balance. Such a policy situation can be considered sustainable.

Notably, this procedure does not make any requirements regarding the specification how the primary surplus ratio has to be achieved. Neither does it define whether this results from a revenue increase or expenditure reduction nor of which particular type it is supposed to be. The precise policy design is not (pre-)determined.

Reconsidering equation (2.7) Bohn (1998)'s idea can be reformulated to

$$s(t) = \upsilon\, b(t) + \rho(t), \tag{3.5}$$

now $\rho(t)$ is capturing all other effects on the primary surplus ratio. That is assumed to be bounded from above and below by a finite value, $|\rho| < \infty$. This is appropriate because these influences are reasonably be limited, cf. also Fincke and Greiner (2011c, sec. 2) or Greiner and Fincke (2009, p. 7) for example.

Inserting the relationship of (3.5) in equation (3.1) and solving it for the present value of public debt leads to

$$B(t)\, e^{-\int_0^t r(\mu)d\mu} = e^{-\upsilon t}B(0) - e^{-\upsilon t}\int_0^t \rho(\mu)\; Y(0)\; e^{-\int_0^\mu (r(\phi)-\gamma(\phi))d\phi}\; e^{\upsilon\mu}d\mu. \tag{3.6}$$

For fulfilling sustainability according to equation (3.3) the left hand side of (3.6) has to converge to zero asymptotically. For the right hand side this means the parameter υ must be larger than zero. In addition, for the second term on the right hand side (with accounting for $|\rho| < \infty$) the numerator has to be bounded in order for the expression to converge to zero with $\upsilon > 0$. If it is not finite, the rule of L'Hôspital points out:

$$\frac{\rho\; Y(0)\; \int_0^t e^{-\int_0^\mu (r(\phi)-\gamma(\phi))d\phi}\; e^{\upsilon\mu}d\mu}{e^{\upsilon t}} \quad \overset{\text{L'Hôspital}}{\rightarrow} \quad \lim_{t\to\infty} \frac{\rho\; Y(0)\; e^{-\int_0^t (r(\mu)-\gamma(\mu))d\mu}\; d\mu}{\upsilon} \tag{3.7}$$

It reveals that for this perspective of sustainability $\upsilon > 0$ and $\lim_{t\to\infty} \int_0^t (r(\mu) - \gamma(\mu))d\mu = \infty$ must hold.[3] The latter requirement means that the interest rate/growth rate difference must be positive on average in order for the present value of public debt to converge to zero asymptotically.

Excursus I: Interest rate and growth rate gap - Theory

For assessing sustainability the difference between the real interest rate, as a marginal product of capital, and the growth rate of an economy is of importance for the approach above and is considered as a characteristic condition addressing dynamic efficiency, cf. for example Wilcox (1989, sec. 1) or Greiner et al. (2005, sec. 2). The concept of dynamic efficiency regards the (potentially over-) accumulation of capital in an economy, see Abel et al. (1989) or Wilcox (1989, p. 294). However, a distinction between a deterministic and a stochastic environment setting has to be made. In a deterministic economy the requirement of an interest rate larger than the growth rate assigns dynamic efficiency and dynamic inefficiency in the opposite way, cf. Wilcox (1989, p. 294). As often observed interest rates may be very low, but this must not indicate dynamic inefficiency as Abel et al. (1989) have shown. They conclude, that in a stochastic environment approach, the US economy indicates to be dynamically efficient despite low interest rates. Bohn (1995) also considers a stochastic setting. However, for this section, in accordance with Wilcox (1989), the requirement of the constraints from the analysis above are retained. Meaning here to concentrate on dynamic efficient economies in the deterministic setting. This characterized by a positive difference between the interest rate and the growth rate, cf. for instance Greiner et al. (2005, p. 5). On the contrary, for dynamic inefficient economies the constraints above are not relevant: for example in the deterministic dynamic inefficient case, if the growth rate exceeds the interest rate, the government can roll over debt without consequences for its future surpluses. This holds because in such a situation the government can always clear the interest payments by issuing new bonds, see for instance Wilcox (1989, p. 291) or Greiner et al. (2007, p. 200).

[3] This idea has already been shown by Greiner et al. (2007) appendix 1.

The reaction coefficient υ being constant over time is quite a restrictive assumption. For a more flexible and probably more realistic or practice relevant approach, υ can be allowed to vary over time and is indicated by $\upsilon(t)$, see for example Fincke and Greiner (2011c). Therefore, looking again at equation (3.5) it can now be modified to

$$s(t) = \upsilon(t)\, b(t) + \rho(t). \tag{3.8}$$

By proceeding as above, here the present value of public debt is obtained as:

$$B(t)\, e^{-\int_0^t r(\mu)d\mu} = e^{-\int_0^t \upsilon(\mu)d\mu} B(0) - e^{-\int_0^t \upsilon(\mu)d\mu} \int_0^t \rho(\mu)\; Y(0)\; e^{-\int_0^\mu (r(\phi)-\gamma(\phi)-\upsilon(\phi))d\phi} d\mu. \tag{3.9}$$

According to the aforesaid sustainability condition, that the present value of public debt asymptotically converges to zero, the limits of the two terms on the right hand side are considered separately again.

First, it requires $\lim_{t\to\infty} \int_0^t \upsilon(\mu)d\mu = \infty$, which can be interpreted as a positive average reaction coefficient over time (again, explicitly allowing for temporary negative values; in the long run these must be made up for yielding a positive average). This guarantees convergence of the first term in equation (3.9) to zero.

Then, the second expression on the right hand side in (3.9) gives:

$$\frac{\int_0^t \rho(\mu)\; Y(0)\; e^{-\int_0^\mu (r(\phi)-\gamma(\phi)-\upsilon(\phi))d\phi} d\mu}{e^{\int_0^t \upsilon(\mu)d\mu}}. \tag{3.10}$$

Again, considering the asymptotical traits via $\lim_{t\to\infty}$, if the numerator remains bounded, $\lim_{t\to\infty} \int_0^t \upsilon(\mu)d\mu = \infty$ provides that the term converges to zero asymptotically. However, if it is not bounded, utilizing L'Hôspital yields with $|\rho| < \infty$

$$\lim_{t\to\infty} \frac{\rho\; Y(0)\; e^{-\int_0^t (r(\mu)-\gamma(\mu))d\mu}}{\upsilon(t)}, \tag{3.11}$$

which, unless $\upsilon(t)$ converges to zero exponentially, indicates that for $\lim_{t\to\infty} \int_0^t (r(\mu) - \gamma(\mu))d\mu = \infty$ the term in (3.11) converges to zero asymptotically. That reflects sustainability because for deterministic dynamic efficient economies that requirement is supposed to hold by assumption. Moreover, by demanding $\lim_{t\to\infty} \int_0^t \upsilon(\mu)d\mu = \infty$ to be fulfilled an exponentially declining $\upsilon(t)$ is excluded.[4]

[4] For these calculations cf. also Fincke and Greiner (2011c) appendix A.

Therefore, an average positive reaction coefficient $\overline{\upsilon}$ leading to $\lim_{t\to\infty}\int_0^t \upsilon(\mu)d\mu = \infty$ in combination with $\lim_{t\to\infty}\int_0^t (r(\mu)-\gamma(\mu))d\mu = \infty$ assures sustainability in terms of satisfying the inter-temporal budget constraint when allowing for a time varying reaction of the primary surplus ratio to variations in the debt ratio.

Moreover, regarding international comparisons or, for example, the regulations concerning the European Union convergence criteria with respect to debt, the total public debt amount numbers or level values need to be adjusted to ratios. They are usually set in relation to GDP. Such an approach has already been supposed in section 2.1.2 when introducing Blanchard's tax gap method with the starting equations (2.2) and (2.3) that were formulated in terms of ratios to GDP.

Reconsidering equation (2.2) while allowing for variable real interest and growth rates,

$$\frac{d\left(\frac{B(t)}{Y(t)}\right)}{dt} = (r(t)-\gamma(t))\; b(t) - s(t) \tag{3.12}$$

in combination with Bohn (1998)'s idea shown in equation (3.8) the public debt ratio can be solved to:

$$b(t) = e^{\int_0^t (r(\mu)-\gamma(\mu)-\upsilon(\mu))d\mu}\left\{b(0) - \int_0^t \rho(\mu)e^{-\int_0^\mu (r(\phi)-\gamma(\phi)-\upsilon(\phi))d\phi}d\mu\right\}. \tag{3.13}$$

Equation (3.13) indicates that the sustainability requirement of a positive average reaction coefficient must be refined when looking at ratios. In the limit, with $\lim_{t\to\infty}$ the debt ratio only remains constant or converges to zero if the average reaction coefficient is larger than the average difference of the positive interest rate/growth rate gap. That means only if

$$\int_0^t \upsilon(\mu)d\mu > \int_0^t (r(\mu)-\gamma(\mu))d\mu \tag{3.14}$$

is fulfilled, the debt ratio converges for $\lim_{t\to\infty}$ while it is asymptotically diverging for $\int_0^t \upsilon(\mu)d\mu \leq \int_0^t (r(\mu)-\gamma(\mu))d\mu$. This can be determined from equation (3.13) by distinguishing the three possible cases:

i) $\int_0^t \upsilon(\mu)d\mu > \int_0^t (r(\mu)-\gamma(\mu))d\mu$,
ii) $\int_0^t \upsilon(\mu)d\mu = \int_0^t (r(\mu)-\gamma(\mu))d\mu$,
iii) $\int_0^t \upsilon(\mu)d\mu < \int_0^t (r(\mu)-\gamma(\mu))d\mu$.

For the examination the parameter $\rho(t)$ can be set to its constant finite maximum level $|\rho| < \infty$. Again, this is possible (and reasonable) because it denotes the influence on the primary surplus ratio.[5]

This shows that a sustainable fiscal policy may well be pursued even though the debt ratio is increasing which indicates a positive but smaller reaction coefficient than the positive average interest rate/growth rate gap. However, this may only be a temporary situation because to be sustainable in the long run the debt ratio must be constant.[6] How such a stabilized debt ratio could look like is discussed more detailed in section 3.3.

These conditions for sustainability hold as long as there is enough scope for the government to enhance the primary surplus ratio in order to respond to increases in the debt ratio. However, since all financial expenditures of an economy have to be funded out of GDP, there is obviously a technical upper limit to which the primary surplus to GDP ratio can be increased. This only refers to the theoretical upper bound - not yet including political or practical arguments (which also affect the government's ability to increase the primary surplus ratio). Since this threshold truly depends on country-specific aspects and institutional traits the actual limit value cannot precisely be determined but it can for sure be reasoned that such an upper limit does exist, cf. Fincke and Greiner (2011c, sec. 2).

Therefore, Bohn (1998)'s mechanism to address sustainability has limits. Section 3.4 elaborates further on the upper bound aspect and suggests calculations on possible thresholds.

3.3 The stabilized debt ratio

As indicated in the previous section, in the long run the debt ratio must (at least) be constant for pursuing a sustainable fiscal policy. Now, this section specifies analytically in greater detail how to determine such a stabilized debt ratio.

As Burger et al. (2011), Burger and Marinkov (2012) and Burger (2012) pointed out, it

[5] Cf. Fincke and Greiner (2011c) sec. 2 and appendix A for these calculations on the debt ratio.

[6] Cf. for example Greiner et al. (2007) p. 200 for a similar conclusion.

is possible to calculate the debt ratio with relation to Bohn's fiscal response mechanism. Such a stabilized debt ratio would not change anymore. Burger's approach can be assigned to this section's calculations by reconsidering equation (3.12):

$$\frac{d\left(\frac{B(t)}{Y(t)}\right)}{dt} = (r(t) - \gamma(t))\ b(t) - s(t) \tag{3.15}$$

with a non-changing debt ratio meaning $\frac{d\left(\frac{B(t)}{Y(t)}\right)}{dt} = 0$. That results in

$$s(t) = (r(t) - \gamma(t))\ b(t). \tag{3.16}$$

Thus, equation (3.16) presents the required primary balance ratio $s(t)$ which stabilizes the debt to GDP ratio $b(t)$ and keeps it constant over the time horizon, see also Buiter (2004, sec. 2c) for example. Further, Burger et al. (2011, p. 7f.), Burger and Marinkov (2012, sec. 4.1) and Burger (2012, pp. 936f.) reveal an equation structure similar to Bohn (1998)'s fiscal response function for that stabilized debt ratio situation, denoted by *, here with $b(t) = b^* = const.$ and the term $(r(t) - \gamma(t))$ being joined to $\beta(t)$:

$$s(t) = \beta(t)\ b^*. \tag{3.17}$$

A simplified version of Bohn (1998)'s reaction function (here omitting all other control variables and the regression errors for a moment, i.e. concentrating on a deterministic setting) has already been given in equation (2.7)

$$s(t) = \upsilon\, b(t) + \alpha_0, \tag{3.18}$$

again with the familiar notation: υ is the reaction parameter and α_0 includes the other effects. Assuming that realizations of the primary surplus attain the required variable values for stabilization of the debt ratio so that $b(t) = b^* = const.$ allows to denote the corresponding primary surplus:

$$s(t) = \upsilon\, b^* + \alpha_0 \ \Leftrightarrow\ s^* = \upsilon\, b^* + \alpha_0. \tag{3.19}$$

Using s^* from equation (3.19) in equation (3.17) leads to $s^* = \beta^*\, b^*$. With this information it is possible to calculate the stabilized level of debt to GDP ratio that settles in this situation, cf. Burger (2012, pp. 936f.) for this reasoning:

$$\begin{aligned} \beta^*\ b^* &= \upsilon\, b^* + \alpha_0 \\ b^* &= \frac{\alpha_0}{(\beta^* - \upsilon)} \end{aligned} \tag{3.20}$$

Thus, this constant level of b is influenced by the variable α_0, the required response for stabilization of the debt ratio and the reaction coefficient. For sustainability $\upsilon > \beta^*$ is required according to the previous reflections, indicating a negative denominator here.[7] This means, the response is stronger than the required coefficient for stabilization. Moreover, the variable α_0 then determines whether this debt ratio level b^* will be positive or negative. A negative value indicates a positive constant debt ratio. For positive values the stabilized debt ratio might be negative, thus the country becomes a lender. For $\beta^* > \upsilon$ the fiscal reaction is not strong enough to stabilize the debt ratio, i.e. the required surplus for keeping the debt ratio constant could not have been achieved. Thus, fiscal sustainability does not seem to be given for these situations, cf. also Burger (2012) or Burger and Marinkov (2012, sec. 4) for this reasoning.

Please note, this stabilized debt ratio depends on the coefficients that can be determined by past fiscal behavior as well as (historical) country specific characteristics such as the interest rate and the growth rate which shape the parameter β^*. Here again the interest rate/growth rate gap is of importance. It determines the sign and size of β^*. In accordance with the reasoning from the previous section a positive interest rate/growth rate difference is assumed here as well. This indicates $\beta^* > 0$. Further, based on the arguments in section 3.2 for sustainability $\upsilon > 0$ is requested with the additional requirement $\upsilon > (r - \gamma)$ when looking at ratios as pointed out in equations (3.13) and (3.14).[8] The latter again gives $\upsilon > \beta^*$ for constant values of r and γ which has just been discussed above.

These calculations depend on assumptions and do not include further specific effects on the primary balance in equation (3.18) for example. But they do give a rough orientation and additional information on possible constant debt ratios which may help in fiscal sustainability assessment and political decision making.

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7 Here, the case of $\upsilon = \beta^*$ is omitted in order to avoid a denominator of zero.

8 Constant values for υ, r, γ are inserted for reasons of simplicity and section consistent notation here. They may be interpreted as averages for example.

3.4 A sustainable debt ratio benchmark

With the reasoning from section 3.2, that there is a limit to which the primary surplus ratio can only be raised, further calculations show supplementary information regarding public debt sustainability.[9] Even though the exact limit of the primary surplus ratio to GDP cannot be determined, by supposing that it exists it may be signaled by u. That u is assumed to be smaller than one and constant, i.e. $u < 1$. Assuming a situation in which that maximum value has been achieved the primary surplus ratio cannot be raised anymore in response to an increasing public debt ratio. In such a setting the response parameter $\upsilon(t)$ would be equal to zero. If now the primary surplus ratio would permanently be set to its maximum upper level u, equations (3.1) and (3.12) modify to:

$$\frac{dB(t)}{dt} = r(t)B(t) - uY(t) \tag{3.21}$$

$$\frac{d\left(\frac{B(t)}{Y(t)}\right)}{dt} = \left(r(t) - \gamma(t)\right)\, b(t) - u$$

respectively, with u substituting for $s(t)$, see Fincke and Greiner (2011c) sec. 2 and appendix B. Equation (3.21) can be solved in present value form to:

$$B(t)\, e^{-\int_0^t r(\mu)d\mu} = B(0) - uY(0) \int_0^t e^{-\int_0^\mu (r(\phi)-\gamma(\phi))d\phi} d\mu. \tag{3.22}$$

Regarding sustainability, which according to equation (3.3) requires the present value of public debt asymptotically converging to zero, means the right hand side of (3.22) needs to be zero for $t \to \infty$. That indicates there is a benchmark for the initial debt ratio:

$$\frac{B(0)}{Y(0)} = b(0) = u \int_0^\infty e^{-\int_0^\mu (r(\phi)-\gamma(\phi))d\phi} d\mu. \tag{3.23}$$

For any initial debt ratio exceeding $u \int_0^\infty e^{-\int_0^\mu (r(\phi)-\gamma(\phi))d\phi} d\mu$ sustainability is impossible.

This yields important insight concerning sustainability and debt ratios: for the sustainability condition according to (3.3) in combination with Bohn (1998)'s mechanism on fiscal policy response and an existing limit of the primary surplus ratio, size does matter in terms of the initial debt ratio $b(0)$. If a country's initial debt ratio is beyond that threshold, public debt sustainability is unattainable regardless of the fiscal effort undertaken by the government.

[9] Please note, this section's idea is based on Fincke and Greiner (2011c).

Moreover, for such a reasoning a critical debt ratio can be obtained from equation (3.23), with a more feasible approach employing again averages for the interest rate $\bar{r}$ and the growth rate $\bar{\gamma}$:

$$\hat{b}_{thsh} = u \int_0^\infty e^{-(\bar{r}-\bar{\gamma})\mu} d\mu = u \frac{1}{(\bar{r}-\bar{\gamma})} \tag{3.24}$$

u being again the upper limit of the primary surplus ratio from above.[10] Here once more the role of the interest rate and growth rate gap is important as they strongly influence the calculation of that threshold. Plus, the competence of a government in achieving primary surplus ratios - the in fact unknown u - influences these rather arbitrary critical benchmarks. But they propose a tentative suggestion of the extent of (initial) sustainable debt ratios.

Another important aspect in this context concerns the assumed independence of the variables. For this calculation the interest rate $\bar{r}$ and the growth rate $\bar{\gamma}$ are considered to be independent of the debt ratio b. But in fact the interest rate will increase as the public debt or the debt ratio rises, because it accounts for the danger of default (risk premium). And the growth rate might be affected negatively by increasing debt as well. However, as long as the interest rate exceeds the growth rate (both reasonably assumed to be smaller than infinity) the analysis applies, even though the actual $\hat{b}_{thsh}$ cannot be determined.

3.5 Summary

For theoretically assessing public debt sustainability this chapter initially started with the budget of a government which has to be balanced in each period. From the budget constraint two equivalent theoretical conditions for sustainability have been determined: the present value of public debt must asymptotically converge to zero, which correspondingly means that the already existing debt amount must be paid off by future primary surpluses. These two conditions, also referred to as No-Ponzi-Game condition and intertemporal budget constraint, are essential for debt sustainability analysis.

In addition, a fiscal response mechanism introduced by Bohn (1998) considers the reaction of the primary surplus ratio to changes in debt ratio, which can be incorporated into

[10] See also International Monetary Fund (2003), especially p. 148, for a comparable computation.

the sustainability conditions above. Such an effect is measured by a reaction coefficient. It indicates sustainability if it is positive, meaning a government implements corrective actions by achieving or enhancing the primary surplus ratio when the debt ratio has increased. Such a response may be constant or time-varying.

By further demanding an at least constant debt ratio, such a positive reaction request must be amended to require additionally that the response parameter exceeds the positive difference in the real interest and growth rate. That particular relationship between the interest rate and the growth rate is important for the theoretical sustainability approach in general. It has been recognized in an excursus. This has also addressed the economic setting and the traits for that gap to be positive. In deterministic dynamic efficient economies the real interest rate is larger than the growth rate.

As for example suggested by Burger (2012) such a constant long run debt ratio can be calculated including Bohn's fiscal response mechanism. That stabilized debt ratio is determined by coefficients of the estimated regression as well as the required response parameter for stabilization of the debt ratio. The latter is shaped by the growth rate/interest rate difference. For fiscal sustainability the estimated reaction coefficient must exceed the required response parameter. This is consistent with the sustainability requirement from above.

However, Bohn (1998)'s mechanism has limits, as there is an upper bound to which the primary surplus to GDP ratio can maximally be increased. This point is closely connected to the discussion concerning the level and size of the debt ratio as well as determinations of a critical sustainable debt ratio, beyond which sustainability is excluded. An upper limit of the primary surplus ratio allows to calculate such a theoretical threshold, but it is strongly determined by the ability of a government to achieve primary surplus ratios. In addition, the difference between the interest rate and the growth rate influences this level.

Therefore, increasing debt ratios endanger sustainability and those governments run the risk of finding themselves in a situation in which attaining debt sustainability is impossible,

despite their fiscal endeavor. Thus, especially for countries with rising debt ratios, such a fiscal response analysis is revealing but it should be supplemented by additional testing in order to make a more sound statement on public debt sustainability.

Chapter 4

Empirics

"The consequences arising from the continual accumulation of public debts in other countries ought to admonish us to be careful to prevent their growth in our own."

John Adams,
1st Annual Message,
November 22nd 1797,
Yale Law School (2008)

That warning of President Adams - again from the 18th century - emphasizes the reoccurring relevance of the public debt topic. This chapter analyzes public debt sustainability empirically for selected countries. The study is based on the definition of sustainability and the theoretical derivations from the previous chapters. The first section gives a short introduction to the estimation method, subsequently the data set is described and the empirical results are discussed in detail.

4.1 Methodology

This chapter's twofold empirical approach of debt sustainability starts with a brief presentation of the testing technique. First, spline estimation is introduced. Then, some reflections on stationarity tests follow.

4.1.1 Estimation method for Bohn's regression approach

To explore effects and relations of variables econometric modeling analyzes possible correlation by applying specific methods. Among the most common techniques parametric regressions search for a systematic link between variables (a dependent variable y and one - or more - explanatory variable x), which is often implemented by a classical linear regression model estimated via ordinary least squares (OLS). This minimizes the squared deviations and estimates constant coefficients that describe the systematic linear relationship. Also, it allows to illustrate that link by plotting a regression line into the scatterplot if only two variables are considered for instance. However, sometimes such a parametric model may not be suitable to represent the relationship between the variables and a flexible approach seems to be more promising, cf. for example Fahrmeir et al. (2009), Keele (2008) or Ruppert et al. (2003). For this nonparametric regression direction the contribution by Hastie and Tibshirani (1990) has been fundamental and was followed by many publications. Moreover, progress in statistical software has promoted application and research of these modern regression types, cf. Greiner (2009), Kauermann (2006) or Wood and Augustin (2002) for instance.

In line with Fahrmeir et al. (2009)'s motivation the mentioned problem can be illustrated with data. Against the background of the discussion on fiscal sustainability from above, here the example of Austria's primary surplus ratio and its public debt ratio for the period from 1971-2008 is considered, see OECD (2010) for the data.[1]

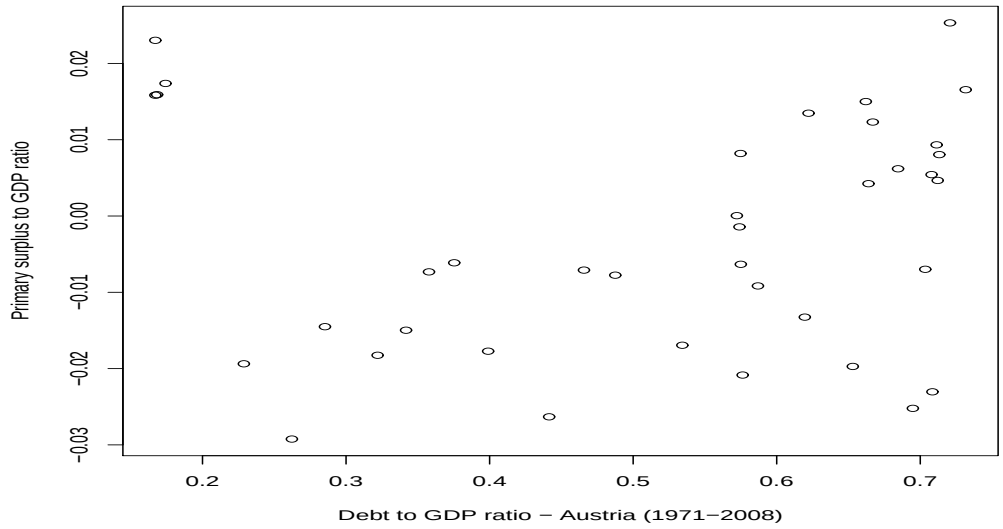

Figure 4.1: Austria's primary surplus to GDP ratio and public debt to GDP ratio.

[1] The graphics and estimations are prepared with the program R (version 2.5.0), see appendix A.

As figure 4.1 shows, there are a few observations on the upper left hand corner meaning high surpluses at times of a low debt ratio, then, the rest of the data points presents primary surpluses as well as deficits for increasing and high debt ratios. For fitting a parametric regression on that situation, a cubic polynomial of the explanatory variable, debt ratio, has been implemented and the graph with the fitted values is shown in figure 4.2.

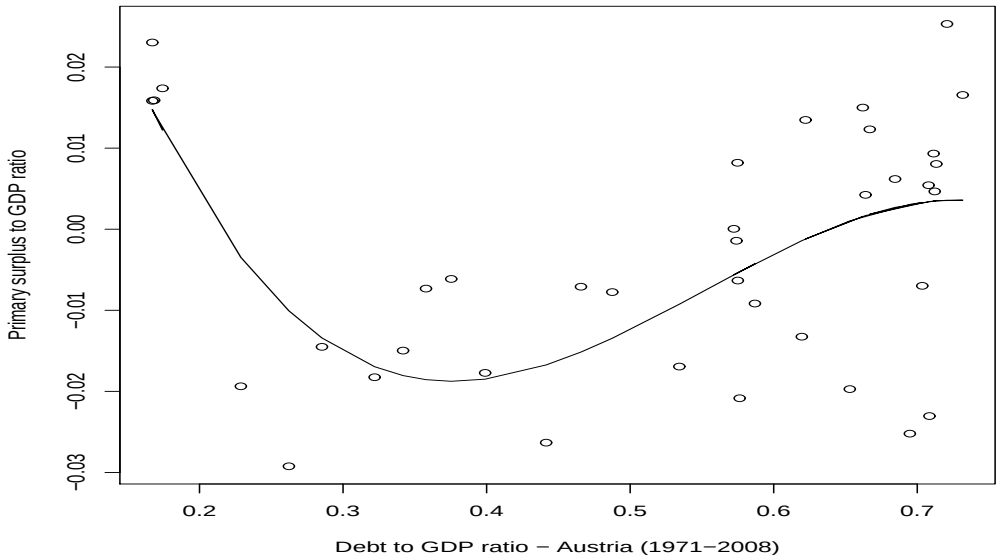

Figure 4.2: Parametrically fitted cubic polynomial on situation of figure 4.1.

Obviously the estimation does not fit very well. For example the minimum of the primary surplus ratio - actually a deficit - of -2.9 % at a debt ratio of 26 % in 1976 is not recognized. But, a more flexible estimation method may provide a suitable instrument to describe the relationship between the primary surplus ratio and the debt ratio appropriately.

Therefore, the empirical estimations resort to splines here. It is a type of smoothing technique that allows to analyze the data in a more flexible way in accordance with the reasoning above. Compared to other nonparametric methods they do have certain benefits like a thorough theoretical background for example, cf. (Keele, 2008, p. 49). Like in Greiner (2009) for describing and applying such an approach assume the regression equation for one explanatory variable x

$$y_i = f(x_i) + \epsilon_i \tag{4.1}$$

for the observations $i = 1, .., n$ of the metric variables y and x with the function f describing the systematic part of the relationship between them. As there may be errors

or deviations from that systematic link, the additive term ϵ captures the stochastic or random part of the equation. It is assumed to possess the common characteristics: to be independent and identically distributed (i.i.d.) with $E(\epsilon_i) = 0$ and a constant variance σ^2, i.e. $\epsilon_i \;\; i.i.d. \;\; N(0, \sigma^2)$. For f no other assumptions are required apart from being continuous and adequately differentiable, cf. Greiner (2009) for example.

Now, the interest is focused on the design and determination of the function f in equation (4.1). As motivated above a simple parametric regression (even with transformed or adjusted explanatory variables) may not be suitable to capture the underlying relationship between x and y. But a local approach could be quite fitting. Thus, generally the idea of flexibility can be implemented by decomposing the whole relationship into appropriate parts plus demanding additional requirements on the overall functional concept.

Therefore, the functional form or smoothness is shaped by decisions on the individual parts, i.e. the changing points which are termed knots, as well as the type of the local regression function in between them, cf. Keele (2008, p. 50). For the piecewise model type choice Fahrmeir et al. (2009, p. 301) suggest using cubic splines as a rough guide because this would result in a smooth twice differentiable function. Concerning the knots the amount and the location must be determined. Since they connect the individual regressions they are important elements for the overall requirement that adjacent parts harmonize, see Wood (2006, p. 124). However, one possibility to ease the knot influence problem is regulation of the estimation's smoothness by a penalty. For a large enough number of knots the effect of their location and amount choice decreases, as rather a penalty or smoothing parameter is driving the model fit and the estimation of the functional shape, cf. Fahrmeir et al. (2009, p. 308) and Wood (2006, p. 128). This parameter can be appointed manually but to preclude arbitrariness it can also be determined by data.

For estimating the function f in equation (4.1) in a familiar regression model style and accounting for the piecewise defined functions, it is possible to find a similar presentation just like linear modeling. If the explanatory variable x, to model the influence on y, is expressed in terms of particular functions - called basis functions B - these may be summarized by constructing a new design matrix $\mathbf{M}$,

$$\boldsymbol{M} = \begin{pmatrix} B_1(x_1) & \cdots & B_J(x_1) \\ \vdots & & \vdots \\ B_1(x_n) & \cdots & B_J(x_n) \end{pmatrix}$$

with $j = 1, \ldots, J$ basis functions. Their amount is influenced by the number of knots and the respective function power, depending on the chosen basis type.[2] This allows to present equation (4.1) by

$$\mathbf{y} = \mathbf{M}\boldsymbol{\alpha} + \boldsymbol{\epsilon} \tag{4.2}$$

with the dependent variable $\mathbf{y} = (y_1, \ldots, y_n)^T$, $\boldsymbol{\alpha} = (\alpha_1, \ldots, \alpha_J)^T$ for the coefficients and $\boldsymbol{\epsilon} = (\epsilon_1, \ldots, \epsilon_n)^T$ captures the errors. Now, with taking $\sum_{i=1}^{n} \left(y_i - \sum_{j=1}^{J} B_j(x_i)\alpha_j\right)^2 = (\mathbf{y} - \mathbf{M}\boldsymbol{\alpha})^T(\mathbf{y} - \mathbf{M}\boldsymbol{\alpha}) = \|\mathbf{y} - \mathbf{M}\boldsymbol{\alpha}\|^2$ into account, the estimation of (4.1) in least squares mode gives the minimization problem

$$\min_{\boldsymbol{\alpha}} \|\mathbf{y} - \mathbf{M}\boldsymbol{\alpha}\|^2 \tag{4.3}$$

with $\| \ \|^2$ for the Euclidian norm and the search for f is reduced to calculation of $\hat{\boldsymbol{\alpha}}$, cf. Wood and Augustin (2002, p. 159). The resulting estimator is $\hat{\boldsymbol{\alpha}} = (\mathbf{M}^T\mathbf{M})^{-1}\mathbf{M}^T\mathbf{y}$. An interpretation of the individual coefficients $\hat{\alpha_j}$ is less informative but the summarization of the scaled bases shows the estimated functional shape of f, see Fahrmeir et al. (2009, sec. 7.1.1) and Wood and Augustin (2002, sec. 2) for these calculations and reasoning.

Introducing a smoothing or penalty term λ in equation (4.1) in order to address smoothness such a model type can be referred to as penalized splines. At this point the value of $\lambda \geq 0$ is assumed to be given. For such a model design (4.1) adjusts to

$$\sum_{i=1}^{n} (y_i - f(x_i))^2 + \lambda \int f''(x)^2 dx \tag{4.4}$$

with the first part targeting the model fit and the second part directing the smoothness via a penalty for too much curvature. This leads to the penalized minimization problem, cf. Greiner (2009) or Wood (2006, sec. 3.2.2)

$$\min_{\boldsymbol{\alpha}} \ (\mathbf{y} - \mathbf{M}\boldsymbol{\alpha})^T(\mathbf{y} - \mathbf{M}\boldsymbol{\alpha}) + \lambda\boldsymbol{\alpha}^T\boldsymbol{P}\boldsymbol{\alpha} \tag{4.5}$$

[2] Different basis types are possible, e.g. truncated power series basis (TP basis) or basic spline basis (B-Splines), see for instance Fahrmeir et al. (2009, sec. 7.1.1) or Wood and Augustin (2002) for details. For example, particular basis functions could be positive only for certain parts of the x values (e.g. $x \geq \kappa$) and zero otherwise, i.e. $B_j(x_i) = (x_i - \kappa)_+$ with κ being a single knot in a linear setting, see Ruppert et al. (2003, sec. 3) or Fahrmeir et al. (2009, sec. 7.1) for instance.

with $\boldsymbol{P}$ being a penalty matrix which consists of second derivatives of the basis functions. These address the roughness of the function f and λ controls the trade-off between smoothness and data fitness.[3] Thus, the new estimator $\hat{\boldsymbol{\alpha}}_{\boldsymbol{\lambda}} = (\mathbf{M}^T\mathbf{M} + \lambda\boldsymbol{P})^{-1}\,\mathbf{M}^T\mathbf{y}$ and the resulting $\hat{f}$ function estimation $\hat{\boldsymbol{f}}_{\boldsymbol{\lambda}}(\boldsymbol{x}) = \mathbf{M}\hat{\boldsymbol{\alpha}}_{\boldsymbol{\lambda}} = \mathbf{M}(\mathbf{M}^T\mathbf{M}+\lambda\boldsymbol{P})^{-1}\mathbf{M}^T\mathbf{y} = \mathbf{H}_\lambda\mathbf{y}$ with the influence or hat matrix $\mathbf{H}_\lambda$ are depending on the smoothing parameter λ. Obviously, the one extreme $\lambda \to 0$ leads to the unpenalized fit like above, while the other extreme $\lambda \to \infty$ is here resulting in a linear or line estimation of f and is oversmoothing the data, see for instance Kauermann (2006) or Ruppert et al. (2003, sec. 3) for this reasoning.

To chose an appropriate data driven penalty parameter λ, it is possible to apply cross validation for example. That is a technique which leaves out one observation i at a time and estimates the model with the remaining other observations and a certain λ. The squared deviation of the left out observation y_i and the model prediction for that value estimated with $l = 1, \ldots, i-1, i+1, \ldots, n$ observations is calculated. Proceeding similarly for all data results in

$$OCV_\lambda = \frac{1}{n}\sum_{i=1}^{n}(y_i - \hat{f}_\lambda^{[-i]}(x_i))^2 \tag{4.6}$$

and $\hat{f}_\lambda^{[-i]}(x_i)$ is denoting the estimate without the $i-th$ observation. To determine the suitable penalty parameter, this OCV criterion is minimized with respect to λ. For practical convenience the generalized cross validation GCV criterion is often used, which is based on a similar idea but takes the advantage of easier computation by resorting to the hat matrix, see for instance Greiner (2009) and Wood (2006, sec. 3.2.3).[4]

Of course this approach can easily be extended to more explanatory variables or including a parametric part (semi-parametric model), which will be resorted to in the fiscal sustainability estimations below. Checking the model's suitability proceeds as for common regression.[5]

Applying this technique to the example of Austria's primary surplus and debt ratio

[3] A penalty based on second derivatives is implemented for penalized splines in the *mgcv* package in R, cf. Fahrmeir et al. (2009, p. 309).

[4] The GCV penalty parameter approach is used in R's *mgcv* package, cf. Fahrmeir et al. (2009, p. 430).

[5] Like in Greiner (2009) no inference aspects will be specified here - for details on that see for instance Ruppert et al. (2003, sec. 6) or Wood and Augustin (2002).

from above results in the plot depicted in figure 4.3.[6] The left hand graphic shows the centered estimated smooth function $\hat{f}$(debt ratio). With the continuous line the effect and with the dashed curves the 95% confidence band is illustrated, cf. Wood (2006, p. 222). The right hand picture in figure 4.3 gives the overall relationship with the fitted model and the data. Here, the smoothing parameter λ has automatically been chosen data driven.

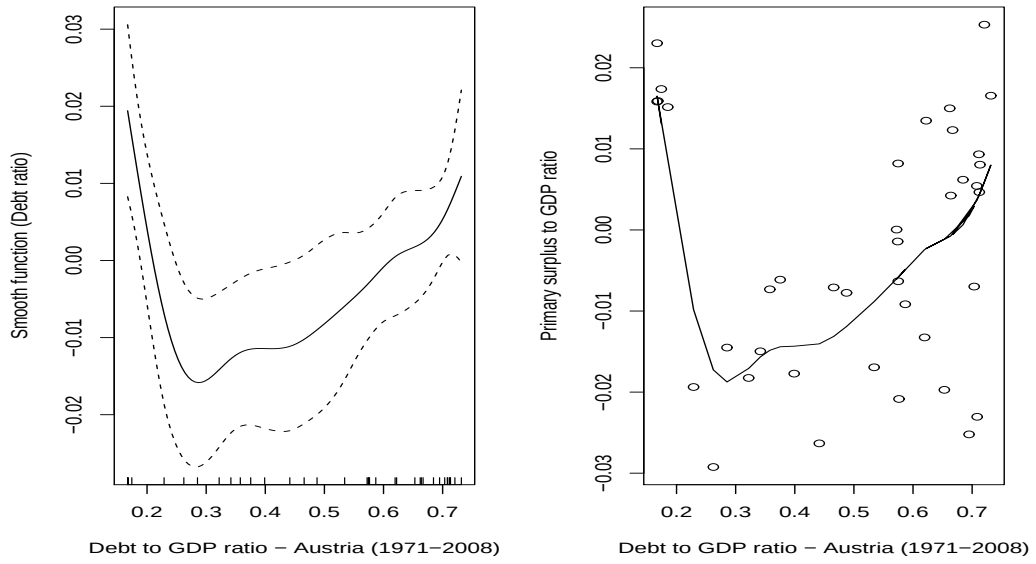

Figure 4.3: Estimated function $\hat{f}$ and model fit for the Austria example.

Comparing the right hand graphic in figure 4.3, i.e. the spline model fit, with the parametric model plot of figure 4.2 directly shows the merits: for example the spline model appropriately recognizes the minimum observation of 1976 and the upwards trend on the right hand corner. Checking the goodness of fit of the spline model $R^2_{adj} = 0.40$ against the one of the parametric model $R^2_{adj} = 0.35$ also supports this reasoning, cf. appendix A.

Further, possible interactions between explanatory variables may be taken into account. For motivation this may again be visualized with an example like above. Here, the primary surplus ratio and public debt ratio for Portugal for the period from the late 1970s until 2009 is depicted in figure 4.4 including the early stage of the crisis , see OECD (2010) for the data.

Figure 4.4 shows some observations with low debt ratios and deficits on the left hand side, several observations pooled in the middle with balanced budgets and debt ratios

[6] The estimation has been implemented in R 2.5.0 with *mgcv* version 1.3-23, cf. appendix A.

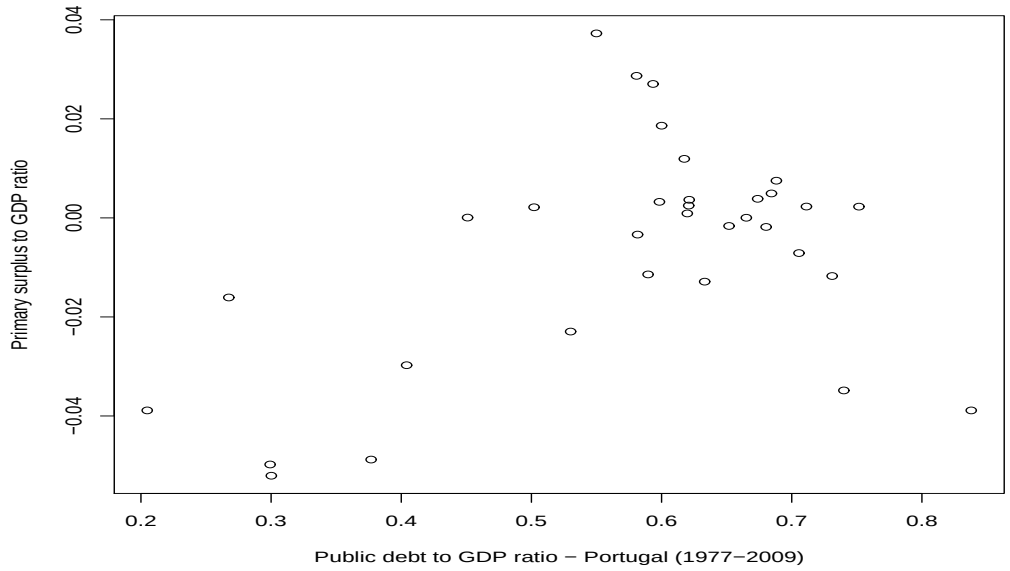

Figure 4.4: Portugal's primary surplus to GDP ratio and public debt to GDP ratio.

around 50% to 70% and then the beginning of the financial crisis on the right hand side with primary deficits and high debt ratios.

If now these observations are conditioned on time, meaning to look separately on each decade's relationship of Portugal's primary surplus and debt ratio for instance, it is possible to decompose the overall situation. Then, the initial relationship is (potentially) modified by a second explanatory variable - in this case time. Such a situation can be modeled by interactions. Figure 4.5 shows such a modification for the Portuguese example with decomposition of the relationship for three decades.[7] Also, a simple linear OLS regression line has been included to illustrate the individual trends.

Figure 4.5 shows there are different relationships at hand once the overall situation has been decomposed according to time. The left hand graph shows an increasing trend for the 1980s, meaning as the debt ratio rose the primary deficits were reduced heading towards surpluses. For the middle picture, the 1990s, this trend has eased and signals mainly an almost balanced budget with debt ratios around 60%. However, a negative slope (admittedly of poor quality) can be found. Without the outlier the trend turns weakly positive. For the 2000s the picture changes and the relationship indicates a down-

[7] The 1992 outlier ($x_{92} = 54,99\%, y_{92} = 3,73\%$) may well be removed here. The high surplus indicates to be influenced by a VAT tax reform that year, cf. Bronchi and Gomes-Santos (2001, p. 19).

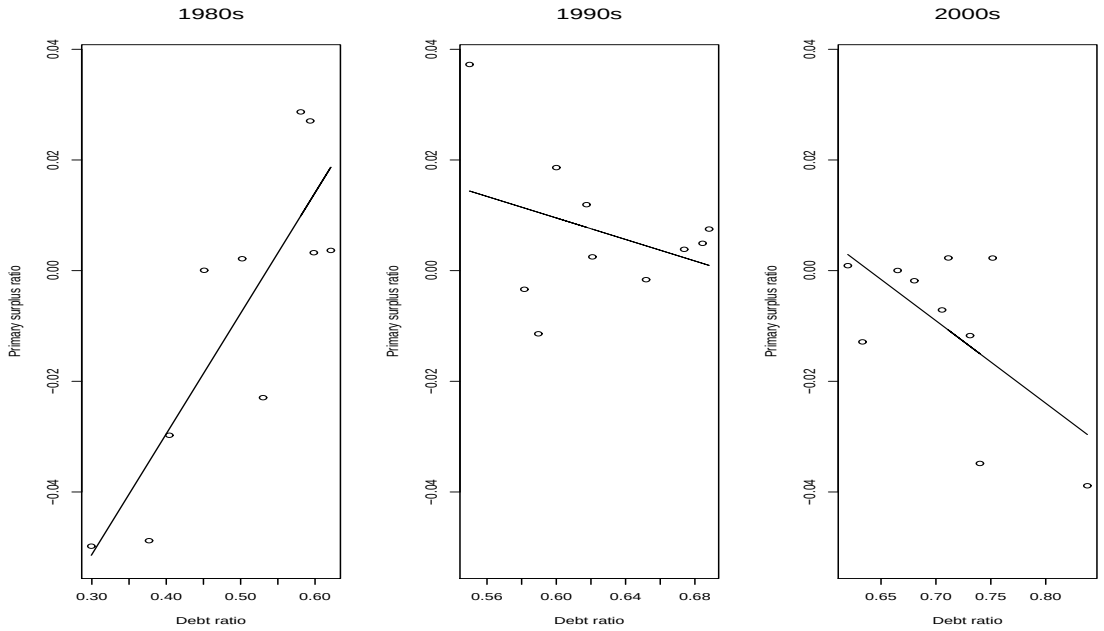

Figure 4.5: Decomposition of Portugal's primary surplus ratio and debt ratio by decades.

turn: high debt ratios come along with mainly primary deficits. That worsened with the 2009 crisis observation.

Assigning this situation to the regression method reflections from above, the idea of interactions can now be included into equation (4.1). Introducing a new explanatory variable z_i with $i = 1, \ldots, n$ the regression equation changes to

$$y_i = f(x_i)z_i + \epsilon_i. \tag{4.7}$$

Equation (4.7) expresses the relationship between the dependent variable y_i and the explanatory variable z_i which is modified by x_i. In other words, based on given values of the modifying variable x, the effect of z on y can be formulated parametrically. This is also referred to as a varying coefficient model, cf. Ruppert et al. (2003, p. 235) for instance.

Adding the parametric main effect $\beta_1 z_i$ and an intercept β_0 in equation (4.7) gives

$$y_i = \beta_0 + \beta_1 z_i + f(x_i)z_i + \epsilon_i. \tag{4.8}$$

Such a semi-parametric model can be written like

$$\mathbf{y} = \mathbf{Z}\boldsymbol{\beta} + \mathbf{M}_{\mathbf{vary}}\boldsymbol{\alpha}_{\boldsymbol{vary}} + \boldsymbol{\epsilon}. \tag{4.9}$$

Here, matrices are given by $\mathbf{y} = (y_1, \ldots, y_n)^T$, $\boldsymbol{\beta} = (\beta_0, \beta_1)^T$, $\boldsymbol{\alpha}_{\boldsymbol{vary}} = (\alpha_1^{vary}, \ldots, \alpha_J^{vary})^T$, $\boldsymbol{\epsilon} = (\epsilon_1, \ldots, \epsilon_n)^T$ and the two design matrices $\boldsymbol{Z} = \left(\begin{smallmatrix} 1 & \cdots & 1 \\ z_1 & \cdots & z_n \end{smallmatrix}\right)^T$ and

$$\boldsymbol{M_{vary}} = diag(\boldsymbol{z})\boldsymbol{M} = \begin{pmatrix} z_1 & 0 & \cdots & \cdots & 0 \\ 0 & z_2 & 0 & \cdots & \vdots \\ \vdots & & \ddots & & \vdots \\ \vdots & & & \ddots & 0 \\ 0 & \cdots & & 0 & z_n \end{pmatrix} \begin{pmatrix} B_1(x_1) & \cdots & B_J(x_1) \\ \vdots & & \vdots \\ B_1(x_n) & \cdots & B_J(x_n) \end{pmatrix} = \begin{pmatrix} z_1 B_1(x_1) & \cdots & z_1 B_J(x_1) \\ \vdots & & \vdots \\ z_n B_1(x_n) & \cdots & z_n B_J(x_n) \end{pmatrix}.$$

Now $\boldsymbol{M_{vary}}$ includes for all bases a multiplication with the respective z_i variable values. The estimation procedure remains like above, see for these calculations Wood (2006, sec. 4.2.1), Fahrmeir et al. (2009, sec. 8.3) and Ruppert et al. (2003, sec. 12.4) for example.

Returning to the Portugal example such a time varying coefficient may be estimated with the data from above. Figure 4.6 visualizes the time varying relationship between the primary surplus and the debt ratio, which is centered around its average value (the mean equals zero in the graphic).[8] So, the actual coefficient is determined by the average coefficient plus the deviation which is given by a smooth function.

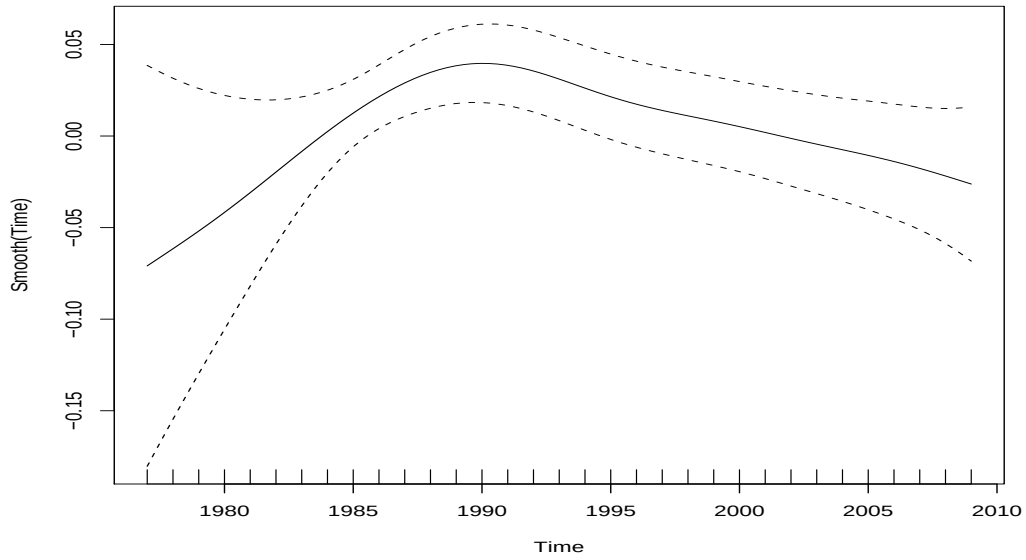

Figure 4.6: Smooth function over time for Portugal.

Figure 4.6 shows an increasing trend until the 1990s, then the relationship decreases. Comparing this figure with the decomposed relationship in figure 4.5 indicates a similar general shape. Thus, such a time varying smooth depicts the Portuguese primary surplus and debt ratio situation quite well and it performs rather fine. Plus, interpreting the shape in figure 4.6 from a political and economic perspective shows the upcoming European Union and Euro Zone incentive for Portugal and the efforts of adequate fiscal performance.

[8] Again, the estimation has been implemented in R 2.5.0 with *mgcv* version 1.3-23, see appendix A.

4.1.2 Additional testing for debt sustainability

As pointed out above for studying debt sustainability the regression approach from the previous subsection will be supplemented by further testing.[9] Here, a stationarity test on the real budget deficit will be used. Such an approach has been introduced by Trehan and Walsh (1991) and their idea has already been outlined in section 2.1.2, especially with equation (2.6). Calculating the real budget deficit, which is often referred to as the deficit inclusive of interest payments, means to divide the nominal amount of public debt $B^{nom}(t)$ by the GDP deflator $P(t)$. This results in the series of the real public debt $B(t)$. The budget deficits $DEF(t)$ follow from computing the first differences of those real values, i.e. $\Delta B(t)$.

Testing stationarity properties of a data series may be implemented by a unit root test. One of the most common methods is the ADF test which will be applied here. It is based on the idea to test the hypothesis of nonstationarity against the alternative of stationarity, see for example Enders (1995, pp. 221-224),

$$H_0 : \pi = 0 \quad \text{vs.} \quad H_1 : \pi < 0$$

for the regression equation which has already been presented in equation (2.6):

$$\Delta DEF(t) = \pi DEF(t-1) + \sum_{l=1}^{m} \psi_l \Delta DEF(t-l) + \epsilon(t) \tag{4.10}$$

with DEF being the real budget deficit series that has been calculated as described above. There may be different types of this test equation. For example, also a constant θ_0

$$\Delta DEF(t) = \theta_0 + \pi DEF(t-1) + \sum_{l=1}^{m} \psi_l \Delta DEF(t-l) + \epsilon(t) \tag{4.11}$$

or an additional trend may be included

$$\Delta DEF(t) = \theta_0 + \pi DEF(t-1) + \theta_2 t + \sum_{l=1}^{m} \psi_l \Delta DEF(t-l) + \epsilon(t). \tag{4.12}$$

Since the decision of which model type to use is depending on the usually unknown data generating process, it is advisable to follow the guideline outlined by Enders (1995, p. 254-258) and Pfaff (2006, p. 26-29) for instance. They suggest to start with the full model,

[9] Please note this section's reasoning is based on Fincke and Greiner (2012, sec. III) and Fincke and Greiner (2011c, sec. 4.2).

i.e. equation (4.12), and gradually adjust it according to the manual. That procedure involves testing whether the constant and the trend are actually present. Moreover, for a choice concerning the relevant number of lags l in the equations the general-to-specific approach may be employed. It implies to begin with a quite large amount of lags that may be removed stepwise once they are not statistically significant, cf. Enders (1995, pp. 226f.) or Pfaff (2006, p. 27).

For the decision of rejection or acceptance of the null hypothesis the value of the test statistic is compared to the appropriate critical value. A table for those critical values can be found in Enders (1995, p. 419) for instance. Once the critical value from the table is larger than the test statistic amount for the initial setting of equation (4.12), it is possible to end the testing procedure and reject the H_0 hypothesis: the series indicates to be stationary.

Regarding the model diagnostics, with a visual study and a Box-Ljung test (test statistic values are denoted by Q) eventual residual correlation can be checked.

4.2 Data set

The data for this country by country analysis has been taken from different sources even though they all share the same idea: to depict the government's fiscal and especially debt situation. Neither has data from the financial sector been taken into account, such as banks or financial agencies for instance, nor has the detailed perspective on the involved individual government unit or the particular financed project been considered. Rather, the focus is set on the aggregated or macroeconomic angle to illustrate the public sector's position. This study concentrates on displaying the circumstances and positions of the government on a yearly basis by resorting to official statistics with information on the economic and fiscal condition of the public sector. Thus, annual data is utilized here.

For the European countries this becomes apparent in section 4.3.1.1 as the principally used data of OECD (2010) refers to general government data. That clearly reflects the public sector adequately as it contains all subordinated governmental units, cf. OECD

(2011) for instance. The GDP deflator has been taken from International Monetary Fund (2010). Such a consistent official data source utilization facilitates country comparisons and statements on public debt sustainability. This applies especially to uniform demarcations and thus reliable information and evaluation, see also Burger (2012, fn. 2). Plus, it reduces the risk of measuring errors. Due to the application of smoothing with splines, the interest and results relate to the general shape and trend of the series and their relationship.

Regarding the Japanese and USA data set, both have mainly been taken from national sources. The USA data is reported in detail in United States Government (2008). For Japan, Japan Statistics Bureau (2009) presents substantial information on the public sector. As already mentioned in section 2.2, for Japan (financial) assets have a considerable effect. Thus, when studying public net debt, i.e. government liabilities less financial assets, that data will be taken from OECD (2009) to avoid arbitrariness and asset related problems as discussed above. Again, IMF data has been utilized for the GDP deflator with International Statistical Yearbook (2009). Please note, for the national sources attention must be paid to country specific characteristics and customs. For instance concerning the time horizon for the public sector series: the fiscal year may differ from country to country and must not comply with the calendar year. For further details on the applied Japanese and USA data sets see also Fincke and Greiner (2011c).

4.3 Estimation results

The presentation of the outcomes of the empirical approach is structured into four parts. They are derived from the theoretical reflections of chapter 3. First, the regression results based on Bohn (1998)'s idea are shown. Then, the additional stationarity properties of the budget deficit are tested as suggested by Trehan and Walsh (1991). Further, some calculations follow: initially, for the stabilized debt ratio according to Burger (2012) and, finally, for the sustainability benchmark. Please note, these results simply focus on the fiscal perspective and other effects, such as polit-economic, social or welfare aspects for instance, are neglected, cf. also Burger (2012, p. 937).

For the study eight economies have been chosen, six European and two countries from abroad. Being founding members of the European Union France and Germany have been decided on because they represent the biggest economies within the EMU. Further, an analysis of the Austrian situation is interesting because it suffers from an almost steadily increasing debt ratio. These three have been joined in a group of central European economies. For a cluster of southern European countries Greece, Italy and Portugal have been combined. Italy, also a founding member, is among the biggest economies within Europe as well, whereas Portugal has been exposed to an increasing debt ratio and applied for financial aid in 2011. Greece is in severe trouble recently and thus gives interesting insight (and the possibility to control effectiveness of the tests) to the fiscal situation. Additionally, Japan and the USA have been selected since they rank among the largest economies worldwide and, thus, should not be missing in international comparisons.

Generally, before starting with any test or estimation it is important to check whether the required assumptions hold. First, from an econometric perspective the stationarity properties of the variables should be discussed. Here, the focus is set on the debt to GDP ratio and the primary surplus ratio because they represent the main explanatory variable and the dependent variable for the sustainability approach in section 4.3.1. Especially the debt ratio may reveal a nonstationary behavior as for instance the figures for the selected countries in section 4.3.1 show. Reconsidering the stationarity test procedure according to section 4.1.2 for the debt ratio b (and neglecting the lagged control variables here) equation (4.10) is then given by:

$$\Delta b(t) = \pi \; b(t-1) + \epsilon(t)$$

which may also be conveyed to

$$b(t) = \rho \; b(t-1) + \epsilon(t) \tag{4.13}$$

with $\pi = \rho - 1$ indicating nonstationarity for $\pi = 0$ (or equivalent: $\rho = 1$), see also Enders (1995, pp. 221-224). Expressing the government's budget from equation (2.1) - also in discrete time for the purpose of comparisons - in terms of ratio to GDP gives:

$$b(t) = \frac{1 + r(t)}{1 + \gamma(t)} \; b(t-1) - s(t) \tag{4.14}$$

cf. for instance Blanchard (2000, ch. 27). On the right hand side equation (4.14) explicitly accounts for the fraction including the interest rate and the growth rate as suggested by Burger (2012, pp. 937f.) instead of the common approximation $1 + r(t) - \gamma(t)$. Because in this way, as further reasoned by Burger (2012), it is possible to show the problems of detecting (non)stationarity in time series: by simply concentrating on the debt ratio variables in equations (4.13) and (4.14) the relevant information is presented by ρ which corresponds to $\frac{1+r(t)}{1+\gamma(t)}$. For $\gamma(t) > r(t)$ the denominator exceeds the numerator indicating stationarity because $\rho < 1$ (meaning $\pi < 0$) holds. Due to the small amounts of the real interest rate and the real growth rate the fraction is close to one as for instance the averages of US data for the period from 1960 to 2007 reveal: $\bar{r} = 0.03266$ and $\bar{\gamma} = 0.03272$ give $\frac{1+\bar{r}}{1+\bar{\gamma}} = 0.99994$, see Fincke and Greiner (2011c, sec. 4.1.4) for the data. If $r(t) \geq \gamma(t)$ holds, the primary surplus $s(t)$ in equation (4.14) may compensate the influence of the aspect just discussed above and thus may still indicate stationarity of the debt ratio series. For this reasoning and discussion cf. Burger (2012, pp. 937f.).

Further, Burger (2012) notes that Bohn, when proposing his fiscal reaction test, does not specifically check for the stationarity properties of the relevant series. Here, this thesis also pursues Bohn's and Burger's style by assuming stationarity of the data. Moreover, since the estimation technique resorts to splines and time-varying coefficients instead of OLS the relationship between the primary surplus ratio and the debt ratio is not presented with a constant coefficient. Rather it allows to display the development over time. This method may be considered more flexible and robust in capturing the relationship between the two variables.

Secondly, the theoretical reflections above have shown: another essential assumption considers the difference between the interest rate and the growth rate. In excursus I in section 3.2 that condition has already been discussed theoretically. Here, the focus is set on the empirical situation in the selected economies.

Table 4.1 in excursus II indicates that for all selected economies the assumption $r(t) > \gamma(t)$, a positive difference between the real interest rate and the real growth rate, holds at least on average for certain periods. Thus, the theoretical condition of dynamic

efficient deterministic economies seems to be valid and the approach may be applied, for this reasoning see also Fincke and Greiner (2011b, sec. 3) and Fincke and Greiner (2011c, sec. 4.1.4) for instance.

Excursus II: Interest rate and growth rate gap - Empirics

The first excursus in section 3.2 has indicated the importance of the difference between the interest rate and the growth rate from a theoretical perspective. To see whether that gap is positive according to real data the table below summarizes the results.

	$(\bar{r} - \bar{\gamma})$	**Time period**
Austria	0.0079	1971-2008
France	0.0085	1971-2008
Germany	0.0162	1971-2009
Greece	0.0037	1993-2009
Italy	0.0185	1980-2009
Portugal	0.0137	1980-2009
Japan	0.0121	1980-2006
USA	0.0148	1980-2007

Table 4.1: Interest rate and growth rate gap for selected countries.

The data for Austria, France, Germany, Italy and Portugal has been taken from OECD (2010) and for Greece from International Monetary Fund (2010). However, that is continuously available only from 1993 onwards. Also, for Italy the time period had to be adjusted. For the US and Japanese data see United States Government (2008), Japan Statistics Bureau (2009) and International Statistical Yearbook (2009) respectively. For both of them the earlier years have been shaped by higher economic growth rates as discussed in Fincke and Greiner (2011c, sec. 4.1.4) that result in a negative $r - \gamma$ gap. The situation changed with the 1980s and from then on that difference has been positive. Thus, for all selected countries a positive $r - \gamma$ gap may be realized, at least on average for the past 15 to 20 years.

4.3.1 Regression approach

This chapter presents the fiscal sustainability conditions according to Bohn (1998)'s regression approach with the spline estimation method introduced in section 4.1.1. The studies account for time varying coefficients. Initially all of the sections depict a visual impression of the relevant series. Then, the estimation results are presented and interpreted from a debt sustainability perspective. The starting point of the regression equation is again equation (2.7) from section 2.1.2:

$$s(t) = \upsilon(t)\, b(t) + \mathbf{Z}(\mathbf{t})\alpha + \epsilon(t), \tag{4.15}$$

that is now combined with the reasoning discussed in section 3.2 and especially equation (3.8) to include the time varying coefficient idea. Of course, the reaction coefficient $\upsilon(t)$ remains the parameter of interest to check for debt sustainability. To cover a broad scope of model designs and to emphasize robustness of the approach, different settings of the control variables in $\mathbf{Z}$ are presented. However, to assure comparability within each country cluster the same model type is applied.

4.3.1.1 Europe

The first part in section 4.3.1.1.1 concentrates on the three central European countries Austria, France and Germany. They all are members of the European Monetary Union and share a sound fiscal reputation. The second component in section 4.3.1.1.2 studies the group of the three southern EMU economies Greece, Italy and Portugal, that have recently got into trouble and are part of the so-called PIIGS countries, i.e. Portugal, Italy, Ireland, Greece and Spain. The period for their estimations has been chosen according to availability and quality of data.

4.3.1.1.1 Central European countries

To start in alphabetical order, the first economy that will be analyzed is Austria.[10] Then, France and Germany follow. Here, equation (4.15) is formulated by

$$s(t) = \alpha_0 + \upsilon(t)\, b(t-1) + \alpha_1 YVar(t) + \alpha_2 Soc(t) + \epsilon(t). \tag{4.16}$$

Meaning $\mathbf{Z}$ consists of $YVar$ and Soc besides the intercept. $YVar$ is a form of business cycle variable and accounts for revenue variations. It is calculated by the deviations of the

[10] Please note, the reasoning of this section is based on Fincke and Greiner (2012).

real GDP series from its trend, which is obtained (via *log*) by HP (Hodrick-Prescott) filtering. *Soc* accounts for the surplus of social security systems as ratio to GDP. This variable is considered for the central European countries because of their distinctive social insurance systems. If revenues in these systems do not cover the expenditures, governments often support them financially. Thus, it addresses a special kind of public expenditure. For the coefficients of both variables it is reasonable to expect a positive sign. Of course, for sustainability $v(t)$ is also supposed to be positive on average. The lagged debt ratio $b(t-1)$ is included because of different reasons. First, usually budget plans and decisions are made in advance. Thus, corrective actions are only possible lagged in time. Moreover, from a technical perspective it avoids potential endogeneity problems. For further information and additional country studies with this model see Fincke and Greiner (2012) for instance.

AUSTRIA

Like in many other European countries, Austria's public debt has continuously been increasing for the last three or four decades. For a first impression figures 4.7 and 4.8 depict the Austrian public debt to GDP ratio and the primary surplus to GDP ratio respectively for the period from 1971 until 2008, see OECD (2010) for the data.[11] This reflects the same series that have already been used for the illustration of the estimation method in section 4.1.1.

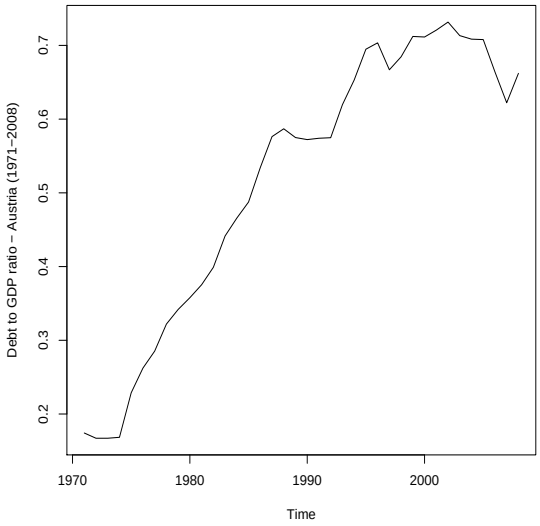

Figure 4.7: Public debt to GDP ratio for Austria (1971-2008).

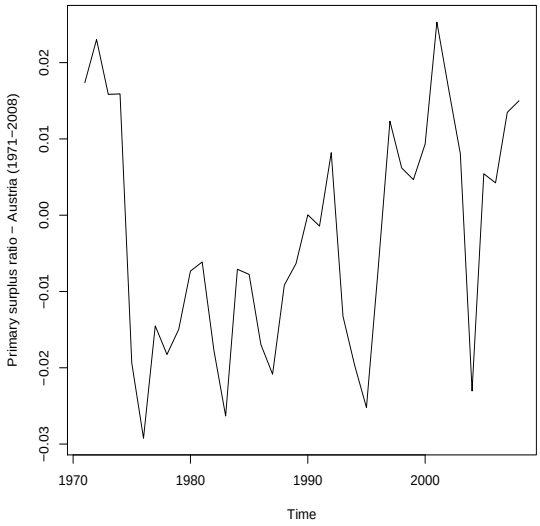

Figure 4.8: Primary surplus to GDP ratio for Austria (1971-2008).

[11] Again, the graphics have been constructed with R 2.5.0.

The Austrian public debt ratio is shaped by a remarkable steady increase starting in the mid 1970s, e.g. Neck and Haber (2008) relate it to the first oil price shock in 1975, and it eventually stopped towards the end of the 1980s. When looking at the primary surplus ratio, figure 4.8 shows that for this time period the debt ratio trend was accompanied by persistent primary deficits. Here, the minimum of the primary balance in 1976 of -2.9 %, that has already been mentioned in connection with figure 4.2, is visible. However, the slowdown of the debt ratio trend in the 1990s and the fiscal discipline, expressed through some balanced primary budgets, may be due to the upcoming Austrian EU entry in 1995. A plateau around the year 2000 of the debt ratio with values around 70 % can be observed from figure 4.7. Around that time also the maximum of the primary surplus with 2.5 % in 2001 occurred. All in all for Austria a continuous rise in debt ratio can be noticed with changing primary surplus movements, that call for a closer study of the debt sustainability situation with the regression approach from equation (4.16). This allows to see how the primary surplus ratio reacted to variations in debt ratio. Table 4.2 summarizes the results, see OECD (2010) and International Monetary Fund (2010) for the data.[12]

	Coefficient	**Stand. error (t-stat)**	**Pr(>t)**
Constant	0.008	0.029 (0.263)	0.794
$b(t-1)$	0.118	0.065 (1.804)	0.083
$YVar(t)$	0.078	0.108 (0.716)	0.480
$Soc(t)$	2.261	0.687 (3.290)	0.003
sm(t)	edf 7.314	F 7.775	p-value $1.58 \cdot 10^{-5}$
	R^2(adj): 0.66	DW: 1.85	

Table 4.2: Estimation results for equation (4.16) for Austria (1971-2008).

Starting with the coefficient of interest $\bar{v}$, table 4.2 shows it is positive and statistically significant. Thus, there is indication of debt sustainability for Austria. Even though it shows only a low significant level of 10 %. Further, neither the intercept nor the business cycle variable are statistically significant. But the coefficient for the social security surplus also seems to be relevant. The diagnostics with the goodness of fit $R^2(adj) = 0.66$ and the Durbin Watson test $DW = 1.85$ imply suitability of the model and do not suggest autocorrelation of the residuals. Information on nonlinearities - here in terms of the time varying component - is presented with the smooth term sm, which is highly significant

[12] For the estimations in R 2.5.0 the package *mgcv* version 1.3-23 has been used.

for the Austrian estimation. The estimated degrees of freedom *edf* 7.314 indicate strong signals for time variation of the reaction coefficient. How this development of the smooth term looks like is presented in figure 4.9.

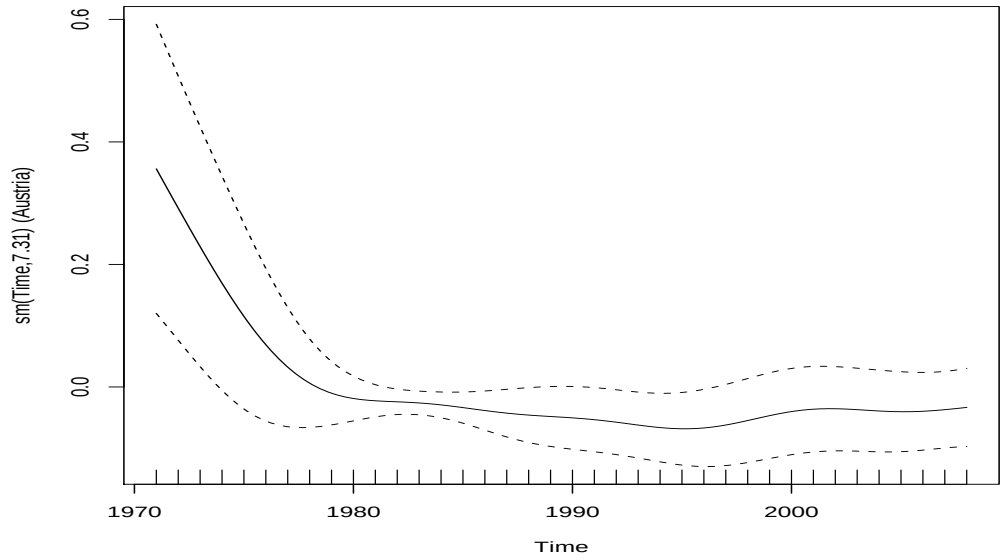

Figure 4.9: Deviation $sm(t)$ from the average coefficient for $b(t-1)$ for Austria.

The shape of the graph in figure 4.9 clearly shows a decreasing trend that has settled a low level from the 1980s onwards. From an economic point of view this decline can be interpreted as a reduced emphasis on debt stabilization and consequently fiscal sustainability. This is also consistent with the observed increase in debt ratio over time in figure 4.7. A slight advancement seems apparent for the end of the 1990s. Here, again the European participation effect of enforcing sound public finance performance might matter. This outcome is supported for instance by Haber and Neck (2006, p. 152f.)'s finding of a positive influence of the Maastricht treaty on the primary balance for Austria.

However, as pointed out above, the smooth term is centered, so zero in the smooth graphic denotes the average value. Therefore, for a particular point in time, the concrete value of the reaction coefficient $v(t)$ is composed by the respective value of the smooth term $sm(t)$ from the smooth graph and the average value $\bar{v}$ given by the main effect coefficient in the table, cf. also Greiner and Schütt (2009, p. 173) for instance.

Adding these components together and summing up the regression outcome indicates a positive reaction coefficient over the time period and the results suggest public debt sustainability for Austria.

FRANCE

Next, the French public debt and primary surplus situation will be analyzed particularly with regard to fiscal sustainability. As figures 4.10 and 4.11 illustrate France has also experienced an increasing debt ratio over the last thirty years.

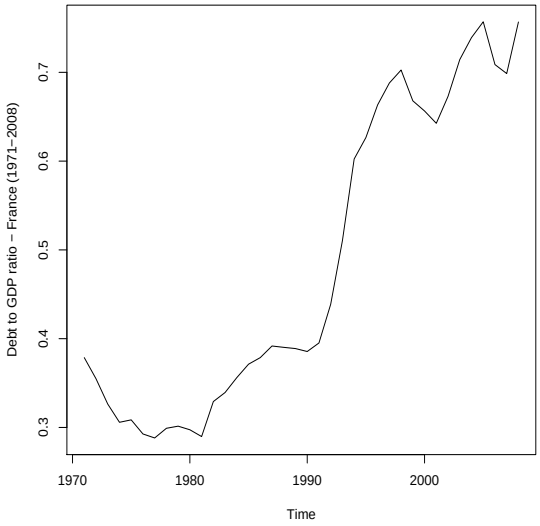

Figure 4.10: Public debt to GDP ratio for France (1971-2008).

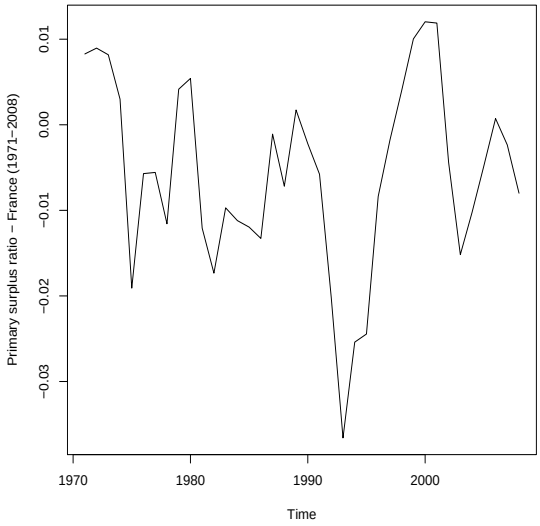

Figure 4.11: Primary surplus to GDP ratio for France (1971-2008).

With a decreasing trend at a low level until the 1980s the French debt ratio afterwards rose moderately until the 1990s as figure 4.10 shows. From then on it almost doubled within a few years to a first peak in 1998 of 70.3 %. During that period also the largest deficit of 3.7 % in 1993 was run according to figure 4.11. These persistent deficits contributed to the fast rise in debt ratio. Is such a development compatible with debt sustainability? To answer that question again equation (4.16) is estimated for France for the time period from 1971 until 2008, see again OECD (2010) and International Monetary Fund (2010) for the data. Table 4.3 presents the outcome.

The results for France indicate statistical significant coefficients for all included variables, though of lower value for the social security surplus ratio Soc. Of particular interest is the positive and highly significant reaction coefficient $\bar{v}$. It suggests debt sustainability for France despite the increasing debt ratio. The diagnostics with $R^2(adj) = 0.809$ and the Durbin Watson test statistic around two suggest a suitable model and no correlation in the residuals. For the time varying model component the smooth term sm indicates

	Coefficient	**Stand. error (t-stat)**	**Pr(>t)**
Constant	-0.103	0.020 (-5.211)	$1.84 \cdot 10^{-5}$
$b(t-1)$	0.187	0.045 (4.123)	0.0003
$YVar(t)$	0.336	0.080 (4.211)	0.0003
$Soc(t)$	0.683	0.276 (2.480)	0.0198
sm(t)	edf 7.569	F 16.23	p-value $1.24 \cdot 10^{-8}$
	R^2(adj): 0.809	DW: 2.07	

Table 4.3: Estimation results for equation (4.16) for France (1971-2008).

strong time dependency. The development of the deviations from the average value is illustrated in figure 4.12.

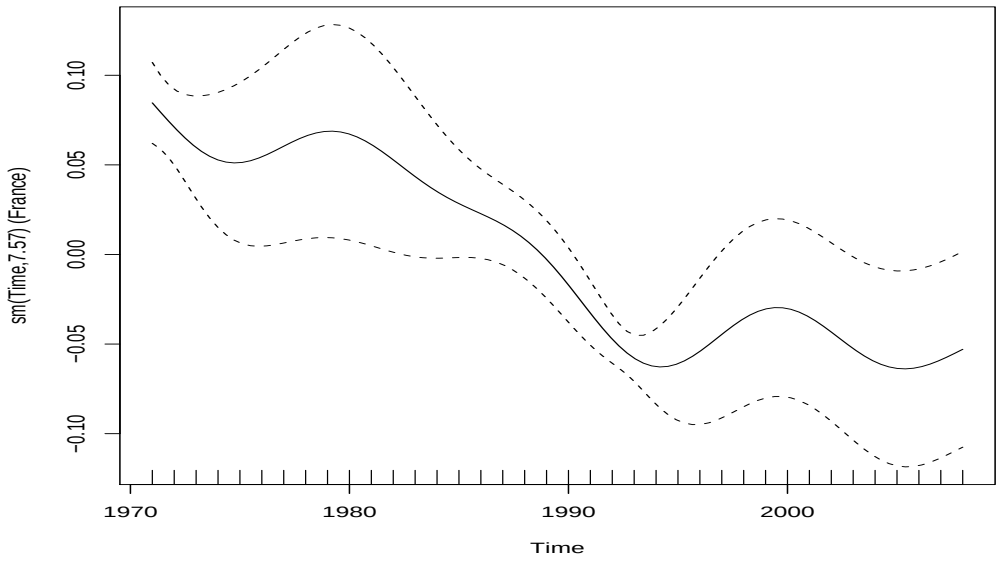

Figure 4.12: Deviation $sm(t)$ from the average coefficient for $b(t-1)$ for France.

Just like for Austria, the French graph of the smooth term in figure 4.12 also declines, albeit more wiggly over time. A steady drop from the 1980s until about 1994 was followed by a minor upward movement until around 2000. Then, the decline continues with some improvement in more recent years. This general shape also indicates a decreasing accent on debt stabilization over time.

Since the addition of the graph's values and the average coefficient for $b(t-1)$ are positive for the considered time horizon the estimation result implies fiscal sustainability for France.

GERMANY

The last central European economy under consideration in this section is Germany. Again, for a first impression the public debt ratio and primary surplus ratio are depicted.[13]

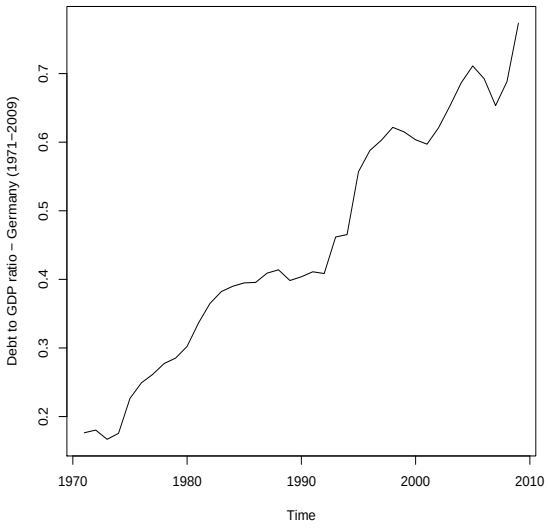

Figure 4.13: Public debt to GDP ratio for Germany (1971-2009).

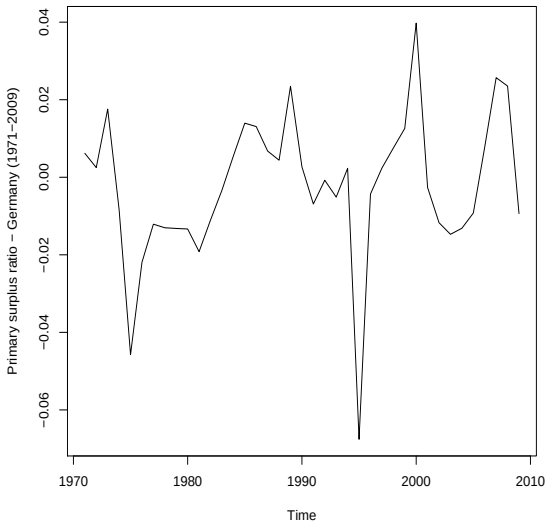

Figure 4.14: Primary surplus to GDP ratio for Germany (1971-2009).

Figure 4.13 shows that Germany has also been exposed to a rising debt ratio since the 1970s. A moderate increase is observable until the middle 1990s. Then, a considerable rise occurred, for which the Reunification has mattered, that eased a little towards the early 2000s, before the upward trend proceeded. Regarding the primary balances in figure 4.14, deficits shape the time period from the middle of the 1970s until the early 1980s. Then, they are replaced by surpluses and balanced budgets until the early 1990s. With a deficit of over 6 % a distortion is shown for 1995.[14] The more recent observations show up- and downward changes. In general for Germany an increasing trend in its debt ratio can be realized. In a next step fiscal sustainability is tested again with equation (4.16). The estimation results for the period from 1971 to 2009 are given by table 4.4.

[13] Please note, until 1991 data for West Germany are used for Germany. The sources are the same as above.

[14] An outlier effect for 1995 has been identified by Joumard et al. (2008, p. 31) as a one-off operation of debt assumption with the Inherited Fund (German: Erblastentilgungsfond). They also recognize the UMTS license sale in 2000 as a balance improving effect, cf. ibid. However, since the outcomes of sustainability studies for Germany by for instance Greiner and Kauermann (2008) and Greiner and Schütt (2009) are similar, the general result and conclusion of this analysis seems to apply.

	Coefficient	**Stand. error (t-stat)**	**Pr(>t)**
Constant	-0.136	0.038 (-3.566)	0.001
$b(t-1)$	0.366	0.105 (3.479)	0.002
$YVar(t)$	0.254	0.130 (1.949)	0.061
$Soc(t)$	1.156	0.525 (2.203)	0.036
sm(t)	edf 6.818	F 4.407	p-value 0.0012
	R^2(adj): 0.53	DW: 2.38	

Table 4.4: Estimation results for equation (4.16) for Germany (1971-2009).

The estimation outcome shows significant coefficients for all variables, that also possess the expected signs. Especially, since the mean of the reaction coefficient is positive it indicates a sustainable debt policy path for Germany. Again, the diagnostics are fine. Further, the smooth parameter suggests non linear behavior with the high *edf* value. How the graph evolves over time is illustrated in figure 4.15.

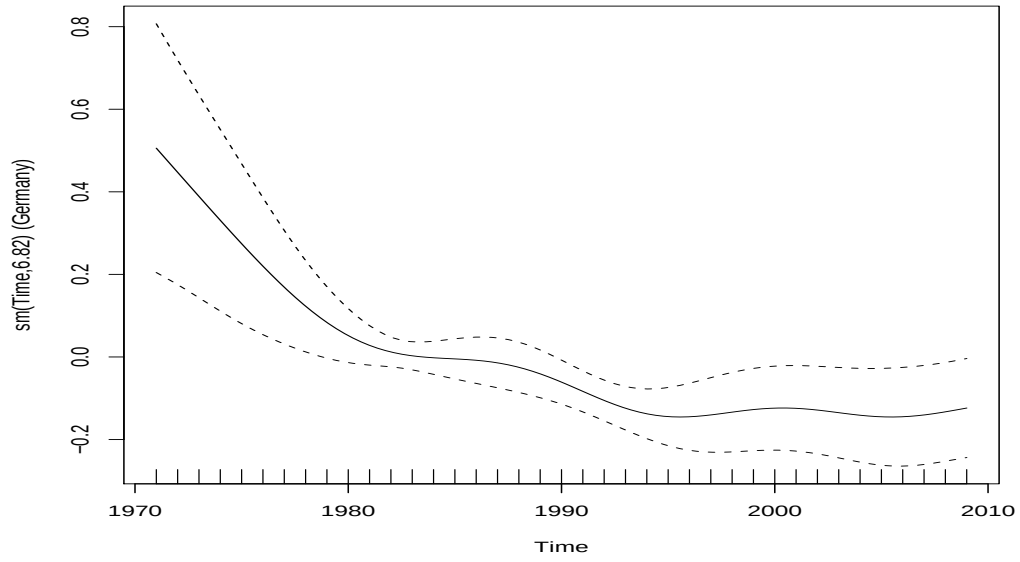

Figure 4.15: Deviation $sm(t)$ from the average coefficient for $b(t-1)$ for Germany.

In general figure 4.15 shows a declining trend that stabilized within the 1990s. Again, this means a loss of priority and relevance of debt stabilization over the considered years. However, since the sum of the mean of the reaction coefficient from table 4.4 and the values of the run of the smooth graph has been positive over these years, the estimation indicates a sustainable debt policy for Germany.

4.3.1.1.2 Southern European countries

The second group of European economies for which debt sustainability will be analyzed consists of Greece, Italy and Portugal.[15] For these countries such studies are particularly relevant as they have recently got into fiscal trouble and Greece and Portugal received financial support from special programs to stabilize their public finances and economies. Those programs also involve an austerity policy for which, amongst other aspects, the revenue and expenditure side of the public budget are involved. To account for that, instead of Soc a more general expenditure variable $GVar$ is included into the regression equation. $GVar$ is constructed similar to $YVar$: it reflects the variations of real public expenditures from their trend. For calculating $GVar$, the trend, which is obtained by HP filtering, is subtracted from the realized values. It is reasonable to expect a negative sign for this coefficient because if the expenditures are above their trend, the effect on the primary surplus will probably be negative. Thus, equation (4.16) modifies to:

$$s(t) = \alpha_0 + \upsilon(t)\, b(t-1) + \alpha_1 YVar(t) + \alpha_2 GVar(t) + \epsilon(t). \tag{4.17}$$

The explanations for the other variables remain valid. For further details see Fincke and Greiner (2011b).

GREECE

The first country under consideration is Greece. Data for the years from 1976 until 2009 is applied. Meaning the time period starts shortly after the end of the military regime and ends before the serious difficulties of the recent crisis arose. A first financial aid was resolved in spring 2010. To get an impression of the fiscal situation of Greece for that time horizon figures 4.16 and 4.17 show the series of the public debt ratio and the primary surplus ratio respectively, again see OECD (2010) and International Monetary Fund (2010) for the data.[16]

The graphics for Greece show, that not only an almost steady increase of the debt ratio occurred but also the magnitude is remarkable. The public debt ratio in figure 4.16 rose from around 20% to over 110 % of GDP within twenty years. That development was accompanied by high levels of the primary deficits as shown in 4.17. Especially during the 1980s persistent primary deficits oscillated around 5% of GDP. By achieving some

[15] Please note, this section's reasoning is based on Fincke and Greiner (2011b).

[16] For this section R version 2.9.0 and *mgcv* version 1.6-1 have been used for the figures and estimations.

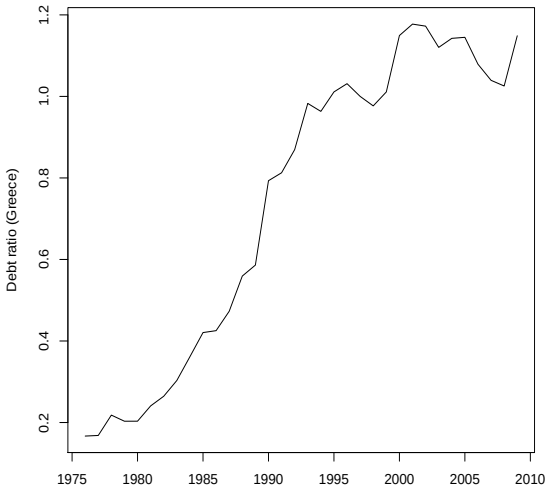

Figure 4.16: Public debt to GDP ratio for Greece (1976-2009).

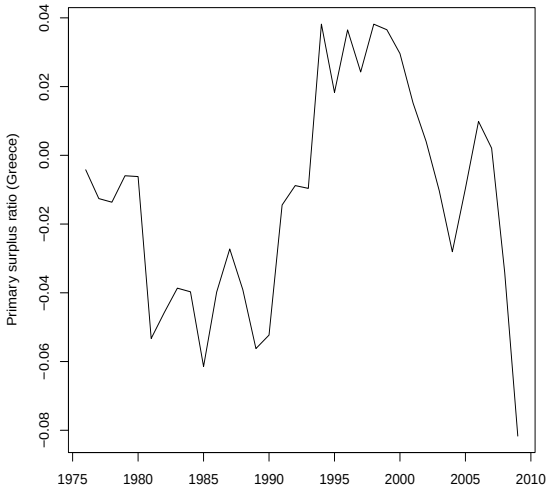

Figure 4.17: Primary surplus to GDP ratio for Greece (1976-2009).

primary surpluses in the late 1990s and a few subsequent years Greece was able to slow down the trend and stabilize its debt ratio around the early 2000s - even though at a high value. However, the current developments have worsened the situation. To see whether this fiscal evolution is compatible with debt sustainability equation (4.17) is estimated for the Greek data. Table 4.5 gives the results.

	Coefficient	**Stand. error (t-stat)**	**Pr(>t)**
Constant	-0.017	0.045 (-0.377)	0.71
$b(t-1)$	-0.402	0.126 (-3.202)	0.004
$YVar(t)$	0.504	0.127 (3.957)	$7.12 \cdot 10^{-4}$
$GVar(t)$	-0.399	0.09 (-4.415)	$2.37 \cdot 10^{-4}$
sm(t)	edf 9.343	F 19.88	p-value $1.77 \cdot 10^{-8}$
	R^2(adj): 0.886	DW: 1.98	

Table 4.5: Estimation results for equation (4.17) for Greece (1976-2009).

Except for the intercept all variables are statistically significant and $YVar(t)$ and $GVar(t)$ possess the expected signs. For the reaction coefficient table 4.5 presents a negative average value. It indicates that Greece lowered its primary surplus in times of increasing debt ratios. The diagnostics indicate suitability of the model. Further, the

smooth term is significant and suggests time variation. Its development is illustrated in figure 4.18.

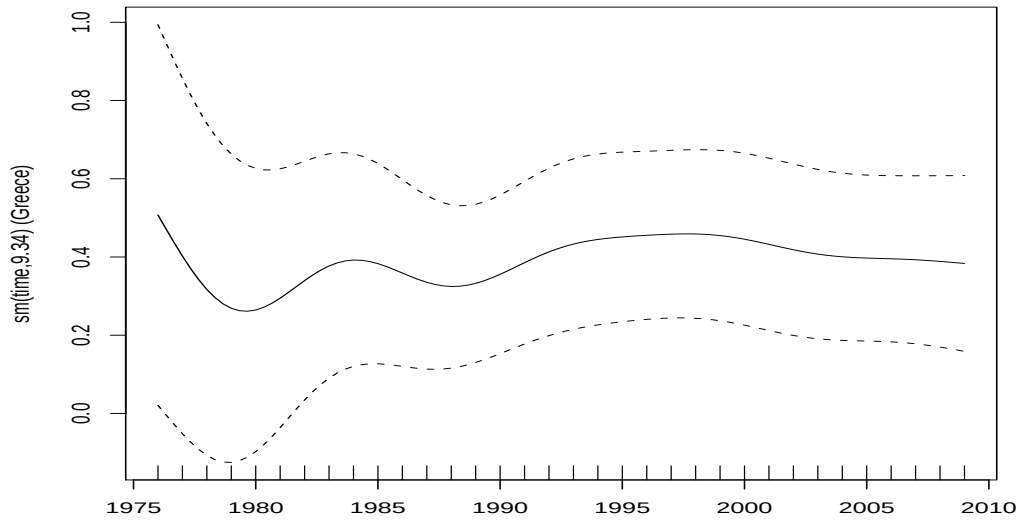

Figure 4.18: Deviation $sm(t)$ from the average coefficient for $b(t-1)$ for Greece.

The run of the smooth term shows some fluctuations for the early phase of the time horizon. Then, beginning with the 1990s the shape remains mainly unchanged. Adding up again the mean of the reaction coefficient from table 4.5 and the smooth graph points shows positive values only for the early stage of the period and a few years in the late 1990s.

Summing up the debt sustainability analysis outcome for Greece it can be stated that its fiscal policy for this time period cannot be considered sustainable. Plus, the study's observations ended in 2009. Against the background of this result the recent severe difficulties did not emerge all that surprisingly.

ITALY

The next economy to be analyzed for debt sustainability is Italy. Like many of the European countries it also suffered from an increasing and high debt ratio over the last years. Figures 4.19 and 4.20 illustrate the development of the debt to GDP ratio and the primary surplus ratio, respectively, for the period from 1972 until 2009. The data sources from above have been maintained.

As figure 4.19 shows the Italian debt to GDP ratio already started with a high level of 66% in 1972. From then on it rose considerably over time and doubled within less than

Figure 4.19: Public debt to GDP ratio for Italy (1972-2009).

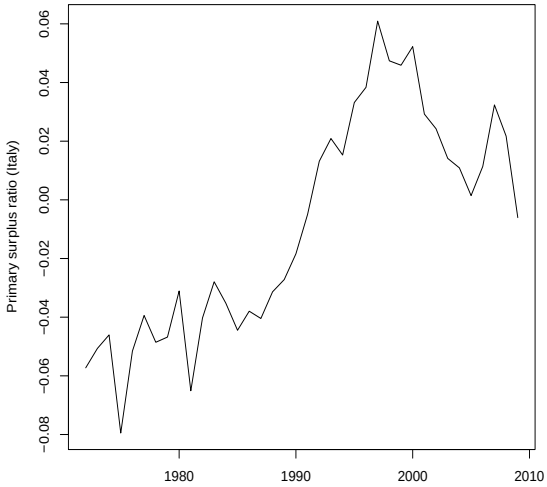

Figure 4.20: Primary surplus to GDP ratio for Italy (1972-2009).

thirty years to the peak of 132% of GDP in 1998. Afterwards a downward trend appears that has been reversed with the most recent observations. Galli and Padovano (2008) reveal that Italy's public finances are likely to be influenced by institutional aspects, such as the Maastricht Treaty effect for example. For the primary balances figure 4.20 presents an increasing development that turned the permanent deficits of the seventies and eighties into surpluses from 1992 onwards. However, after the maximum of 6% in 1997 a more or less decreasing tendency occurs. As identified by Joumard et al. (2008) the impact of the temporary *eurotassa*, the 'Euro-tax', displays in 1997. Graphically the Italian situation appears promising for the sustainability idea with the upward movement of the primary balance for the period of the rising debt ratios. With equation (4.17) debt sustainability is estimated for the Italian data. In table 4.6 the outcome is presented.

The estimated coefficients shown in table 4.6 possess the expected signs and the parameter of interest, $\bar{v}$, is positive. But it is not statistically significant which means, a conclusion concerning sustainability of Italy's debt policy is not possible. It should be noted that debt sustainability estimations for Italy strongly depend on the applied time period, for a small discussion see Fincke and Greiner (2011b, p. 11) for instance. The path of the significant smooth term over time is depicted in figure 4.21.

	Coefficient	**Stand. error (t-stat)**	**Pr(>t)**
Constant	-0.078	0.044 (-1.775)	0.087
$b(t-1)$	0.012	0.022 (0.531)	0.599
$YVar(t)$	0.238	0.117 (2.032)	0.052
$GVar(t)$	-0.026	0.115 (-0.228)	0.821
sm(t)	edf 6.545	F 9.89	p-value $2.39 \cdot 10^{-6}$
	R^2(adj): 0.927	DW: 1.82	

Table 4.6: Estimation results for equation (4.17) for Italy (1972-2009).

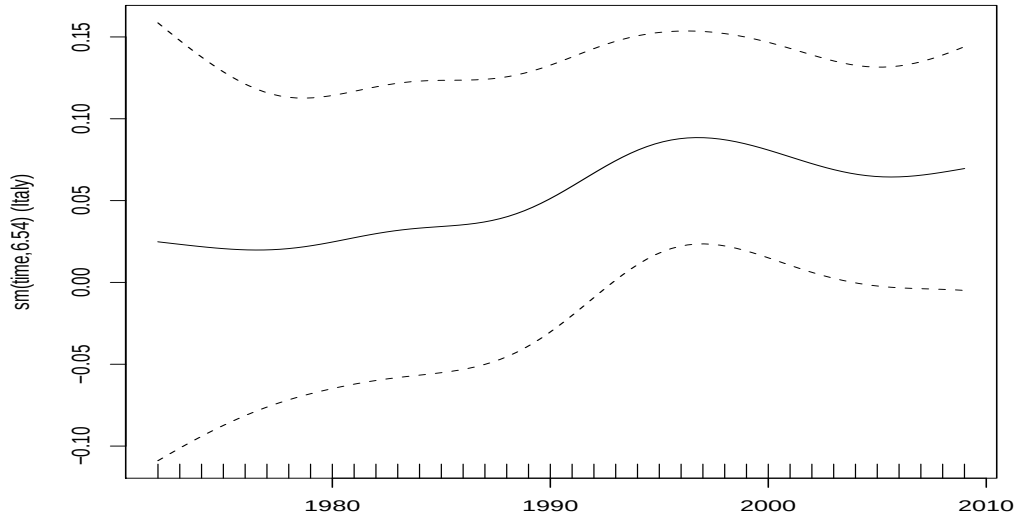

Figure 4.21: Deviation $sm(t)$ from the average coefficient for $b(t-1)$ for Italy.

Figure 4.21 illustrates a slightly increasing shape of the curve with a peak in the late 1990s. This enhanced emphasis on debt stabilization and fiscal performance may be influenced by the more pressing European aspects around that time.

No final statement on Italy's debt sustainability can be drawn from the estimation only.

PORTUGAL

Finally, the Portuguese economy will be considered. Again, for an illustration of the fiscal situation the debt ratio and the primary balance ratio to GDP are depicted. As for Italy, the data sources remain unchanged. The Portuguese situation has already been

glanced through in section 4.1.1 as to the motivation of time varying coefficient models.

Figure 4.22: Public debt to GDP ratio for Portugal (1977-2009).

Figure 4.23: Primary surplus to GDP ratio for Portugal (1977-2009).

For Portugal figure 4.22 shows the debt ratio has increased over the considered time period with a steep increase in the early 1980s, then some up and down changes around a level of 60% until 2000. Afterwards the upward trend continues. Initially, the primary balance ratio in figure 4.23 is generally shaped by an increasing tendency that reached surpluses in the 1990s. The peak in 1992 has already been mentioned above with relation to figures 4.4 and 4.5. For the second half of the observations the primary surplus ratios declined. To see whether the Portuguese fiscal stance is consistent with debt sustainability equation (4.17) is tested. In table 4.7 the results are shown.

	Coefficient	**Stand. error (t-stat)**	**Pr(>t)**
Constant	-0.078	0.021 (-3.724)	$9.54 \cdot 10^{-4}$
$b(t-1)$	0.073	0.02 (3.578)	0.001
$YVar(t)$	0.294	0.099 (2.965)	0.006
$GVar(t)$	-0.205	0.061 (-3.359)	0.002
sm(t)	edf 3.478	F 9.264	p-value $6.76 \cdot 10^{-5}$
	R^2(adj): 0.71	DW: 2.03	

Table 4.7: Estimation results for equation (4.17) for Portugal (1977-2009).

Focusing the discussion of the estimation outcome on the reaction coefficient table 4.7

shows it is positive and statistically significant. This indicates a sustainable debt policy of the Portuguese government despite the monotonic rise in debt ratio. The other coefficients are also significant. Due to the diagnostics information the model seems to be suitable. Further, the significant smooth term sm indicates variation over time for the reaction coefficient. Its graph is plotted in figure 4.24.

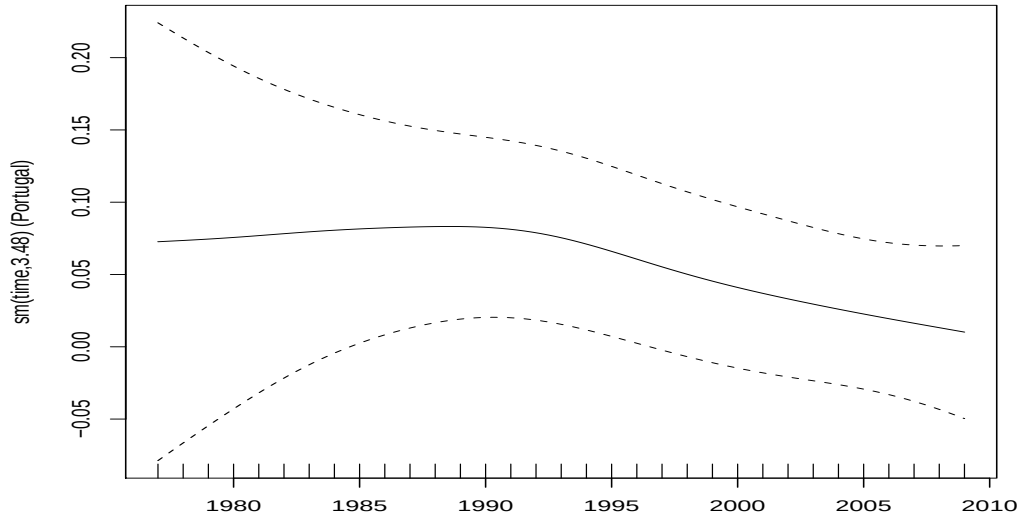

Figure 4.24: Deviation $sm(t)$ from the average coefficient for $b(t-1)$ for Portugal.

The shape of the curve in figure 4.24 mainly shows no changes until the nineties. Afterwards it dropped a little. Looking at the composed reaction coefficient $\upsilon(t)$ it is possible to conclude from this estimation that the results suggest debt sustainability for Portugal.

However, the study ends in 2009. With the intensification of the crisis the difficulties deteriorated and the economy got into severe trouble. Eventually, Portugal was forced to apply for international financial support from the joint (EFSM, EFSF, IMF) program in spring 2011.

For an intermediate result it is possible to resume for the selected European countries that the estimations indicate debt sustainability for Austria, France Germany and Portugal. According to the approach they reacted to rising debt ratios by enhancing their primary surplus ratios. For Italy no precise conclusion can be made. Indeed, the reaction coefficient is positive but it is not statistically significant. Finally, the Greek government obviously implemented an unsustainable fiscal policy.

4.3.1.2 Overseas

The second group of countries to be analyzed for debt sustainability according to Bohn (1998)'s test consists of Japan and the USA.[17] They are among the largest industrialized economies and thus should not be omitted for a comparative review. Moreover, Japan has accumulated an enormous debt ratio over the last years and, therefore, fiscal sustainability studies are especially interesting. For the estimation the same variables as in section 4.3.1.1.2 for the southern European countries are included. So, equation (4.17) can be reconsidered:

$$s(t) = \alpha_0 + \upsilon(t)\, b(t-1) + \alpha_1 YVar(t) + \alpha_2 GVar(t) + \epsilon(t).$$

The notation of the variables remains valid from above. For further information see Fincke and Greiner (2011c).

4.3.1.2.1 Japan

As mentioned above the Japanese public debt conditions have deteriorated. To get an idea of the circumstances, figures 4.25 and 4.26 show the Japanese public debt and primary surpluses relative to GDP, respectively, for the years from 1966 to 2006, cf. Japan Statistics Bureau (2009) for the data.[18] For a longer time period and a historical approach of the Japanese public debt situation see Fincke and Greiner (2011c, sec. 3) for example. The starting point in 1966 (with regard to the lagged estimation approach) has been chosen because in 1965 Japan's government had to give out bonds for the first time in post-war years, cf. Asako et al. (1991, pp. 452f.) or Ihori et al. (2001, sec. 1) for instance.

Figure 4.25 shows the remarkable increase in debt ratio for Japan: first from the middle of the seventies until the middle of the eighties and then, especially severe since the 1990s. The latter may be explained with the breakdown of the bubble economy. Starting from a moderate value of 6.7% in 1966 the public debt ratio has reached 50% by 1985. The rise after 1991 is exceptional and within a few years the maximum of 164.4% of GDP has been attained. This rapid increase in the middle of the 1990s has been accompanied by primary deficits as figure 4.26 shows. The about 10 years before had been shaped by surpluses. To see whether this development of the Japanese fiscal situation can be

[17] Please note, this section's analysis for Japan and the USA is based on Fincke and Greiner (2011c).

[18] The figures and estimations have been implemented in R version 2.5.0.

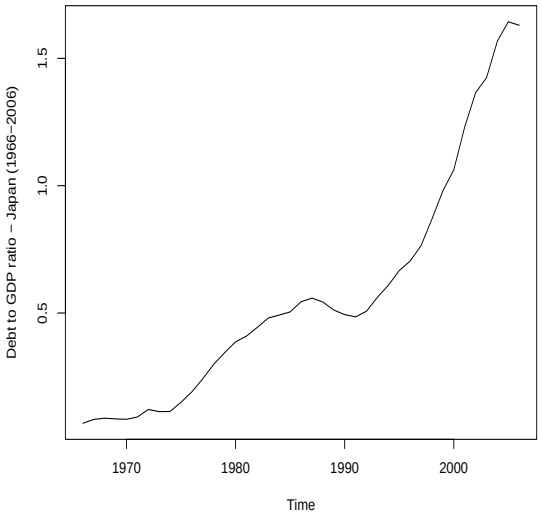

Figure 4.25: Public debt to GDP ratio for Japan (1966-2006).

Figure 4.26: Primary surplus to GDP ratio for Japan (1966-2006).

considered sustainable, equation (4.17) is estimated, see Japan Statistics Bureau (2009) and International Statistical Yearbook (2009) for the data. In table 4.8 the results of the regression are presented.[19]

	Coefficient	**Stand. error (t-stat)**	**Pr(>t)**
Const.	-0.008	0.007 (-1.163)	0.254
$b(t-1)$	0.015	0.031 (0.464)	0.646
$YVar(t)$	0.168	0.030 (5.558)	$4.71 \cdot 10^{-6}$
$GVar(t)$	-0.057	0.024 (-2.375)	0.024
sm(t)	edf: 6.789	F: 46.27	p-value $3.17 \cdot 10^{-15}$
	R^2(adj): 0.937	DW: 1.86	

Table 4.8: Estimation results for equation (4.17) for Japan (1966-2006).

As shown in table 4.8 the average reaction coefficient for Japan is positive. But no statistical significance seems to be given. Just for $YVar$ and $GVar$ significance is shown. The diagnostics indicate a fair fit of the model and the significant smooth term again signals deviations from the average value of υ over time. That development is shown in figure 4.27.

[19] Please note, here *mgcv* package version 1.3-28 has been used. For more tested regression types for Japan please see Fincke and Greiner (2011c, sec. 4.1.1).

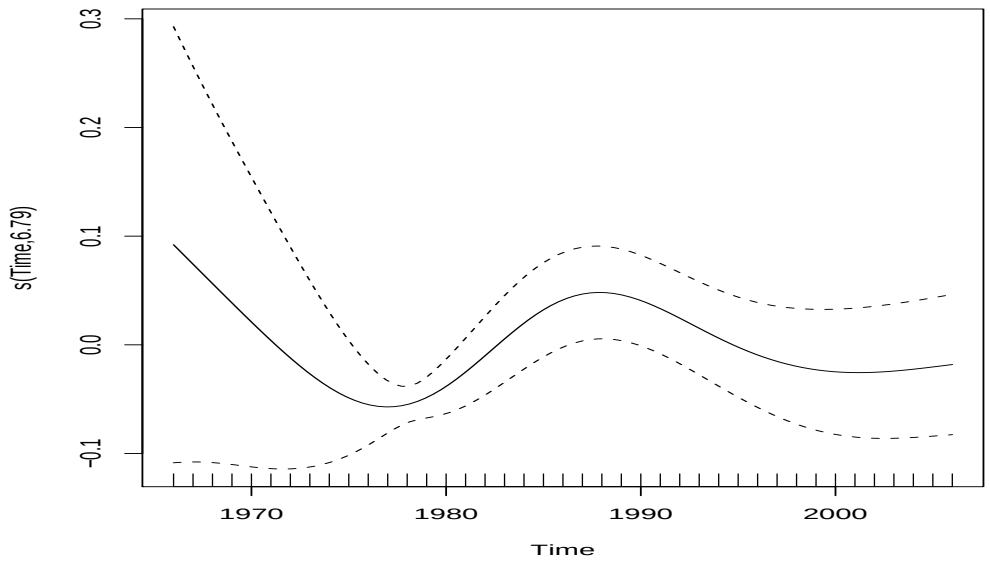

Figure 4.27: Deviation $sm(t)$ from the average coefficient for $b(t-1)$ for Japan.

Adding the smooth term values of the graph and the mean from table 4.8 together gives the combined reaction coefficient. It reveals negative values around the middle of the 1970s until the early 1980s and then again since the middle of the 1990s. Both periods correspond to the increases in debt ratio as shown in figure 4.25. They can be interpreted as a fallen focus on debt stabilization. However, no explicit statement on sustainability can be made due to the lack of statistical significance.

As stated above, for Japan financial assets matter a lot. For instance in 2007 Japan's financial assets summed up to over 80% of GDP - about four times higher than in the USA for example, see OECD (2012) for the data. So, for a more profound analysis public net debt is taken into account now, for the net debt data see OECD (2009) available from 1970 on.[20] The other data and sources have been maintained. The development of the Japanese net debt relative to GDP is presented in figure 4.28.

Clearly, the general net debt ratio pattern is alike and comparable with the shape of gross debt in figure 4.25. Figure 4.28 shows, Japan's public net debt ratio is also characterized by the two jumps: the moderate one in the middle of the seventies and the abrupt one beginning in the 1990s. Now, sustainability is again addressed with equation (4.17)

[20] Since Italy's financial asset to GDP ratio was only about 25% in 2007, which is less than a third of Japan's, this approach will merely be implemented for Japan, see again OECD (2012) for the data.

Figure 4.28: General government net financial liabilities, Japan (1970-2006).

accounting for net debt for the years from 1971 until 2006. Table 4.9 presents the results.

	Coefficient	**Stand. error (t-stat)**	**Pr(>t)**
Const.	-0.016	0.002 (-8.650)	$7.20 \cdot 10^{-9}$
$b(t-1)$	0.036	0.007 (5.181)	$2.57 \cdot 10^{-5}$
$YVar(t)$	0.365	0.056 (6.586)	$7.89 \cdot 10^{-7}$
$GVar(t)$	-0.111	0.030 (-3.690)	0.001
sm(t)	edf: 7.804	F: 53.07	p-value $9.54 \cdot 10^{-14}$
	R^2(adj): 0.953	DW: 2.31	

Table 4.9: Estimation results for equation (4.17) with net debt for Japan (1971-2006).

The outcome indicates a positive and highly significant average reaction coefficient, that seems to have changed over time. The intercept and the other coefficients for the business cycle $YVar$ and for the public expenditure deviations $GVar$ are also significant. Plus, the latter have the expected signs. The diagnostics with $R^2(adj) = 0.953$ and the DW test suggest a good fit. Interesting for sustainability aspects is again the shape of the smooth term sm over time. It is shown in figure 4.29. Again, the sum of both, the smooth term values from the graph and the mean from the table, is considered for the actual time varying reaction coefficient. Thus, negative values are specified only for the years prior to 1980 and the observations in the new century. Further, it reveals increased emphasis on debt stabilization since the middle of the seventies that changed and dropped

with the developments in the 1990s. Recently the decrease has decelerated.

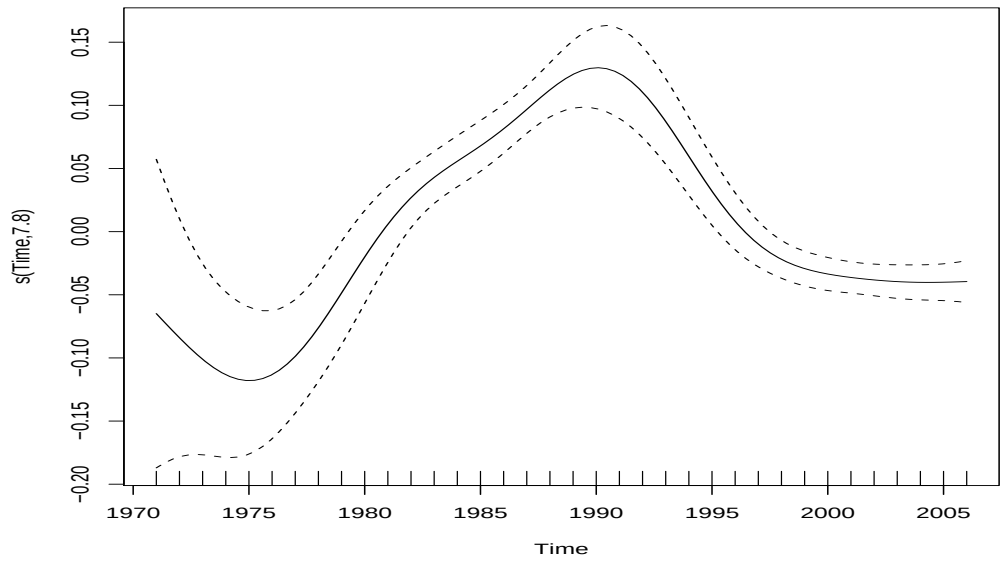

Figure 4.29: Deviation $sm(t)$ from the average coefficient for $b(t-1)$ with net debt, Japan.

Therefore, the estimations accounting for assets for Japan reveal a positive and significant average reaction coefficient. Plus, the development over time indicates periods with high relevance of debt stabilization. All in all the results suggest debt sustainability for Japan despite the high debt ratio if country specific characteristics are considered, that is accounting for net debt.

4.3.1.2.2 USA

The final country to be analyzed for debt sustainability is the USA. With a real GDP of about 12,000 billion dollars in 2008 they are the biggest economy worldwide, cf. Fincke and Greiner (2011c, sec. 1). For an impression of the fiscal situation in the United States the public debt and primary surplus, both relative to GDP, are depicted in figures 4.30 and 4.31 respectively. Here, a very long data series is available that allows to include early data that goes back to the 1940s including the World War II period. It presents a fine historical overview that is not too broad to concentrate on the contemporary fiscal developments. The graphics show observations of federal debt for the years from 1940 until 2007, please see United States Government (2008) for the data.

Clearly, the World War II years have had an exceptionally effect on the US fiscal position. In 1946 the maximum of the public debt ratio with almost 122% of GDP has been reached, as figure 4.30 shows. That period was also shaped by extraordinary primary

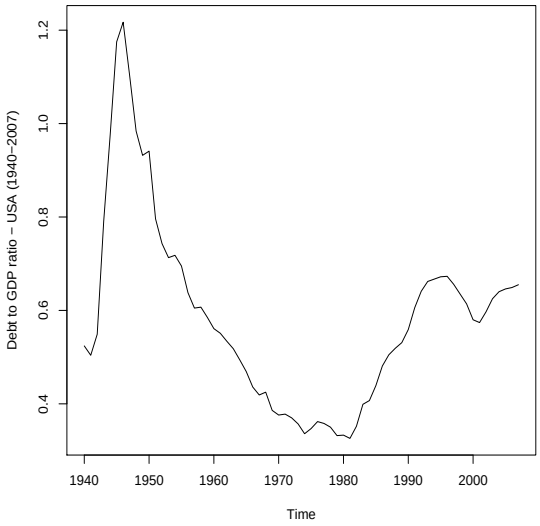

Figure 4.30: Public debt to GDP ratio for the USA (1940-2007).

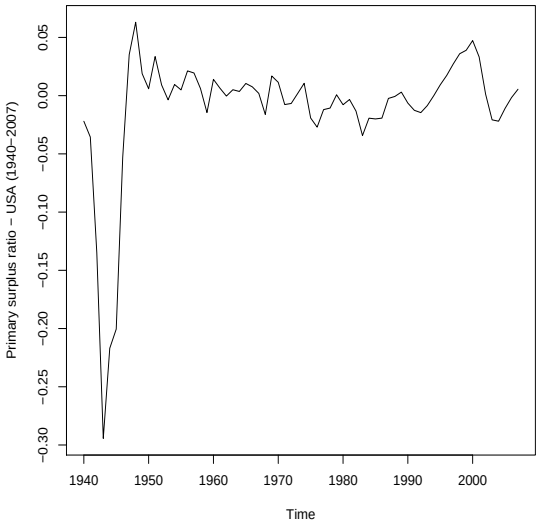

Figure 4.31: Primary surplus to GDP ratio for the USA (1940-2007).

deficits, for instance with nearly 30% in 1943, as presented in figure 4.31. In the post-war era those conditions have mitigated and a reduction in debt and deficits can be observed. Within circa 10 years the debt ratio has been cut in half and by 1980 it amounted to about 33% of GDP only. Starting afterwards, an increase in debt ratio in the 1980s was accompanied by primary deficits. The deficits then, run during peace time, are occasionally denoted by 'Reagan deficits' since Ronald Reagan was US president in those days. With budget discipline in the middle of the 1990s and achievement of primary surpluses the US debt ratio decreased. However, that development changed with the new century.

Whether this long-run US fiscal behavior is compatible with debt sustainability is now tested with equation (4.17). For the data see United States Government (2008). In table 4.10 the results of the regression are given.[21]

The outcome in table 4.10 show for all coefficients the expected signs and statistical significance. Especially, the average reaction coefficient has a positive sign that suggests debt sustainability for the USA for the considered time horizon. The R^2(adj) indicates a good fit of the model and if an $\alpha = 0.01$ significance level is assumed, the Durbin Watson test does not imply correlation of the residuals. Since the smooth term *sm* is

[21] The US estimation is implemented in R 2.5.0 with *mgcv* package version 1.3-28 as well.

	Coefficient	**Stand. error (t-stat)**	**Pr(>t)**
Const.	-0.128	0.018 (-7.130)	$2.17 \cdot 10^{-9}$
$b(t-1)$	0.223	0.034 (6.608)	$1.57 \cdot 10^{-8}$
$YVar(t)$	0.347	0.091 (3.806)	0.0004
$GVar(t)$	-0.204	0.017 (-11.834)	$< 2 \cdot 10^{-16}$
sm(t)	edf: 7.317	F: 53.28	p-value $< 2 \cdot 10^{-16}$
	R^2(adj): 0.934	DW: 1.58	

Table 4.10: Estimation results for equation (4.17) for the USA (1941-2007).

significant with a high $edf = 7.317$ value, it indicates deviations over time for v. How that development looks like is illustrated in figure 4.32.

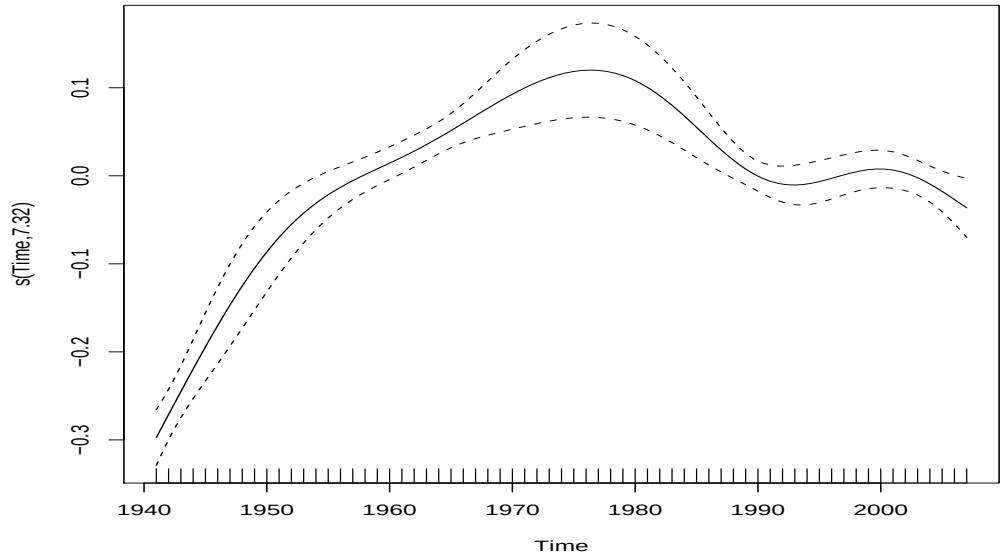

Figure 4.32: Deviation $sm(t)$ from the average coefficient for $b(t-1)$ for the USA.

The general increasing shape of the reaction in figure 4.32 until the middle of the seventies enlightens the decrease in debt ratio from figure 4.30 in the post-war years. It signals enhanced importance of debt stabilization of the government. The turn in trend came up with the Reagan Administration in the 1980s and less emphasis on fiscal discipline. Except for a moderate increase towards the new century the negative trend proceeded. However, adding up again the average reaction coefficient value from the table and the smooth term in the graph suggests negative values only for the war period. Thus, this test result indicates debt sustainability for the USA.

Thus, for both countries from abroad, Japan and the USA, debt sustainability can be recognized from the tests as well. The next section presents a review of all the regression results from this study.

4.3.1.3 Summary

The results of Bohn (1998)'s test for public debt sustainability with time varying coefficients from the previous section for all analyzed economies can be summarized as follows. There is a group of countries that seem to pursue sustainable fiscal policies despite high and increasing debt ratios. That cluster consists of Austria, France, Germany, Portugal and the USA. Then, for Italy no explicit statement can be made since the reaction coefficient is positive but not statistically significant. A similar situation can be seen for Japan. But once Japan's net debt is taken into account, the test suggests fiscal sustainability. Finally, there is Greece whose debt policy can not be considered sustainable and the recent developments support that outcome. Table 4.11 outlines the findings.

Public Debt Sustainability

According to Bohn's test for the selected countries

	Yes	**No**	**No clear statement**
Austria	x		
France	x		
Germany	x		
Greece		x	
Italy			x
Portugal	x		
Japan*	x		(x)
USA	x		

*Japan's result depends on the public debt type (gross or net debt).

Table 4.11: Estimation result overview.

However, as discussed in chapter 3, these results should be supplemented by additional testing since there is an upper limit for the reaction mechanism - especially for economies with rising debt ratios. Thus, the next section studies the stationarity properties of the budget deficits of the selected countries as suggested by Trehan and Walsh (1991).

4.3.2 Additional testing

As the study above has shown, Bohn (1998)'s regression should be complemented by additional testing for sustainability.[22] Here, Trehan and Walsh (1991)'s approach is chosen that analyzes stationarity properties of the budget deficit, i.e. inclusive of interest payments: stationarity of DEF indicates debt sustainability for economies with positive real interest rates. The technique has been introduced in section 4.1.2 and it tests the hypothesis of nonstationarity $H_0 : \pi = 0$ versus the alternative $H_1 : \pi < 0$ indicating stationarity. Accordingly, the full model (4.12) with trend and drift is tested first:

$$\Delta DEF(t) = \theta_0 + \pi DEF(t-1) + \theta_2 t + \sum_{l=1}^{m} \psi_l \Delta DEF(t-l) + \epsilon(t)$$

that can be adjusted to a drift model (4.11) or a plain type (4.10) if appropriate.

That approach is applied to the real budget deficit of those selected countries that have rising debt ratios and showed a positive average reaction coefficient in the regressions in section 4.3.1, i.e. all economies but Greece.[23] Table 4.12 summarizes the results.

	Aug. Dickey-Fuller	**Est. model type**
Austria	-5.48***	Trend and Drift,Lags: 1
France	-3.73**	Trend and Drift,Lags: 0
Germany	-4.90***	Trend and Drift,Lags: 0
Italy	-4.59***	Trend and Drift,Lags: 0
Portugal	-5.46***	Trend and Drift,Lags: 1
Japan $_{gross\ debt}$	-1.25	Plain,Lags: 3
Japan $_{net\ debt}$	-3.32*	Trend and Drift,Lags: 6
USA	-4.62***	Trend and Drift,Lags: 1
H_0 is rejected at	***(1% level)	**(5% level) *(10% level)

Table 4.12: Stationarity test results for the selected economies.

[22] Please note, this section's idea is based on Fincke and Greiner (2012, sec. III) and Fincke and Greiner (2011c, sec. 4.2).

[23] The tests are run with package *urca* in R 2.5.0. The data sources and time period of the estimations is maintained, except for Portugal: due to data availability only the DEF for 1978 - 2009 is utilized. Cf. Fincke and Greiner (2012, Tab. 2) and Fincke and Greiner (2011c, Tab. 17-19).

The outcome supports the results from the estimations above. Meaning fiscal sustainability can also be indicated for these European countries (in detail: Austria, France, Germany, Italy and Portugal) and the USA with stationarity of their budget deficits according to Trehan and Walsh (1991)'s idea. Especially for Italy a more sound statement is possible now, implying a decision for sustainability of its debt policy supported by the data. For Japan, again, the debt type must be discriminated: with gross debt H_0 cannot be rejected. However, when accounting for Japan's financial assets, nonstationarity of the deficit series can be rejected at the 10% significance level, which also indicates fiscal sustainability and strengthens the previous regression outcome. Thus, both tests demonstrate that country specific debt characteristics matter in particular for Japan. For the outcomes correlation of the residuals is checked amongst others with Box-Ljung test statistics that do not suggest correlation, see for instance Fincke and Greiner (2011c, sec. 4.2).

Thus, it is possible to conclude that for these countries both test results consistently provide empirical evidence of public debt sustainability. That holds despite the increasing trend in their debt ratios. However, in compliance with sustainability that development must reverse or at least stabilize at some point.

For Greece, both, the result from the regression test and the current severe fiscal circumstances with the international financial support starting in spring 2010 suggest an unsustainable fiscal policy by the Greek administration. As the development of the reaction over time in figure 4.18 has shown, there has been almost no improvement and no countersteering or enhanced emphasis on debt stabilization since the middle of the 1990s. Based on those findings with the flexible spline method an application of a conventional ADF test has been neglected.

How debt stabilization may look like and which debt ratios may result from it is studied in the next section.

4.3.3 The stabilized debt ratio

In section 3.3 Burger (2012)'s approach of calculating a stabilized debt ratio with Bohn (1998)'s idea has been discussed theoretically. Now, with the implemented debt sustainability estimations from the previous sections and available data it is possible to check his idea empirically for the selected economies. This transfers the deterministic reflections to the estimations. It may resort to the regression error term characteristics (to be i.i.d. $N(0, \sigma^2)$) - meaning here, the errors are expected to be zero.[24]

Reconsidering equation (3.20) implies for the stabilized debt ratio b^*:

$$b^* = \frac{\alpha_0}{(\beta^* - \upsilon)}.$$

Here α_0 gives the estimation's intercept, β^* the interest rate and growth rate difference and υ the reaction coefficient.

Accordingly, the first important aspect to check is whether $\upsilon > \beta^*$ holds, indicating sustainability since the fiscal reaction is stronger than required for stabilization. Or if $\beta^* > \upsilon$ is empirically given, an unsustainable fiscal situation is suggested. In a next step, the sign of the intercept should be studied and, finally, b^* according to equation (3.20) can be calculated. Table 4.13 summarizes the relevant information.

	α_0	$\beta^* = (\bar{r} - \bar{\gamma})$	$\bar{\upsilon}$	$\beta^* - \bar{\upsilon}$	$b^* = \frac{\alpha_0}{(\beta^* - \upsilon)}$
Austria	0.008	0.0079	0.118	-0.1101	-
France	-0.103	0.0085	0.187	-0.1785	0.58
Germany	-0.136	0.0162	0.366	-0.3498	0.39
Greece	-0.017	0.0037	-0.402	0.4057	-
Italy	-0.078	0.0185	0.012	0.0065	-
Portugal	-0.078	0.0137	0.073	-0.0593	1.32
Japan*	-0.016	0.0121	0.036	-0.0239	0.67
USA	-0.128	0.0148	0.223	-0.2082	0.62

*Japan's coefficients refer to the net debt estimation.

Table 4.13: Stabilized debt ratio for the selected countries.

[24] Employing the expectations E on $s(t) = \upsilon\, b^* + \alpha_0 + \epsilon(t)$, i.e. the first part of equation (3.19) including regression errors, also results in s^* and the other calculations remain unchanged.

Please note, the $\beta^* = (\bar{r} - \bar{\gamma})$ data has been adopted from table 4.1. The coefficients refer to the respective estimation results from tables 4.2 to 4.10 with $\bar{v}$ for the average reaction coefficient.[25]

For the first aspect, to check for sustainability with $\beta^* < \bar{v}$, the fifth column is important. For Austria, France, Germany, Portugal, Japan and the USA the estimated average reaction coefficient $\bar{v}$ is larger than the required parameter for stabilization β^*, indicating sustainable debt policies of those countries. This supports the findings from above. Moreover, as expected for Greece the response has not been strong enough to stabilize the debt ratio. With a positive difference of $\beta^* - \bar{v}$ this outcome suggest unsustainability and strengthens the regression result from above. For Italy that difference is positive as well, pointing out unsustainability of its debt policy. The mixed sustainability findings for the Italian public finance situation are not too astonishing because empirical assessments for Italy depend very much on the considered data and time horizon as already discussed in Fincke and Greiner (2011b, sec. 3.3 and fn. 13): while for instance Greiner and Fincke (2009)'s Italy estimation for the period from 1975 to 2006 is showing a significantly positive reaction coefficient, their result disagrees with the finding of Greiner and Kauermann (2008), who use data for the years 1975 until 2003. Thus, neither for Greece nor for Italy b^* will be calculated.

In a next step the individual intercepts are studied. For all selected countries except Austria they show the expected negative sign. The positive value for Austria may be due to the data, the estimation design or the regarded time period for instance. However, with a slightly different model design the intercept for Austria may also be negative, as for instance Neck and Haber (2008), Haber and Neck (2006) and Greiner and Fincke (2009) have shown with their estimations. Thus, in contrast to the approaches above, this subsection refrains from considering the case of Austria further and b^* will not be computed either.

Therefore, b^* has been calculated for five economies. The stabilized debt ratio for

[25] Strictly speaking the estimations should be done without the control variables according to equation (3.18) in section 3.3. Here, however, the coefficients have been adopted from the estimations in section 4.3.1.

France is 58%, which is close to the allowed 60% criterion for EMU economies and implies a reasonable approach. For Germany the level indicates to be lower, about 40% of GDP, which according to figure 4.13 corresponds to the stabilized level of the middle of the 1980s before the Reunification effect occurred. For Portugal b^* implies a very high level of over 130%, which is opposing the circumstances that Portugal had to apply for international financial assistance recently. This number needs to be checked for robustness by further research. However, the general finding of Portugal's debt sustainability is unchallenged by this calculation. For Japan and the USA stabilized debt ratio levels of 67% and 62%, respectively, can be calculated. That seem to be plausible values since for instance for the USA the 62% corresponds approximately to the mean of the debt ratio since the 1990s, see figure 4.30. Moreover, it is close to Burger (2012)'s value for the US b^*.

In summary, this section's calculations relating to debt sustainability mainly support the previous outcomes with the exception of Italy. Moreover, country specific stabilized debt ratios could have been calculated for France, Germany, Portugal, Japan and the USA. However, the Portuguese case leaves questions for further research. For France, Japan and the USA the levels are more or less close to the 60% benchmark while the German level of about 40% is lower. However, to achieve them a turn around in trend should come up sooner or later.

Of course these numbers are not free of criticism and depend on strong assumptions. For instance, the calculation considers only extracted data and simplifications. However, they may serve as a rough guide and additional checking of the previous sustainability approaches.

4.3.4 A sustainable debt ratio benchmark

Recalling the arguments from the theoretical reflections on a possible sustainable debt ratio benchmark in section 3.4 shows that for the empirical perspective the central equation is (3.24).[26] It allows to get an impression of the potential magnitude of a critical debt ratio beyond which sustainability is not attainable anymore. That is due to the fact that there exists a limit for the primary surplus ratio and it cannot be increased any

[26] Please note, this section's reasoning is based on Fincke and Greiner (2011c), especially appendix C.

further than that. That actually unknown upper limit is again denoted by u, with $u < 1$. Equation (3.24) is given by:

$$\hat{b}_{thsh} = u \int_0^{\infty} e^{-(\bar{r}-\bar{\gamma})\mu} d\mu = u \frac{1}{(\bar{r}-\bar{\gamma})}.$$

As above, $(\bar{r}-\bar{\gamma})$ presents the difference between the average value of the interest rate and growth rate. The empirical information of those numbers has already appeared in table 4.1 and can be adopted. To get an idea of u the historical maximum primary surplus ratio values may be applied as a proxy. However, these may possibly be affected by one-off budget impacts. Since not all of the selected countries under consideration here have been studied by Joumard et al. (2008) for instance, the potential influence of those one-off effects has been reduced by calculating and employing the average value of the three largest *ps* observations in the individual sample periods. This also alleviates war aftermath and catching up effects, as for instance for the USA time series here. Moreover, since the three largest values for Greece all have been achieved in the middle or late 1990s (i.e. 1994, 1998, 1999) with the mean of 3.76% (more than the sum of the Austrian and French average together) and generally that period's reported data points should be handled with care this section refrains from considering the Greek case further. Also, in times of crisis these critical benchmarks tend to decrease. This holds because primary surpluses are likely to shrink and lower the numerator of $\hat{b}_{thsh}$. In addition, the denominator usually increases since interest rates as a form of risk premium rise and growth rates drop. Both effects reduce the critical benchmark value. The previous estimations with the available reported data have already shown empirically that the Greek fiscal situation seems to be unsustainable and the recent international financial aid supports this outcome. Table 4.14 summarizes the relevant information for the critical benchmark calculations for the remaining countries under consideration.[27]

The values in table 4.14 present the critical debt ratios $\hat{b}_{thsh}$ for the selected economies. It shows that for France the number is comparatively low with 132.9% of GDP, which is owed to the low average value of the primary surplus ratio of 1.13% of GDP. A second group composed of Germany, Japan and Portugal has a $\hat{b}_{thsh}$ value of around 200% with moderate u proxies but higher interest rate/ growth rate differences. The benchmarks of Austria and Italy are close to 300% of GDP for which in the Austrian case the low $(\bar{r}-\bar{\gamma})$

[27] The data sources from above have been retained.

	u	$(\bar{r}-\bar{\gamma})$	$\hat{b}_{thsh}=\frac{u}{(\bar{r}-\bar{\gamma})}$
Austria	0.0219	0.0079	277.2%
France	0.0113	0.0085	132.9%
Germany	0.0297	0.0162	183.3%
Greece	0.0376	0.0037	-
Italy	0.0535	0.0185	289.2%
Portugal	0.0310	0.0137	226.3%
Japan	0.0265	0.0121	219.0%
USA	0.0497	0.0148	335.8%

Table 4.14: Critical debt to GDP ratios for the selected countries.

is responsible while Italy has performed high primary surpluses on average. Finally, for the USA the critical sustainable debt ratio is about 335% of GDP. If simply the *ps* maximum of 6.3% in 1948 was taken into account, the US $\hat{b}_{thsh}$ value would amount to over 425% of GDP.

At a first glance these benchmark values seem to be quite high. However, since they reveal maximum sustainable debt ratio limits they should of course be larger than the stabilized ones from the previous section. And they exceed the current values, which enables possibilities for fiscal maneuver. See also International Monetary Fund (2003) for a comparable computation of such maximum debt ratios.

Please note, these calculations are to some extent arbitrary and strongly depend on the country specific historical values of the difference between the interest rate and the growth rate and also on the government's ability to achieve (high) primary surplus ratios. Nevertheless, they may serve as a tentative suggestion of the magnitude of sustainable debt ratio limits.

4.4 Summary

Being the centerpiece of this thesis the present chapter has covered the description of the employed methodology, information on the data set and detailed presentation of the

empirical results that have been attained by different analysis and testing procedures.

With the introduction of the methods in section 4.1 both techniques, the modern and flexible spline estimation and the traditional stationarity approach in the form of an ADF test, have been described shortly. Within the context of spline estimation also the possibility of interactions in terms of time-varying parameters has been introduced. It allows to show how a certain relationship has developed over time. With the ADF test stationarity properties of relevant time series can be tested. Here, it is used to supplement the regression estimation outcomes.

For the analysis official time series related to the government's fiscal position have been employed. A consistent and official data source application facilitates international comparisons and reliable debt sustainability verdicts. They are reliant upon reported data.

The empirical analysis has studied the debt sustainability situation for selected countries in Europe and abroad. For the first group central European economies, namely Austria, France and Germany, and southern European countries, i.e. Greece, Italy and Portugal, have been distinguished. For a broader country comparison also the public debt situation of the two large industrialized economies of Japan and the USA has been considered.

Each economy has been analyzed separately. After a brief depiction and discussion of the debt history the relationship between the primary surplus to GDP ratio and the public debt ratio according to Bohn (1998)'s fiscal response sustainability approach has been estimated with a time-varying technique. It reveals that for Austria, France, Germany, Portugal and the USA debt sustainability seems to be given. According to that test for Italy with a positive but insignificant reaction coefficient no clear conclusion may be drawn. For Japan a similar situation appears. But with net debt the results support debt sustainability. As a final point for the Greek fiscal position the result implies unsustainability. However, the time-varying coefficients reveal that the development of the reaction, indicating emphasis on debt stabilization, has decreased over time in many countries.

To strengthen these findings the ADF test has been applied to the real budget deficits in order to analyze debt sustainability. Mainly the results from the first test have been supported. For Italy the ADF test outcome implies a sustainable policy path now.

With further calculations it is possible to compute stabilized debt ratios utilizing the regression coefficients from the first test. They indicate situations with stabilization of the debt ratio that can be derived by supposing a non-changing debt ratio. These values show for instance for France a stabilized debt ratio of 58% of GDP, which is quite close to the allowed 60% criterion for EMU members.

In a last step critical benchmarks have been calculated that hint at debt ratio values beyond which sustainability is unattainable. They only present tentative suggestions and proxies of the actual unknown limit. With for example 183.3% of GDP for Germany or 335.8% for the USA they are relatively large.

These calculations depend on historical country specific fiscal and economic behavior and are not without shortcomings. For instance, this study and its sustainability statements are based on observations mainly over the last 30 to 40 years and as already pointed out by Greiner et al. (2007) such findings do not necessarily assure sustainability for the years to come. It is up to the governments' efforts to keep up or improve the current status in the future. Nevertheless, for evaluating and assessing debt sustainability the information provided by these approaches may be helpful.

All in all, from these various empirical debt sustainability considerations it may be concluded that the results indicate fiscal sustainability for Austria, France, Germany, Portugal, Japan (with net debt) and the USA. For Italy the outcomes are mixed, which, however, is not too unusual as discussed in section 4.3.3. Finally, the approaches reveal an unsustainable debt situation for Greece, which is not too surprising with regards to the recent developments and the financial support since spring 2010.

Chapter 5

Conclusion

> "...there is no point in even talking of any of the 'green', social and political dimensions of sustainable development, unless the state can finance, now and in the future, the public expenditure programmes required to meet widely shared economic, social, political, cultural and environmental objectives in an efficient and sustainable manner..."
>
> Buiter (2004), Fiscal Sustainability, p. 1.

Even though Buiter (2004)'s perspective is quite rigorous the previous chapters have shown the relevance of fiscal or debt sustainability. In particular this study has addressed the question of whether governments of selected economies in Europe and abroad have pursued sustainable debt policies over the last 30 to 40 years.

For that purpose a demarcation of debt sustainability has been derived ahead of the effective analysis since no precise definition of sustainability exists. As part of that study historical references have shown that the idea of sustainability arose in forestry about 300 years ago. When concentrating on public finance aspects the solvency of a govern-

ment also appears to be quite an old feature. For debt sustainability the three common characteristics can be extracted: an inter-temporal attribute, a distributional aspect and a constraining manner. The territorial trait is twofold, both international and national aspects matter. The literature review has pointed out two main directions, that is indicators and sustainability tests in terms of time series analysis. Both have been shortly addressed. Also some reflections on types of debt and classifications problems have been discussed briefly. For sustainability studies usually long term debt and general government classification are used.

Subsequently, the theoretical background of the fiscal sustainability approach has been introduced. The starting point has been the government's budget. Two central sustainability conditions have been determined from that theory: the inter-temporal budget constraint and the NPG condition. They state that the existing stock of public debt has to be compensated by the sum of discounted future primary surpluses in order to assure that the present value of public debt converges to zero asymptotically. Including Bohn (1998)'s fiscal response mechanism into these considerations reveals another relevant requirement for sustainability: the reaction coefficient, which measures the effect of the response between the primary surplus ratio and the debt ratio, has to be significantly positive. Moreover, that coefficient is further required to exceed the positive difference between the interest rate and the growth rate in order for the debt ratio to become at least constant. This idea is also internalized in Burger (2012)'s approach on stabilized debt ratios. Additionally, it has been pointed out that Bohn (1998)'s mechanism has limits since there exists a theoretical threshold to which the primary surplus ratio can maximally be raised. Once this level has been reached, attaining sustainability is not possible anymore. Thus, in particular for economies with increasing debt ratios that sustainability approach should be complemented by additional testing.

For the empirical evidence, first, the utilized methodology has been presented briefly. It has been demonstrated that spline estimation is more flexible than traditional OLS regression. Within that context also the possibility of interactions has been introduced that allows to account for time-varying parameters. In this way the development of the relationship between the dependent variable and an explanatory variable may be observed

over time. Further, for the additional testing, the ADF test has been employed. It studies the stationarity properties of a data series with a regression equation.

Following the technical part the empirical test results are presented. The estimation outcomes for the spline regression are described separately for each economy. The countries under consideration are the central European states of Austria, France, Germany, also the southern European economies Greece, Italy and Portugal plus Japan and the USA from abroad. The fiscal response estimations indicate debt sustainability for Austria, France, Germany, Portugal and the USA. For Italy, with a positive but insignificant reaction coefficient, no clear statement can be made. A similar situation appears for Japan. But once taking net debt into account the results support debt sustainability. Finally, for Greece the result implies an unsustainable fiscal policy. However, the time-varying coefficients show that the development of the reaction, indicating emphasis on debt stabilization, has decreased over time in many of the analyzed economies.

In a second step the ADF test has been implemented. The results mainly support the test results from the first approach. Now, for Italy the outcome indicates a sustainable debt policy path.

With further calculations the stabilized debt ratio and the critical benchmark can be addressed. For instance the stabilized debt ratio value based on the regression coefficients from the first test indicates for France a level of 58% of GDP. That is fairly close to the allowed 60% criterion for EMU members. Finally, critical benchmarks have been calculated that act by proxy for the debt ratio values beyond which sustainability is unattainable. However, they only present tentative suggestions of the actual unknown limit. With for instance 277.2% for Austria it is rather large.

Returning to the initial central research question it can be concluded that the various empirical debt sustainability considerations of this study have indicated fiscal sustainability for Austria, France, Germany, Portugal, Japan (with net debt) and the USA. For Italy the results are divers, which, however, is not too unusual as discussed in section 4.3.3. As a final point, the tests reveal an unsustainable public debt situation for Greece. However,

that finding is not too surprising with regards to the recent developments and the two financial rescue programs since May 2010.

In view of future prospects or research the findings may enable ties not only with other research directions within economics but also could support interdisciplinary future cooperation and further studies with different sciences such as political disciplines or law for example.

It should not be omitted to note that these calculations depend on historical country specific fiscal and economic behavior and are not without shortcomings. This study and its sustainability statements are based on observations mainly over the last 30 to 40 years and as Greiner et al. (2007) have already pointed out such findings do not necessarily assure sustainability for the years to come. It is up to the governments' efforts to keep up or improve the current status in the future. Thus, even administrations of countries with currently sustainable debt policies should not rest and settle but rather should be attentive to possible changes and challenges to come. And how quickly circumstances may change has been demonstrated by the Portuguese situation.

Appendix A

Selected R codes

For most of the graphics and all estimations the public domain software R has been used. Further information and the program can be obtained at `http://www.r-project.org/`. This appendix briefly presents selected examples of R codes for some of the graphics and estimations. For further reading and guidance on R see for instance Crawley (2007).

Starting with the Austrian example of section 4.1.1 it analyzes the relationship between the primary surplus ratio and public debt ratio, which has been illustrated in figure 4.1 on page 39. The corresponding (and sometimes edited) R code is

```
################ Data: OECD Econ. Outlook,
################       OECD Fiscal Pos. and Business Cycl.....
################       cf. OECD (2010)
################ All in R 2.5.0 with mgcv 1.3-23

timeganz7008_OES<-c(1970,1971,1972, ... ,2007,2008)

debtratioganz7008_OES<-c(0.185133385,0.17425002, ... ,0.66208)

psratioganz7008_OES<-c(0.015153335, ... ,0.015001222)

plot(debtratioganz7008_OES[-1],psratioganz7008_OES[-1],
xlab="Debt to GDP ratio - Austria (1971-2008)",
ylab="Primary surplus to GDP ratio")
```

First, the data is read, then the **plot** command constructs the figure. Here, only data from 1971 onwards is included (in order to correspond to the estimation later on). With $[-1]$ the first data observation is excluded from the set. To fit and include a model into that graphic the explanatory variable *debtratio* has been considered as a cubic polynomial in a parametric setting and fitted with OLS and the command **lm**:

```
model7108<-lm(psratioganz7008_OES[-1]~debtratioganz7008_OES[-1]
+I(debtratioganz7008_OES[-1]^2)+I(debtratioganz7008_OES[-1]^3))

summary(model7108)
Call:
lm(formula = psratioganz7008_OES[-1] ~ debtratioganz7008_OES[-1] +
    I(debtratioganz7008_OES[-1]^2) + I(debtratioganz7008_OES[-1]^3))

Residuals:
      Min        1Q    Median        3Q       Max
-0.028281 -0.006994  0.002285  0.007509  0.021739

Coefficients:
                                 Estimate Std. Error t value Pr(>|t|)
(Intercept)                       0.11420    0.03466   3.295  0.00231 **
debtratioganz7008_OES[-1]        -0.85351    0.28070  -3.041  0.00452 **
I(debtratioganz7008_OES[-1]^2)    1.72027    0.67185   2.561  0.01506 *
I(debtratioganz7008_OES[-1]^3)   -1.03924    0.49284  -2.109  0.04242 *
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.01233 on 34 degrees of freedom
Multiple R-Squared: 0.4022,     Adjusted R-squared: 0.3495
F-statistic: 7.626 on 3 and 34 DF,  p-value: 0.000498

lines(debtratioganz7008_OES[-1], predict(model7108))
```

With **summary** essential model information is presented, for instance on the significance of explanatory variables or the goodness of fit R^2_{adj}. The command **lines** produces the result of figure 4.2, while **predict** is applying the fitted model, see Crawley (2007) for details.

For the smooth function and the model fit illustrated in figure 4.3 on page 44 the R code reads as follows:

```
library(mgcv)
This is mgcv 1.3-23

del7108<-gam(psratioganz7008_OES[-1]~s(debtratioganz7008_OES[-1]))

summary(del7108)
family: gaussian
Link function: identity
Formula:
psratioganz7008_OES[-1] ~ s(debtratioganz7008_OES[-1])

Parametric coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) -0.002912   0.001917  -1.519    0.139

Approximate significance of smooth terms:
                                edf Est.rank     F p-value
s(debtratioganz7008_OES[-1]) 5.199         9 3.812 0.00236 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

R-sq.(adj) =  0.403   Deviance explained = 48.7%
GCV score = 0.00016683   Scale est. = 0.00013962   n = 38

plot(del7108,xlab="Debt to GDP ratio - Austria (1971-2008)",
ylab="Smooth function (Debt ratio)")

plot(debtratioganz7008_OES,psratioganz7008_OES,
xlab="Debt to GDP ratio - Austria (1971-2008)",
ylab="Primary surplus to GDP ratio")

lines(debtratioganz7008_OES[-1], predict(del7108),
```

```
xlab="Debt to GDP ratio - Austria (1971-2008)",
ylab="Primary surplus to GDP ratio")
```

The package *mgcv* has to be loaded, then the spline model is fitted with the command **gam**. Again, **summary** outlines the central information. The first **plot** corresponds to the left hand graphic in figure 4.3, while the second **plot** command is constructing the right hand graphic and **lines** is adding the model fit.

Please note for reasons of clarity and illustration no further model options for **gam** have been chosen here. The default selection for the basis type is thin plate regression splines, cf. Wood (2006, p. 223). Further, Wood (2006, p. 224) gives the basis dimension default example of 10. However, as pointed out further by Wood (2006), usually these (default) choices have only minor effects on the model fit, as it is rather insensitive to these types of specifications. For refining possibilities and additional modeling options see for instance Wood (2006, ch. 5).

Accounting for the interaction in the Portugal example, again, first the data has to be read. For the decomposition by decades the data set has been separated and plotted similarly like above. More insight can be gained from the smooth including the interaction presented in figure 4.6:

```
time_POR<-c(1977,1978, ... ,2008,2009)
debtratio_POR<-c(0.267499122,0.300181024, ... ,0.751641802,0.8379)
psratio_POR<-c(-0.016073563,-0.052068438, ... ,-0.03888)
library(mgcv)
This is mgcv 1.3-23

modelPOR<-gam(psratio_POR~debtratio_POR+s(time_POR,by=debtratio_POR))

plot(modelPOR,xlab="Time",ylab="Smooth(Time)")
```

Again, the model is fitted with **gam**. The interaction is now included with the **by** command, cf. also Wood (2006, p. 169). This allows to illustrate the relationship over time and gives a 'time varying coefficient model'. Due to the centering, the main effect *debtratio_POR* is also included, cf. also Wood (2012, p. 48;135f.).

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