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Estimating dynamic tax revenue elasticities for Germany

Gerrit B. Koester
(Deutsche Bundesbank)

Christoph Priesmeier
(Deutsche Bundesbank and Humboldt University Berlin)

Deutsche Bundesbank, Wilhelm-Epstein-Straße 14, 60431 Frankfurt am Main,
Postfach 10 06 02, 60006 Frankfurt am Main

Tel +49 69 9566-0
Telex within Germany 41227, telex from abroad 414431

Please address all orders in writing to: Deutsche Bundesbank,
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Abstract:
We analyse tax revenue elasticities by applying dynamic models to a new disaggregated dataset for Germany, which is adjusted for the effects of tax reforms. We estimate long-run elasticities that are substantially lower than in comparable studies for profit-related taxes and are slightly lower for value-added taxes, whereas the long-run elasticity for wage taxes is close to the consensus estimate in the literature. Additionally, we find that differences between short- and long-run elasticities are particularly important with respect to profit-related taxes. Here we estimate a far lower contemporaneous response to tax base changes than other studies and a dynamic reaction pattern spanning several years, which can be explained, for example, by tax collection lags.

Keywords:
Dynamic tax revenue elasticities; Disaggregated analysis; Error correction models.

JEL-Classification:
H2, H24, H25, E26.

Non–technical summary

Fluctuations in economic activity directly affect public finances and in particular tax revenues. In the literature, this influence of economic activity on tax revenues is modeled by tax revenue elasticities, which can be quantified empirically. These elasticities play a central role for policy analyses, for example, in the adjustment of public finances for business cycle effects, the calculation of structural deficits and – potentially – as well in tax revenue forecasting.

A general problem of the tax elasticities, which are applied in policy analyses, is that they frequently focus just on the contemporaneous relationship, i.e. the effect of economic activity on public finances only in the period of the economic shock. However, there is nearly no evidence, which would exclude that economic developments do affect tax revenues over more than one period. Therefore, a more dynamic approach – taking the adjustment of tax revenues to economic shocks over several periods into account – is called for. Additionally, the data-bases for estimating tax revenue elasticities are frequently not corrected for the effects of tax reforms, which can substantially distort the general relationship between economic developments and tax revenues.

Against this background our paper builds on a dynamic conception of tax revenue elasticities. This approach takes into account the short-run dimension of the tax revenue elasticity (related to the effects of the business cycle on tax revenues), the long-run dimension (related inter alia to the long-run growth of tax bases and the effects of changing tax progressivity) as well as the adjustment between these two. We use error correction models as this class of model appropriately captures the four main components defining the relation between tax revenues and tax bases: a long-run equilibrium relationship between tax bases and tax revenues, a direct short-run relationship, an equilibrium adjustment effect and additional terms covering persistence and sluggish adjustment to economic shocks.

Our data-base consists of new and disaggregated time series for Germany from 1970-2009. We are focusing on the three main tax revenue categories, which have accounted on average for more than 75% of overall tax revenues in the period analyzed: Wage taxes, value-added taxes (VAT) and profit-related taxes. Revenues in all three categories are adjusted for fiscal effects of tax reforms and are therefore "policy-neutral". The definition of the tax bases builds on the disaggregated framework applied in the European System of Central Banks (ESCB).

Our estimations yield long-run elasticities, which are substantially lower than in comparable studies for profit-related taxes and are slightly lower for value-added taxes,

whereas the long-run elasticity for wage taxes is close to the consensus estimate in the literature. Additionally, our dynamic analyses indicate that differences between short- and long-run elasticities are particularly important with respect to profit-related taxes. Here we estimate a far lower contemporaneous response than other studies, followed by a slight overshooting and finally a convergence to the long-run equilibrium elasticity. This dynamic reaction pattern spans several years. One explanation for this pattern could be tax collection lags in this tax category.

Nicht-technische Zusammenfassung

Die gesamtwirtschaftliche Aktivität wirkt sich direkt auf die Entwicklung der Staatsfinanzen und vor allem auf die Steuereinnahmen aus. In der Literatur wird dieser Einfluss der wirtschaftlichen Aktivität auf die Steuereinnahmen im Rahmen von Steuerelastizitäten untersucht und empirisch quantifiziert. Diese Elastizitäten sind von zentraler Bedeutung für die wirtschaftspolitische Analyse, zum Beispiel bei der Bereinigung der Staatsfinanzen um konjunkturelle Effekte, bei der Berechnung struktureller Defizite und potentiell auch bei der Prognose der Steuereinnahmen.

Problematisch ist jedoch, dass die oftmals verwendeten Steuerelastizitäten lediglich kontemporäre Zusammenhänge erfassen, also nur den Effekt der Wirtschaftsentwicklung auf die öffentlichen Finanzen in einer Periode berücksichtigen. Und dies obwohl es kaum Evidenz dafür gibt, dass wirtschaftliche Veränderungen nicht über mehrere Perioden auf die Steuereinnahmen wirken, der grundsätzliche Zusammenhang somit eher einen dynamischen Charakter aufweist. Zudem wird die Datengrundlage für die Schätzung von Steuerelastizitäten oftmals nicht um die Effekte aus Steuerrechtsänderungen bereinigt. Diese Rechtsänderungen können jedoch die grundlegende Beziehung zwischen Wirtschaftsentwicklung und Steuereinnahmen signifikant verändern.

Vor diesem Hintergrund baut dieses Papier auf einem dynamischen Konzept von Steuerelastizitäten auf. Dieses berücksichtigt sowohl die zyklisch bedingte kurzfristige Dimension der Elastizität, als auch die durch längerfristiges Wachstum und Veränderungen in der Steuerprogression getriebene Langfristdimension sowie den Anpassungsprozess zwischen diesen beiden. Zur empirischen Modellierung dieses Ansatzes verwenden wir dynamische Fehler-Korrektur Modelle. Diese Modellkategorie erlaubt es uns, die vier wesentlichen Komponenten der Beziehung zwischen Steueraufkommen und Aufkommensbasis adäquat zu erfassen: Eine langfristige Gleichgewichtsbeziehung, einen direkten Kurzfristzusammenhang, einen Gleichgewichts – Anpassungseffekt und ergänzende Terme zur Abbildung der *Persistenz* makroökonomischer Variablen.

Die Datengrundlage bildet ein neuer und disaggregierter Datensatz für Deutschland für den Zeitraum 1970 bis 2009. Unser Fokus liegt dabei auf den drei Steuerkategorien mit dem grössten Anteil am Gesamtaufkommen in diesen Zeitraum: den Lohnsteuereinnahmen, den Umsatzsteuereinnahmen und dem Aufkommen aus gewinnabhängigen Steuern. Jede Aufkommenskategorie ist dabei um den verzerrenden Einfluss von Steuerrechtsänderungen bereinigt und somit "politik-neutral". Die Definition der jeweiligen steuerlichen Bemessungsgrundlagen folgt weitgehend dem disaggregierten

Ansatz des Europäischen Systems der Zentralbanken (ESZB).

Unsere Schätzungen ergeben langfriste Elastizitäten, die für die Einnahmen aus gewinnabhängigen Steuern deutlich geringer und für die Mehrwertsteuereinnahmen etwas niedriger sind als in anderen Studien. Hingegen stimmt die von uns geschätzte Langfristelastizität für das Lohnsteueraufkommen weitgehend mit den in der Literatur zu findenden Werten überein. Unsere dynamische Analyse ergibt zudem, dass die Unterschiede zwischen Kurz- und Langfristelastizitäten vor allem hinsichtlich der gewinnabhängigen Steuern eine große Rolle spielen. Zentrale Eigenschaft des dynamischen Musters ist hier der mehrjährige Anpassungsprozess von einer sehr niedrigen Kurzfristelastizität über ein leichtes mittelfristiges Überschiessen der Steuereinnahmen bis hin zur nachfolgenden Konvergenz auf eine gleichgewichtige Langfristelastizität. Eine Erklärung für dieses Muster könnten zeitliche Verzögerungen bei der Steuererhebung und –abführung bei den gewinnabhängigen Steuern sein.

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1 Introduction

Elasticities of tax revenues with respect to changes in their base play an important role in monitoring, analyzing and forecasting public finances. Revenue forecasts for public budgeting employ tax elasticities to calculate the expected revenues based on macroeconomic predictions. Cyclical adjustment methods, used to calculate the structural public balances, that are decisive for example for assessing fiscal policy developments in the framework of the European stability and growth pact, rely on these tax elasticities as well.[2]

Despite this importance, the literature on estimating tax revenue elasticities is relatively sparse and often fails to take tax reform effects and the dynamic dimension of the core relationships into account. First, tax revenues might generally react differently to short-run fluctuations than to long-run developments of their tax bases. Furthermore, lags in tax collection, loss carry-forward in profit taxes or composition effects in consumption taxes can make a purely short-run analysis, which focuses only on the contemporaneous effects of changes in the tax base on tax revenues, inadequate.[3] Therefore, an appropriate analysis considers and estimates short-run as well as long-run tax revenue elasticities. Tax reforms distort the general relationship between tax revenues and their base, which a tax revenue elasticity tries to capture. This stresses the importance of estimating tax elasticities based on "policy-neutral" datasets, i.e. the tax revenue data adjusted for tax reform effects.

[1]Christoph Priesmeier: Corresponding author; Deutsche Bundesbank, Economics Department, Wilhelm-Epstein-Str. 14, 60431 Frankfurt, Germany; Humboldt University Berlin, Germany. Email: christoph.priesmeier@bundesbank.de. Gerrit B. Koester: Deutsche Bundesbank, Economics Department, Wilhelm-Epstein-Str. 14, 60431 Frankfurt, Germany. Email: gerrit.koester@bundesbank.de. We are grateful to Charles B. Blankart, Christian Breuer, Heinz Herrmann, Ian McLoughlin and Karsten Wendorff for their valuable comments. We thank Gerhard Kempkes, Jana Kremer and Michael Scharnagl for their input and support. The opinions expressed in this paper are those of the authors and do not necessarily reflect the views of the Deutsche Bundesbank or its staff. Any remaining errors are ours alone.

[2]Cyclical adjustment methods usually combine tax revenue elasticities with tax base elasticities with respect to GDP developments to calculate the cyclical component of the budget deficit. The European System of Central Banks (ESCB) approach to the cyclical adjustment of budget balances and the disaggregated framework for the analysis of structural fiscal developments (DF) relies on these tax elasticities. See for the general framework, Kremer et al. (2006, 2009), for the general estimation of elasticities in this framework Bouthevillain et al. (2001), or the applied analysis to the estimation of elasticities in profit-related taxes in Priesmeier, Kempkes, Koester and Kremer (2010).

[3]See Dye (2004) for a detailed discussion.

This paper seeks to contribute to the literature by applying error correction models (ECM)[4] to a new German dataset, which is adjusted for the effects of tax reforms. We estimate the long- and short-run elasticities and the adjustment path between them for the three categories of taxes, which together account for around 80% of tax revenues in Germany (wage taxes, profit-related taxes and value-added taxes (VAT)).[5] The estimates reveal substantial differences between short-run and long-run elasticities in some of the major German taxes. Furthermore our results indicate that a partial overhaul of the size and the dynamic structure of the elasticities currently applied in tax policy might be worth considering.

The paper proceeds as follows. In section 2 we review – based on the existing literature – the conception of dynamic tax revenue elasticities and the econometric approach to model them adequately for the case of German data. In section 3 we discuss data issues: the selection of tax revenues analyzed, the definition of their adequate tax bases and the method for adjusting tax revenues for the fiscal effects of reforms. Section 4 studies the time series properties of the variables. In section 5 the estimation procedure is introduced before our results are presented in section 6. Section 7 concludes.

2 Dynamic tax revenue elasticities

2.1 Conception and related literature

In the literature we find mainly three different conceptions of tax elasticities: i) tax base elasticities, which explain the development of tax revenues based on the relationship between the corresponding tax bases and macro variables such as aggregated income usually measured by GDP, i.e. a base-income elasticity (Bruce, Fox and Tuttle, 2006);[6]ii) tax revenue elasticities, which explain the development of revenues directly based on the relationship between tax revenues and GDP developments, i.e. a revenue-income elasticity (Acquaah and Gelardi, 2008);[7] and iii) tax revenue elasticities, which explain

[4]Such an approach was originally proposed by Hobel and Solcombe (1996), modified by Bruce, Fox and Tuttle (2006) for the estimation of asymmetric tax base elastiticies in the US, and applied to asymmetric tax revenue elasticities for the Netherlands by Wolswjik (2009).

[5]See section 3 for a discussion of the revenue categories.

[6]The main problem of these approaches is that they implicitly assume a proportional relationship with an elasticity of one between tax base and tax revenue developments when using the base as a proxy for the revenue aggregate, which is obviously not the case for a broad range of different taxes in many countries (Fricke and Suessmuth, 2011). Moreover, correct tax base measures are usually very hard to construct, which often leads to – and partly justifies – the use of rather inadequate proxies.

[7]The main problem of this approach is that the development of GDP often differs from actual tax base developments. As the most important tax bases are available, for example, in macro-forecasts, this

the path of tax revenues with respect to the development of their bases, i.e. revenue-base elasticity (Bouthevillain et al., 2001).

Cyclical adjustment methods either rely on revenue elasticities with respect to GDP or combine tax revenue and tax base elasticities to determine the effects of the business cycle on tax revenues (Girouard and André, 2005). In this paper, we study the elasticities of tax revenues with respect to changes in their tax bases - as this is in our view the most appropriate approach. Based on our results we then reassess the elasticities currently used in German tax revenue analysis and cyclical adjustment.

The development of tax bases (see section 3) is closely related to developments in economic activity. Like economic activity, tax bases show cyclical short-run fluctuations as well as long-run developments. Tax revenues do potentially react to both in different ways. A *long-run* tax revenue elasticity measures how the growth of tax revenues depends on the long-run growth of its tax base, i.e. on the growth rate adjusted for any short-run fluctuations.[8] This long-run revenue elasticity should generally be determined by the progressivity of the tax with respect to its base.[9] In contrast, a *short-run* elasticity measures how short-run fluctuations in the tax bases – resulting, for example, from the business cycle – affect tax revenues, i.e. it captures the volatility of revenues.

Differences between short- and long-run revenue elasticities can result, for example, from loss carry-forward regulations in profit taxes or lags in tax collection, which lead to a delayed adjustment of tax revenues to tax base changes. Or, cyclical changes in consumption spending might affect the composition of spending on differently taxed categories of goods differently than long-run changes – which would then lead to differences in the short- and the long-run consumption tax revenue elasticities.[10]

Taking this into account, the intertemporal elasticity of tax revenues of category r, Tax^r, with respect to each of its $n = 1, ..., N$ bases, $B^{r,n}$, can be defined as:

$$\eta_{t+i,t}^{Tax^r,B^{r,n}} = \frac{\Delta Tax_{t+i}^r}{\Delta B_t^{r,n}} \frac{B_t^{r,n}}{Tax_{t+i}^r} \quad i = 0, ...\text{T}. \tag{1}$$

procedure does not take into account all relevant information available and is likely to deliver biased estimates for the impact of economic activity on revenues.

[8]The importance of taking short- and long-run elasticities into account is stressed particularly in the study of tax base elasticities by Dye (2004).

[9]In addition, other long-run trends, e.g. in tax evasion or tax fraud, may affect the long-run relationship.

[10]See, for example, the discussion in Sancak et al. (2010). Additionally, Fricke and Suessmuth (2011, p. 4) point to a general trade-off between the long- and short-run responses, as "faster growing tax revenue sources might react more strongly to macroeconomic fluctuations".

This dynamic elasticity includes the contemporaneous short-run relationship, as well as the long-run relation and the adjustment path between two states.[11]

In the literature, Sobel and Holcombe (1996) apply time series methods to evaluate the dynamic properties of different categories of tax elasticities (base and revenue elasticities with respect to changes in GDP) for a range of categories and US states. With a focus on gross casino gambling revenues in the United States, Nichols and Tosun (2008) evaluate dynamic tax base elasticities. In contrast, Felix (2008) refers directly to the long- and short-run impacts of GDP changes on tax revenues for an aggregate of some US states. The same approach is followed by Acquaah and Gelardi (2008) for the case of the Canadian province of British Columbia. Bruce et al. (2006) allow additionally for state-dependent dynamic tax base-income responses in some US states. This dynamic and non-linear approach is applied as well by Fricke and Suessmuth (2011) to tax revenues with respect to GDP developments in several Latin American countries. Finally, state-dependent and state-independent long- and short-run dimensions of tax revenue changes with respect to their bases are evaluated for the Netherlands by Wolswijk (2009).

Most studies on tax revenue elasticities in Germany focus either on the long-run or short-run revenue elasticity and rarely discuss the dynamic adjustment process between the two. Table 1 on the next page provides an overview of the most important studies, their empirical approach, datasets and findings.

[11] In fact, this dynamic relationship is analyzed later on in section 6, where our focus lies on response functions of tax revenues to impulses in their bases.

Study	Boss and Elendner (2000)	Van den Noord (2000)	Bouthevillain et al. (2001)	Girouard and André (2005)	Kremer et al. (2009)	Buettner et al. (2006)	Boss et al. (2009)	Breuer (2010)
Dataset	•1995 data on gross wage income distribution •Tax codes	•Annual data 1985-1998 •Tax code of 1996	•Annual data 1970-1998 •Tax code of 2000	•Annual data 1970-2003 •Tax code of 2003	•Annual data 1998-2004	•Tax code of 1998 and 2005	•2004 data on gross wage income distribution •Tax codes	•Annual data 1981-2008
Adjustment for tax reform effects	•Yes (based on tax codes)				•Yes (based on estimates of German the federal ministry of finance)			•Yes (based on estimates of German the federal ministry of finance)
Methods	•Derivation of elasticities based on tax laws/tax code •Simulations (2001-2003)	•Derivation of revenue elasticities based on tax laws/tax code	•Derivation of elasticities by tax laws/tax code •Static OLS regressions based on growth rates •Error correction models (ECM)	•Derivation of elasticities based on tax laws/tax code	•Derivation of elasticities based on tax laws/tax code	•Derivation of elasticities based on tax laws/tax code	•Derivation of elasticities based on tax laws/tax code •Simulations (2007-2013)	•Finite distributed lag (FDL) models
Elasticity of profit-related taxes		•$t_0 = 0.8$*	•$t_0 = 0.9$ •$t_1 = 0.2$ •$t_2 = 0.2$	•$t_0 = 1.5$*	•$t_0 = 0.7$ •$t_1 = 0.3$ •$t_2 = 0.1$	•$t_0 = 1.06$*		•Short-run: 0.2-0.6 •Long-run: 1.35
Elasticity of wage taxes	•$t_0 = 1.7$-1.9	•$t_0 = 1.5$	•$t_0 = 1.8$	•$t_0 = 2.3$	•$t_0 = 1.9$	•$t_0 = 1.73$ (1998) •$t_0 = 2.02$ (2005)	•$t_0 = 1.8$	
Elasticity of value-added taxes		•$t_0 = 1$	•$t_0 = 1$	•$t_0 = 1$	•$t_0 = 1$	•$t_0 = 1$		

*Only corporate tax and only available with respect to output gap.

Table 1: The empirical literature on tax elasticities in Germany

2.2 Econometric set up - modeling dynamic elasticities

Long-run tax revenue elasticities: equilibrium tax revenues

A stable *long-run* relation between tax revenues and their base requires a cointegrating relationship between the two (Sobel and Holcombe, 1996).[12] If this relationship exists, the long-run equilibrium relation can be expressed by the following static expression for tax revenues of category r in log levels, tax_t^r, which are explained by their N tax bases in log levels, $b_{n,t}^r$, a constant, β_0^r, potential structural breaks (a level shift)[13], $d_{sh_{LR}}^r$, and some stationary equilibrium errors, $\varepsilon_t^{ec,r}$,

$$tax_t^r = \sum_{n=1}^{N} \beta_{1,n}^r b_{n,t}^r + \beta_0^r + \delta_{sh_{LR}}^r d_{sh_{LR}}^r + \varepsilon_t^{ec,r}. \tag{2}$$

Short-run tax revenue elasticities: direct and indirect effects of tax base changes

In contrast to the log-level relation for the long-run, the immediate effect of a change in a tax base on tax revenues can be modeled by the contemporaneous relation of their growth rates, approximately given by the first differences of the log levels of the variables (Sobel and Holcombe, 1996). The corresponding coefficient is an appropriate measure of the cyclical variability of tax revenues. We refer to this coefficient as the *direct short-run* tax base elasticity of tax revenues. However, it is not the only channel at work in the short run.

Whenever there is a difference between the direct short-run response of tax revenues and the identified long-run relationship, temporary deviations from the stable equilibrium relationship can occur. For example, an immediate revenue response to changes in the tax base higher than the long-run response would generate higher-than-equilibrium tax revenues and thus create a positive equilibrium error (tax revenue overshooting). However, due to the stability of the long-run relation, these deviations can only be transitory and thus have to be corrected within a certain horizon. This adjustment mechanism explains a second – *indirect* – *short-run* channel of tax base changes, which can be captured by loading the lagged equilibrium errors into a (stationary) model for short-run tax revenue dynamics. The corresponding coefficient is referred to as the adjustment elasticity. According to the correction mechanism, we expect negative adjustment elasticities whenever the log-level of tax revenues in the

[12] As elasticities shall be calculated, logarithms of the levels of the variables are taken.

[13] Structural break analyses of the time-series point to breaks in particular around 1991 (caused by German reunification). For profit-related taxation, the comprehensive tax-reform in 2001 leads to additional distortions (see section 4).

previous period was above its equilibrium value – and positive adjustment elasticities whenever it was below its equilibrium value.[14] Equilibrium revenues are calculated using the information from the log-levels of the bases in the previous period. If both short-run effects – the *direct* and the *indirect* channel – are at work, the equilibrium error adjustment can lead to a decrease in tax revenues even though the tax base has increased.[15]

Persistence of tax revenues and tax bases

Additionally, the highly dynamic character of macroeconomic aggregates such as tax revenues and their bases have to be taken into account in an appropriate empirical approach. In particular, tax revenues (and their growth rates) are very likely to be persistent as, for example, shocks in tax bases may affect government receipts for several periods. This can make the inclusion of autoregressive components necessary. Usually, strong evidence for serial correlation in a small and therefore rather less dynamic model is a good indicator of misspecified dynamics. Lagged dependent and independent variables are an appropriate solution to capture the somewhat "richer" dynamics of tax revenues and their bases in such cases.[16] For example, if tax revenues are highly persistent, we can expect a positive sign of at least the one-year-lagged growth rate of tax revenues. For higher orders this sign can also take negative values if, for example, revenue overshooting occurs and is then corrected through a *direct* (lagged) short-run channel.

A dynamic empirical model

Taken together, a sophisticated and adequate dynamic approach to evaluating the elasticities of tax revenues with respect to their bases has to include at least four components: a long-run equilibrium relationship, a *direct* short-run channel, an (*indirect*)

[14]With respect to the research question of this study – the impact of changes in the tax base on tax revenues – this short-run relationship is regarded as an indirect channel, because changes in the tax bases affect revenue development only through their influence on the lagged deviations from the equilibrium relationship.

[15]See Wolswijk (2009) for a discussion of this effect.

[16]Alternatively to lagged dependent variables, autocorrelation is often interpreted as a rather technical violation of an estimator assumption that one can try to eliminate by modeling the residual correlation directly, using GLS procedures (FGLS, Prais-Winston, Cochrane-Orcutt) or correcting OLS estimated residuals using the Newey-West (1987) approach. However, Keele (2005, p. 17) states that "researchers should be hesitant to use either GLS or OLS with corrected standard errors, if one suspects the process is at all dynamic. Even when the process is weakly dynamic, OLS without a lag is [was] biased, and if the process is strongly dynamic, the bias caused by the specification error in OLS and GLS is [was] dramatic."

equilibrium adjustment channel, and finally, lags of the dependent and independent variables. These requirements are fulfilled by the following error correction model of general order (p, q) for each tax category,[17]

$$\begin{aligned} \Delta tax^r_t = & \alpha^r_0 + \delta^r_{imp} d^r_{imp} + \delta^r_{sh_{SR}} d^r_{sh_{SR}} \\ & + \sum_{n=1}^{N} \sum_{j=0}^{q} \alpha^r_{1n,j} \Delta b^r_{n,t-j} + \sum_{i=1}^{p} \alpha^r_{2,i} \Delta tax^r_{t-i} + \alpha^r_3 \varepsilon^{ec,r}_{t-1} + u^r_t \end{aligned} \tag{3}$$

where Δtax^r_t refers to the first difference of log tax revenues of category r in period t, explained by an intercept α^r_0, the effects of structural breaks (impulse and shift), d^r_{imp} and $d^r_{sh_{SR}}$, the impacts of changes in its N contemporaneous log tax bases, $\Delta b^r_{n,t}$, and up to q lags of them, the dynamic properties of the tax revenue growth rate modeled by its own p lags, Δtax^r_{t-i}, the lagged long-run equilibrium errors, $\varepsilon^{ec,r}_{t-1}$, and finally, the *i.i.d.* residuals, u^r_t. Hence, the $\alpha^r_{1n,j}$ coefficients represent the direct short-run tax revenue elasticities, the $\alpha^r_{2,i}$ coefficients are measures for the degree of persistence of tax revenue growth, and α^r_3 is the short-run equilibrium adjustment parameter that indicates the percentage of equilibrium deviation corrected in every period. Our analyses will be based on this model, whenever it is in line with the data.[18]

3 Data

3.1 Tax revenues in Germany

In this paper we estimate the elasticities of tax revenues with respect to their individual tax bases. If we calculate elasticities with respect to disaggregated tax bases, we need to concentrate on the most important taxes to keep the analysis manageable. Over the time period of our analysis (1970-2009), three categories of taxes have dominated overall tax revenues in Germany (see figure 1).[19] Wage taxes, which are levied with progressive tax rates, accounted for the largest share of overall taxes, at 33% on average. Value-added taxes were the second most important category, accounting on average for 25% of all tax revenues. Value-added taxes are levied at proportional rates – a gen-

[17]See as well the approaches of Bruce et al. (2006), Wolswijk (2009) or Fricke and Suessmuth (2011). Hassler and Wolters (2006) present a general derivation of such an ECM for cointegrated levels variables, based on ARDL $(p+1, q+1)$ process for the endogenous variable.

[18]This empirical framework requires the variables to be difference-stationary and to be cointegrated.

[19]A detailed description and discussion of the German tax system and its development over the past few decades can be found in Koester (2009, p. 19 ff.).

eral rate and a reduced rate, for example, for food or short-distance traffic.[20] The third category is profit-related taxes, which in our definition include corporation tax (*"Körperschaftsteuer"*), assessed income tax (*"Veranlagte Einkommensteuer"* – which includes taxes paid on the profits of unincorporated businesses and the self-employed),[21] income tax withheld on capital income (*"Kapitalertragsteuer"* – mainly withholdings on interest and dividends) and local business tax (*"Gewerbesteuer"*). These profit-related taxes accounted for, on average, 21% of all tax revenues – with a decreasing trend since the early 1980s. Profit-related taxes are raised partly at progressive rates (e.g. assessed income tax) and partly at proportional rates (e.g. corporate tax).

Altogether these three tax categories accounted, on average, for 79% of all tax revenues over the last four decades. The remaining 21% of tax revenues came from numerous types of taxes with small revenue volume. Overall tax statistics show revenues for around 40 different taxes in 2010 – consisting in particular of various special consumption, energy, real estate and property taxes.[22]

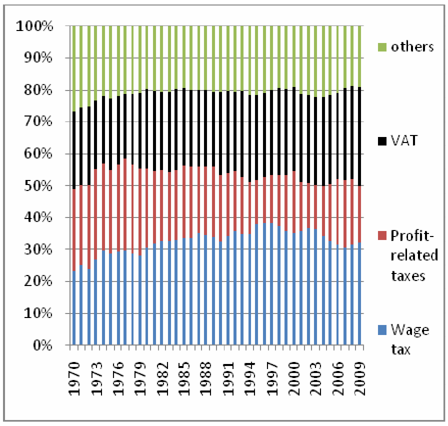


Figure 1: Tax revenue ratios

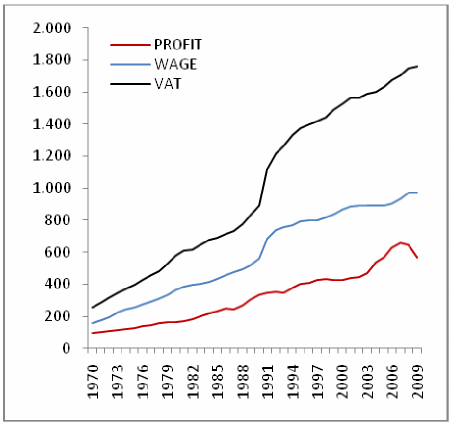


Figure 2: Tax bases in billion Euro

Figure 3 shows the ratio of tax revenues (adjusted for tax reforms) over their bases for the three categories of tax revenues covered in our analysis (see section 3b for a

[20] VAT revenues can be analyzed including or excluding VAT payments to the European Union. In this paper we include VAT payments to the EU, because we focus on the overall elasticity of the aggregate VAT tax revenues.

[21] In the German tax statistics, assessed income tax is recorded net of back payments related to withheld income tax on wages and capital income. For our purposes a subtraction of these back payments from wage tax revenues would be preferable, but is not available. Furthermore a separation does generally not seem possible based on the synthetic system of the German income tax. If, for example, one spouse is self-employed and one is dependently employed, their total income falls under the assessed income tax. This may distort the wage tax revenue variable. However, the overall effects are most likely not large enough to substantially distort our results.

[22] See Koester (2009, p. 19ff.) for details.

discussion of the appropriate bases for the different tax categories). The ratio of wage taxes over its base shows an upward trend – which can be expected due to the progressive rate structure. The ratio of VAT revenues over its base is relatively stable and only slightly decreasing over the sample, while the ratio of profit-tax revenues over its macroeconomic base is quite volatile and decreasing since the early 1980s.

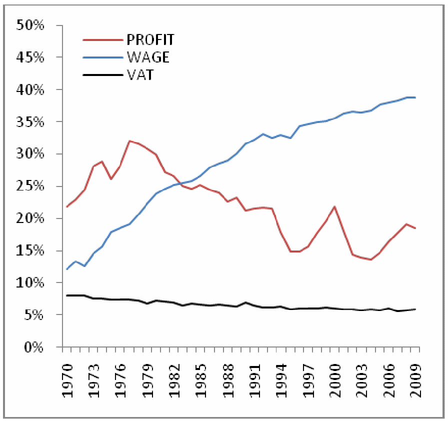


Figure 3: Adjusted tax revenues over tax bases

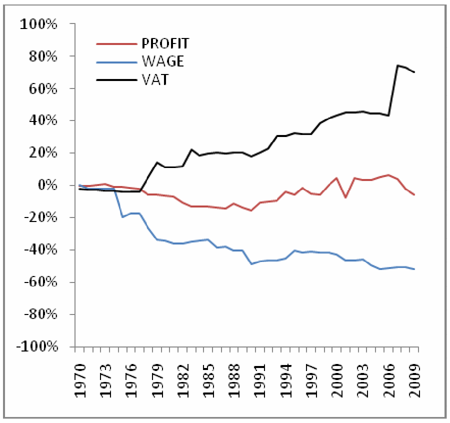


Figure 4: Cumulated impact of tax reforms (% of adj. revenues)

3.2 The adequate base(s) for each tax category

Generally, it is possible to estimate tax elasticities with respect to the true tax bases as defined by German tax law and reported with a considerable time lag[23] in the German tax statistics. However, the most important applications of tax elasticities – cyclical adjustment and tax revenue forecasts – have to rely on timely available data and forecasts of basic macroeconomic aggregates. Therefore, it is crucial for policy analysis to estimate elasticities with respect to these macroeconomic aggregates. In general, we follow the disaggregated approach of the European System of Central Banks (ESCB) in defining the tax bases we apply.[24] The disaggregated framework is well established in the ESCB – this makes a re-estimation of the elasticities based on the data definitions of the framework especially valuable.

For wage taxes we chose the sum of wages and salaries in national accounting terms as the macroeconomic base. Boss and Elendner (2000, p. 3) show that this variable is a viable proxy for the "true tax base" (wages and salaries according to official wage tax

[23]The latest available wage tax statistics, for example, are currently for the 2005/2006 period.
[24]See Bouthevillain et al. (2001) or Kremer et al. (2006).

statistics).[25] Value-added taxes are levied on private consumption, private residential investment and parts of government expenditure – especially investment spending. In this paper we rely on national accounts data for consumption of private households, private residential investment and government expenditure, which are subject to VAT. This is supported by Boss (1997), who presents empirical support for the adequacy of such a definition of the macroeconomic base for VAT in Germany. Selecting a base for profit-related taxes, which consist of several taxes, is most ambitious. We decided to rely on a national accounts measure of entrepreneurial and property income, more specifically net national income at factor costs less compensation of employees (in the following, for short, "profit income"). This is the tax base applied in the disaggregated ESCB approach and as well in other studies for Germany as, for example, Breuer (2010).[26] Figure 2 shows the development of the chosen bases for the three main tax categories analyzed.

3.3 Accounting for tax reforms

Changes in tax revenues result not only from changes in the tax base but as well from discretionary tax reforms. As the conception of a tax elasticity only covers the effects of a change in the base on the revenues, we need to correct the data for the effects of tax reforms (to make it "policy-neutral", as Dye (2004, p. 136) notes). An important advantage of our study is that we are able to adjust the revenue data for distorting tax reform effects for all four decades based on estimates of the Federal Ministry of Finance for the fiscal effects of all tax reforms (for details on the data and the reliability of the estimates see Koester, 2009, pp. 36 ff.).

Figure 4 shows the cumulated fiscal effects of reforms, which we need to subtract from the tax bases to receive a policy-neutral dataset. These cumulated reform effects take into account that, for example, the general VAT rate increase in 1978 affected rev-

[25]In the ESCB's disaggregated framework the effects of changes in employment and of changes in the average wage income (calculated by dividing the sum of wages and salaries by employment) are used as tax bases, as the progressivity of the tax system is decisive for tax revenue increases resulting from increases in individual income. We restrict our benchmark models to just the sum of wages and salaries as the tax base in order to keep our benchmark models simple, but we estimate the models integrating the two bases as well as robustness checks.

[26]Large changes in profit-related tax revenues, which cannot be explained based on currently applied models, have fueled calls for using a different definition for the tax base (see the discussion in Kremer et al., 2009, p. 22 ff.). One approach would be to include the effects of stock prices. However, the inclusion of stock prices not only complicates the model but also raises massive problems when it comes to tax forecasts, as stock prices are hardly predictable. Therefore we stick to the established base. We plan to analyze in future work whether the elasticities derived by a more adequate empirical model can reduce the currently unexplained changes in profit-related tax revenues.

enues not only in 1978 but – as all reforms included here were permanent reforms – those in all years thereafter. Furthermore, the effect of a VAT increase by one percentage point should be twice as large if the tax base doubles. For accumulation of reform effects we therefore use – similarly to Wolswijk (2009, p. 3) – the proportional adjustment method (Prest, 1962) and assume that the permanent effects of tax reforms grow proportionally with their base.[27] With respect to profit-related taxes, cumulated reform effects were large in the 1980s, but the overall effect tapered off in the 1990s and 2000s. Without tax reforms, profit-related tax revenues would have been 6% higher in 2009. Wage tax revenues would be around twice as high if no reforms of the wage tax had taken place. This results from the large rate cuts implemented in wage taxes over the last 40 years, which partly compensated for the bracket creep ("cold progression"). Moreover, we see that all cumulated reform effects have pushed up VAT revenues by 70% over our sample horizon. The large extend of cumulated tax reforms underline the importance of taking these reform effects into account. In particular, with respect to long-run elasticities, an analysis of unadjusted data is heavily biased and misspecified.[28]

4 Time series properties

The existence of long-run equilibrium relationships requires the variables to be non-stationary, in the sense that they are not only driven by a deterministic trend and that the unit root property can be removed by first differencing. Moreover, the series have to be generated by a common stochastic trend, which can be evaluated by cointegration analyses.

We use a set of three different stationarity tests investigating the null hypothesis of a unit root that can be removed by taking first differences against the alternative of stationarity of a process that may include a constant or a linear deterministic trend, to check for robustness and to search and account for structural breaks that may lead to low power of standard procedures: the Augmented Dickey-Fuller test (ADF), the Phillips-Perron test (PP) and the Lanne-Lütkepohl-Saikkonen test with structural break (LLS). Results are reported in appendix A. For the log-level of profit-related tax revenues, the ADF test provides some evidence of trend stationarity, but the PP tests and

[27]The alternative approach - assuming that the permanent effects of tax reforms grow proportionally with revenues – is less convincing because revenues are (in contrast to the bases) directly affected by changes in the tax rates.

[28]For the relevance of reform effects, see also the discussion and findings in Breuer (2010).

also the LLS tests (given that a reunification or a 2001 tax reform shift are taken into account) accept the null of a unit root under the more plausible deterministic specification with only a constant (or respectively only a stochastic trend). The first differences are stationary. Moreover, the log profit-related income is found to be driven by a stochastic trend and to be integrated of order one, $I(1)$. Concerning log wage tax revenues, there is strong evidence for a unit root in the levels, and if the reunification shift is taken into account, there is evidence for a stochastic and a deterministic trend. For the first differences, the ADF and PP tests indicate no unit root, whereas the inclusion of only an impulse in 1991 does not imply stationary growth rates in the LLS procedure. When we model a lower wage tax revenue growth rate after reunification using a trend slope shift in 1993, a unit root is rejected.[29] The same holds for the wage income in logs. The evidence for the log value-added tax revenues is even stronger. Under the more plausible specification with constant and trend in the levels, all tests indicate the series to be $I(1)$. For the aggregated base of value-added taxes a unit root is also found in levels and rejected in first differences. Including structural breaks, this holds only for the version with an impulse in 1990, which corresponds to the shift found in the tax revenue series. The same $I(1)$ properties are indicated for the major component of the base aggregate, log private consumption. Moreover, the other components – log residential investment and log public spending related to VAT – are also found to be integrated of order one.

Based on these results we test for cointegration in each tax category, applying the residual based (Augmented) Engle-Granger (AEG) procedure with different specifications of the general deterministic (constants, trends and lag orders) and structural breaks (indicated in the stationarity analysis).[30] Results are reported in appendix B. For all tax revenue categories, the AEG tests including the corresponding structural shifts provide very strong evidence (at the 1% level) of a long-run equilibrium relationship between each tax revenue category and its bases. If the reunification shifts are ignored, only the wage tax revenues do not have a stationary long-run relationship to the wage income. In the last step, the robustness of these results is checked in

[29] The quasi-non-stationarity properties of the growth rate of wage tax revenues may generate the high coefficients of determination in the wage tax revenue growth equation, which is estimated below. We take this into account, including a growth rate shift in 1993 in the estimated ECMs.

[30] In all tax revenue series and in a majority of the bases, German reunification leads to some significant distortion around 1991. By the LLS search algorithm a shift is indicated in the log level of wage-related tax revenues in 1991, while the year 1990 is indicated for value-added tax revenues. In contrast, 2001 – the date of the comprehensive reform of profit-related taxes in Germany – is indicated for the log level of profit- related tax revenues. The reunification is found to also have a significant impact on profit related tax revenues in 1991. The corresponding impulses are included in the first differences of the series.

cointegration tests evaluating the likelihood ratios of restricted vector autoregressions (VARs) that account for simultaneity and "richer" (short-run) dynamics. Hereby the results of the AEG test are widely confirmed.[31]

5 Estimation

We refer to the widely used two-step (2S) regression method proposed by Engle and Granger (1987) to estimate the long- and short-run elasticities and as well the adjustment process.

In a first step, superconsistent estimates for the long-run coefficients are generated using the dynamic ordinary least squares (DOLS) estimator proposed by Stock and Watson (1993). According to their evaluation, and based on a system of $I(1)$ variables with a single cointegrating vector, we regress the tax revenue variables onto their contemporaneous tax base levels and additionally onto leads and lags of the tax base in first differences (including the contemporaneous first difference), a constant and – if necessary – additional structural break components. Particularly in small samples, this estimator has proved superior to standard OLS or Johansen estimates, as it is not only able to accommodate higher orders of integration, but also to tackle the problem of endogeneity among the regressors, and serial correlation issues (Masih and Masih, 1999).[32] In a second step, the short-run dynamics of tax revenue developments are estimated by ordinary least squares (OLS) based on an error correction model (ECM) with the equilibrium errors from the first stage (corrected for the nuisance terms required in the DOLS procedure) as error correction term. Reliable estimates require a well-specified model. The adequacy of the models is therefore evaluated in diagnostic checks. Whenever there is evidence of serial correlation and or heteroscedasticity we take this as evidence of a "richer dynamic structure" or "persistence" of the tax revenue growth rate that should be taken into account. In such cases, additional lagged dependent (and even independent) variables are included and the model is re-estimated and

[31] Saikkonen and Lütkepohl tests (SL) or Johansen trace tests (JT) are performed depending on the specification of the underlying structural break deterministic in the processes. The results are upon request available from the authors.

[32] Using the DOLS estimator in a small sample, models with many regressors may suffer from overparameterization due to the nuisance terms. In the disaggregated approach for the value-added tax revenues (see section 6.3) where many regressors would be needed in the DOLS regression, we therefore refer to the standard OLS estimation. In general, we restrict the order of additional lead and lag dynamics to one for every tax revenue category, to keep the parameterization manageable and not to lose too many observations. Whenever there is evidence for serial correlation and heteroscedasticity issues, we additionally apply the standard error correction procedure developed by Newey and West (1987).

checked again. To increase the preciseness and to keep the model as parsimonious as possible, obsolete lags of independent variables are eliminated in the final estimation of the benchmark model. In a last step, the benchmark model is simulated and bootstrapped (10,000 iterations) to compute the impulse-response functions and their confidence intervals.

6 Results

6.1 Profit-related taxes

For estimating the long-run dynamics of profit-related taxes, we applied different specifications of the deterministic. Taking into account reunification, in particular, improves the quality of the regression significantly, whereas the comprehensive reform of profit-related taxes in 2001 did not show any long-run impact. Thus, the benchmark estimate includes a reunification shift in the long-run part, which makes the constant unnecessary. As all models indicate some evidence for remaining serial correlation, we applied a Newey-West correction to the covariance matrix.

In contrast to the long run, the benchmark error correction model for the short run includes a (transitory) effect of the tax reform in 2001 (which is on the edge of the 10% significance level). An impulse, which corresponds to the reunification shift in the long run, was not found to be significant in any specification considered. To capture the dynamics of the growth rate of profit-related taxes appropriately, we further included an additional lag of the endogenous variable that indicates a significant and high degree of persistence in the tax revenue growth rate.[33] Diagnostic checks do not show any evidence (at the 5% level) for non-white residuals .

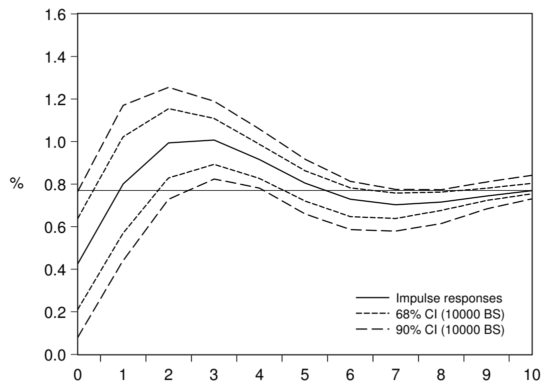
Based on these deterministic specifications, our estimation results presented in table 2 (at the end of the results section) support the finding of other studies, that profit income according to national accounts is – in particular in the long-run – a viable base for profit-related taxes (see, for example, Breuer 2010). But we estimate the *long-run* elasticity at 0.77, which – in contrast to nearly all other studies – is substantially below unity and below the elasticity of 1.1 or 1.3 applied in the disaggregated framework of the ESCB (see table 1). Hence, our results indicate that the effects of tax base changes on profit tax revenues tend to be overestimated in the long run by applying the existing

[33]In robustness checks we also used more dynamic specifications with one, two or three lags of the endogenous and exogenous variables. However, higher lag orders did not improve the fit of the model according to the Schwartz Information Criterion (SIC) and the coefficients for the short-run relationships did not show significant differences.

elasticities.

If we additionally take the *short-run* effects into account, the difference to other studies increases even further: we find the *direct* contemporaneous response to equal only 0.43 (see table 5 at the end of the results section). The adjustment parameter indicates that in case of a deviation from the equilibrium value of tax revenues 41% of the amount are adjusted within one year.
Short- and long-run estimates only provide snapshots of specific points in time. This stands in contrast to the highly dynamic and steadily developing character of the actually observed fluctuations in tax revenues. Thus, when evaluating tax revenue elasticities, the whole picture of *dynamic evolvement* has to be considered. Therefore, we simulated the dynamic evolvement using impulse-response functions that are based on our estimated models. These impulse-response functions in their confidence intervals[34] show the continuous adjustment process of tax revenues after the tax base is shocked.

Figure 5: Impulse responses of profit related taxes



Notes: 1 percentage point shock in the tax base growth rate; Benchmark ECM

In figure 5 we observe that the contemporaneous reaction, at 0.43, is in fact significantly (on the edge of the 90% interval) below the long-run elasticity of 0.77. The elasticity subsequently starts to increase rapidly and finally even “overshoots” to a level of 1.0 - significantly above the long-run elasticity in the third period after the shock (“delayed overshooting”). From then onwards the reaction converges to the long-run elasticity that is reached in period four.

[34]90% confidence intervals are computed based on 10,000 parametric bootstraps. In addition, 68% intervals are presented, approximately corresponding to the less restrictive one-standard-error bands.

How do we interpret these findings? And what causes the dynamic pattern we observe? While some parts of profit-related taxes – capital income tax on interest and dividends, for instance – is directly withheld and should therefore be collected without large time-lags, the largest part of profit-related taxes (as the corporate tax and the assessed income tax) is collected based on advance payments due on the 10th of the last month of the respective quarter.[35] The amount of these payments is generally based on the last annual tax assessment – i.e. advance payments for 2011 are set based on the annual tax assessment from 2010 for 2009. Generally, the concrete consequences of the advance payment system in the complicated regulation of corporate and assessed income taxes are hard to predict, in particular for a category that consists of several taxes. But we nonetheless try to illustrate possible driving forces of the developments we observe in the data. If, for example, a temporary increase of profits occurs in period t (for example, the year 2009) after profits had been stable in the years before, this increase is fully reflected in tax revenues not before the annual assessment in $t+1$ (2010). For $t+2$ (2011), the advance payments are then set based on the temporary increase in profits in 2009 (assessed in 2010). If profits in 2010 and 2011 have fallen back to 2008 level, the annual tax assessment in 2011 for 2010 leads to no additional tax revenue changes, as the level of taxation should be in line with the collected advance payments. In the annual assessment in $t+3$ (2012) the company receives a tax refund as the advance tax payments in 2011 turn out to have been too high. This example nicely illustrates a rationale for the observed reaction pattern, including both the delayed adjustment (i.e. taxes are adjusted here only in 2010 for a shock that already occurred in 2009) and the overshooting (here taking place in 2011 and being corrected in 2012).

While tax collection lags offer an explanation of the dynamic pattern, they cannot explain why the long-run elasticity – despite the proportional rate of the majority of profit-related taxes and the even progressive rate in assessed income taxes[36] – is lower than unity. This finding - which in in line with the downward trend of the ratio of tax revenues of profit-related taxes over profits throughout our sample (see figure 3)- could indicate that the share of non-taxed profits increased over our complete sample. Such a development could be caused by substantial tax circumvention, tax evasion or

[35] Advance payments for the business tax even need to be paid on the 10th of the second month of a quarter.

[36] Assessed income tax is levied with strongly progressive rates. But it should be noted that the data on assesed income taxes are somewhat distorted. Some back payments for wage taxes are subtracted from aggregated revenues and withholding taxes are netted out in the assessment of income taxes. Unfortunately, data net of these special factors was not available for our analysis. See as well footnote 21.

even tax fraud, but could as well be related to possible problems with the estimation of the impact of tax legislation changes.

6.2 Wage taxes

The deterministic specification of our models plays an important role as well for wage taxes. Taking a significant long-run impact of German reunification in 1991 into account in the benchmark specification improves the quality of the regression, and makes - as diagnostic checks indicate - an additional correction of the estimated standard errors unnecessary. The corresponding short-run impulse for reunification turned out to be significant in the error correction models as well. In addition, a significant (10% level) downward shift in the growth rates after 1993, which was indicated earlier in stationary analyses, is taken into account. This downward shift could result from a delayed adjustment to structural distortions linked to German reunification.[37]

Furthermore we include a lag of the endogenous variable in the benchmark specification - even in cases when it was found to be insignificant. This can be justified by the fact that a model with no lags would in our view be too restrictive with respect to the general dynamics of wages and wage tax revenues. While the specification without additional persistence lags could - based on diagnostics - be the preferable choice, it should be noted that the inclusion of a lag of the endogenous variable does not change the estimation results substantially.

Our final OLS estimations deliver a *long-run* elasticity of 1.75 (see table 3 at the end of the results section),[38] which can be justified based on the strongly progressive rate structure of wage taxes. This finding is largely in line with the results of other studies (see table 1).[39]

The estimated *direct short-run* wage tax elasticity of 1.41 (or 1.54 in the model without LDV), is only slightly below the long-run elasticity (20%, or 10% in the model without LDV). These results show that the differences between long- and short-run

[37] The tax elasticity could be affected after reunification by the the comparatively high number of low-wage employees in the eastern states (with wages close to the tax-free threshold) and from very low wage growth after high wage increases directly after reunification. These effects could have triggered a reduction in the growth rate of wage tax revenues.

[38] Our sample for all estimations with respect to wage taxes starts only in 1975. For data from 1970-1975, in particular the wage taxes are heavily distorted by the economic adjustment to the first oil crisis and far-reaching tax reforms with probably misspecified fiscal effects within large economic recovery programs. Estimates for a longer sample (1970-2008) show an even higher long-run coefficient of 1.85.

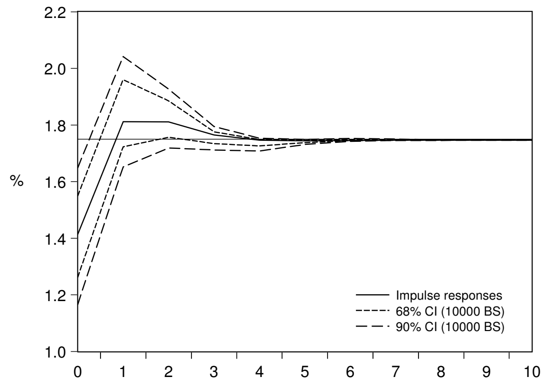
[39] At this point one should keep in mind that we estimate the elasticity for the gross sum of wages and salaries, while some other studies analyze the effects of changes in the number of employees and of the average wages and salaries on tax revenues separately. In particular in times of large changes in employment this limits the comparability of the results across the different studies.

elasticity are far less pronounced with respect to wage than with respect to profit taxes. Furthermore the adjustment parameter for wage taxes is even larger than in the case of profit-related taxes and indicates an even faster correction of equilibrium errors: 71% (62%) of the deviation from the equilibrium value of tax revenues is already adjusted within one period (see table 6).

The whole picture of the *dynamic evolvement* of tax revenue elasticities is displayed in the simulation of impulse-response functions based on the estimated models. Figure 6 shows how the systems converges from the lower short-run elasticity (1.41) to the higher long-run equilibrium elasticity (1.75) already in the first period after the shock.

Taken together, our findings with respect to wage tax elasticities largely support the existing literature and only tend to propose the introduction of a slightly lower short-run elasticity.

Figure 6: Impulse responses of wage taxes



Notes: 1 percentage point shock in the tax base growth rate; Benchmark ECM

The largest remaining challenge is to explain why the short-run elasticity is slightly lower than the long-run elasticity. One "usual suspect" would be tax collection lags. Wage tax revenues are collected (except for public servants) with a delay of one month and the national accounts data employed here are adjusted for this time lag. Therefore, tax collection lags could only contribute to explaining the observed pattern, if a substantial share of wage tax revenue is collected with a time lag larger than one month. Here, detailed studies on the collection lags, e.g. based on cash data statistics, but as well of alternative explanatory factors would be interesting.[40]

[40]Alternatively, a variation of the wage tax revenue responsiveness in different states of the economy,

6.3 Value-added taxes

The deterministic specification of our benchmark regression estimating the long-run dynamics of value-added taxes includes - as the specification for the profit-related and the wage taxes - a German reunification shift. This shift is found to be significant and improves the fit of the model. In line with the findings in the stationarity analysis, the effect is already modeled in the year 1990. In contrast, the deterministic for profit-related and wage taxes includes a reunification shift one year later (1991). This could indicate a faster adaption of consumption taxation to the distortions resulting from German reunification. The corresponding reunification impulse in 1991 is also found to be significant and therefore included in the error correction model. As robustness checks we included additional lags of the dependent and independent variables (up to two lags), but all were found insignificant and did not improve the fit of the model. The diagnostic checks indicate no problems with serial correlation, heteroscedasticity or normality. This indicates that the structure of value-added tax revenues is less dynamic than e.g that of profit-related or wage taxes and is appropriately captured without additional lags of the variables to the model.[41]

Estimates of VAT revenue elasticities employing this deterministic specification (presented in table 4 at the end of the results section) derive a *long-run* elasticity of 0.79 with respect to changes in the tax base. The tax base consists of private consumption (on average 79% from 1970 to 2009), residential investment (12%) and government consumption subject to VAT (9%).[42] This result is significantly below the elasticity of 1, which we would have expected based on the proportional VAT rates and the results of a Wald test.[43]

For this finding, several explanations might play a role. First, there is evidence that composition effects are important. Private consumption represents the lion´s share of

for example, an asymmetrical behaviour in economically "good"and "bad" times may explain the differences in the short-run reaction. The preference structure of households and labor market legislation can lead to less or more responsive employment reaction with respect to the state of the economy. Thus, allowing for state-specific reactions in booms or recessions could provide new insights. This line of research is currently pursued by the authors in another study.

[41]The same specification of the long- and short-run model is used when the three disaggregated bases are used as exogenous variables instead of the aggregate. See appendix C for details.

[42]It should be noted that this long-run elasticity of 0.8 is perfectly in line with the empirical long-run development of the tax base and the tax revenues of VAT – meaning that each doubling of the tax base has increased revenues only by 80% (see figure 3 for the data).

[43]While a deterministic specification with a reunification shift is the best choice from a statistical point of view, we have nonetheless checked several alternative specifications. Excluding the long-run shift, the elasticity increases to 1.0 in the short- and 0.9 in the long-run. Without the short-run impulse dummy, the short-run elasticity equals 0.95 and the long-run elasticity 0.8.

the aggregate base. And private consumption not subject to VAT (particularly rents) grew for example, in the period 1991–2011 (the only period for which this data is available) more than proportionally: it increased by a factor of 2.1 compared to an increase of overall private consumption by a factor of 1.75. The resulting expansion of the share of private consumption not subject to VAT in total private consumption could be one of the effects responsible for pushing the elasticity down below unity. Tax evasion and tax fraud – which are especially common with respect to value-added taxes (see, for example, Keen and Smith, 2007) and which are likely to have increased with rate hikes – could be an important explanatory factor as well, but are hard to quantify.

Summing up we should note that while the estimated VAT elasticity is somewhat lower than expected, it is not fundamentally different from the findings of other studies (see table 1).[44]

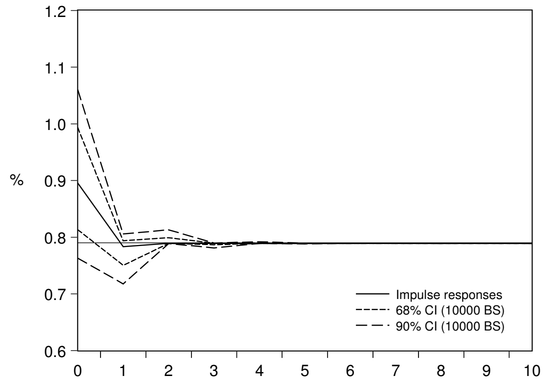
The *direct short-run* elasticity (0.90) is only slighter higher (around 10%) than the long-run value. Furthermore the equilibrium adjustment term indicates that nearly the entire deviation from equilibrium is corrected within one period and. The small divergence of long- and short-run elasticity and the high adjustment parameter both speak in favor of a rather non-dynamic pattern in VAT in Germany (see table 6).

Unsurprisingly the whole picture of the *dynamic elasticity pattern* using impulse-response function that are based on the benchmark error correction model is very stable. Figure 7 indicates that the initial elasticity of 0.90 is only weakly significantly higher (at the 68% level of significance) than the long-run elasticity. Moreover, the elasticity reaches its long-run equilibrium value of 0.79 already within the first year after a shock to the aggregated tax base. In short, there seems to be no significant difference between the short- and long-run reaction of value-added tax revenues to changes in the aggregated base, i.e. no over- or undershooting. Thus policy analysis should employ the same value for the long- and for the short-run elasticity of VAT.

Estimations including the sub-categories of the tax base are presented in appendix C. These estimations show that the discovered higher short-run elasticity of VAT could potentially be driven by private consumption and residential investment, whereas public VAT-related spending does not contribute to an contemporaneous overshooting. Only the contemporaneous overshooting of residential investment is on the border to weak significance. This effect could potentially be caused by a delay of refunds of prepaid VAT to construction companies in the year after the VAT has been paid -

[44] A below-unity elasticity for VAT is also found for other countries. Wolswijk (2009), for example, estimates a long-run elasticity between 0.82 and 0.90 for the Netherlands using a similar methodology.

Figure 7: Impulse responses of VAT



Notes: 1 percentage point shock in the tax base growth rate; Benchmark ECM

but further studies of detailed data would be necessary to analyze and validate this effect. Taken together we would argue - based on the low significance of a deviating short-run elasticity - that the long-run elasticity of 0.77 should be applied in the short as well as in the long run.

Sample (unadj.)	1970-2009	**1970-2009**	1970-2009	1970-2009
Estimator	DOLS (NW)	**DOLS (NW)**	DOLS (NW)	DOLS (NW)
$income^{p}_{t}$	0.56 ***	**0.77** ***	0.60 ***	0.77 ***
	9.09	***94.43***	*11.27*	*91.22*
c^{p}_{LR}	0.96 ***	**-**	0.77 ***	-
	2.64		*2.54*	
$reunification_{1991}{}^{p}$		**-0.27** ***		-0.24 ***
(shift)		***-4.82***		*-3.03*
$reform_{2001}{}^{p}$			-0.07	-0.05
(shift)			*-1.02*	*-0.59*
R^2(adj)	0.87	**0.90**	0.87	0.90
SIC	-0.96	**-1.28**	-0.90	-1.21
DW (test-statistic)	0.64	**0.98**	0.63	0.95
LM: $\chi^2(1)$	*0.00*	***0.00***	*0.00*	*0.00*
LM: $\chi^2(2)$	*0.00*	***0.00***	*0.00*	*0.00*
BPG	0.87	**0.06**	0.95	0.10
White	0.93	**0.09**	0.84	0.15
JB	0.22	**0.66**	0.17	0.59

Note: t-values in italics. Significance on the 10% 5% and 1% level is indicated by *, **, ***. P-values are shown for all diagnostic checks on the estimated residuals, instead for of Durbin-Watson test. Lags and leads of first differences of the regressors are not presented. - refers to a parameter eliminated due to insignificance. Whenever there is evidence for serial correlation in the residuals, the variance-covariance matrices are corrected by the Newey-West (NW) procedure to get more reliable standard errors.

Table 2: Profit taxes
- long-run

Sample (unadj.)	1975-2009	**1975-2009**	1970-2009
Estimator	DOLS (NW)	**DOLS**	DOLS (NW)
$income^{w}_{t}$	1.50 ***	**1.75** ***	1.85 ***
	43.76	***64.06***	*41.47*
c^{w}_{LR}	-4.39 ***	**-5.86** ***	-6.48 ***
	-19.21	***-35.52***	*-24.24*
$reunification_{1991}{}^{w}$		**-0.21** ***	-0.29 ***
(shift)		***-9.76***	*-7.79*
R^2(adj)	1.00	**1.00**	1.00
SIC	-3.33	**-4.76**	-3.64
DW	*0.36*	**1.28**	*1.17*
LM: $\chi^2(1)$	*0.00*	**0.16**	*0.04*
LM: $\chi^2(2)$	*0.00*	**0.12**	0.12
BPG	0.09	**0.44**	*0.00*
White	0.08	**0.51**	*0.00*
JB	0.11	**0.13**	0.81

Note: t-values in italics. Significance on the 10% 5% and 1% level is indicated by *, **, ***. p-values are shown for all diagnostic checks on the estimated residuals, instead for Durbin-Watson test. Lags and leads of first differences are not presented. - refers to a parameter eliminated due to insignificance. Whenever there is evidence for serial correlation in the residuals, the variance-covariance matrices are corrected by the Newey-West (NW) procedure to get more reliable standard errors.

Table 3: Wage taxes
- long-run

Sample (unadj.)	1970-2009	**1970-2009**
Estimator	DOLS	**DOLS**
$base\_agg^{v}_{t}$	0.85 ***	**0.79** ***
	94.11	***36.26***
c^{v}_{LR}	-1.71 ***	**-1.34** ***
	-26.05	***-9.31***
$reunification_{1990}{}^{v}$		**0.06** ***
(shift)		***2.80***
H_0: $base\_agg^{v}_{t} = 1$	0.00	**0.00**
R^2(adj)	1.00	**1.00**
SIC	-4.28	**-4.41**
DW	1.88	**2.08**
LM: $\chi^2(1)$	0.81	**0.79**
LM: $\chi^2(2)$	0.72	**0.52**
BPG	0.94	**0.68**
White	0.91	**0.85**
JB	0.67	**0.39**

Note: t -values in italics. Significance on the 10% 5% and 1% level is indicated by *, **, ***. P-values are shown for all diagnostic checks on the estimated residuals, instead for of Durbin-Watson test. P-values are also presented for the Wald tests. Lags and leads of first differences of the regressors due to DOLS are not presented. - refers to a parameter eliminated due to insignificance.

Table 4: VAT
- long-run

Model	ECM(1,0)
Sample (unadj.)	1970-2009
Estimator	OLS
$\Delta income^{p}_{t}$	0.43 *
	1.72
$\Delta income^{p}_{t-1}$	-
Δtax^{p}_{t-1}	0.55 ***
	5.00
$ec^{tax,p}_{t-1}$	-0.41 ***
	-3.84
c^{p}_{SR}	-0.04 **
	-2.68
$reform_{2001}{}^{p}$	-0.12
(impulse)	*-1.68*
R²(adj)	0.62
SIC	-2.32
DW	2.04
LM: χ²(1)	0.77
LM: χ²(2)	0.06
LM: χ²(3)	0.12
BPG	0.90
White	0.58
JB	0.72

Note: t-values in italics. Significance on the 10% 5% and 1% level is indicated by *, **, ***. An - refers to an not included term. If the term is not included in the benchmark model, it is also excluded from the models with asymmetries. Whenever there is evidence for serial correlation left in the residuals we used additional lags (up to lag 3) of the endogenous and exogenous variables. p-values are shown for all diagnostic checks on the estimated residuals instead for Durbin-Watson test. An impulse in 1991 in the first differences was found unsignificant in each specification.

Table 5: Profit taxes - short-run

Model	ECM (1,0)	ECM (0,0)
Sample (unadj.)	1975-2009	1975-2009
Estimator	OLS	OLS
$\Delta income^{w}_{t}$	1.41 ***	1.54 ***
	8.78	*11.04*
$\Delta income^{w}_{t-1}$	-	-
Δtax^{w}_{t-1}	0.11	-
	1.49	
$ec^{tax,w}_{t-1}$	-0.71 ***	-0.62 ***
	-5.05	*-4.77*
c^{w}_{SR}	0.01	0.02 *
	1.58	*2.02*
$reunification_{1993}{}^{w}$	-0.01 *	-0.01 *
(shift)	*-1.74*	*-2.02*
$reunification_{1991}{}^{w}$	-0.10 ***	-0.12 ***
(impulse)	*-4.04*	*-4.67*
R²(adj)	0.94	0.94
SIC	-5.46	-5.49
DW	1.73	1.65
LM: χ²(1)	0.42	0.22
LM: χ²(2)	0.51	0.47
LM: χ²(3)	0.11	0.24
BPG	0.60	0.42
White	0.67	0.70
JB	0.95	0.90

Note: t-values in italics. Significance on the 10% 5% and 1% level is indicated by *, **, ***. An (-) refers to an not included term. If the term is not included in the benchmark model, it is also excluded from the models with asymmetries. Whenever there is evidence for serial correlation left in theresiduals we used additional lags (up to lag 2) of the endogenous and exogenous variables. p-values are shown for all diagnostic checks on the estimated residuals instead for Durbin-Watson test. High adjusted coefficients of determination result from relatively high persistence of wage revenue growth rates as autorrelation analysis shows. Therefore it makes sense to include at least one lag of the dependent variables even if it was not found significant. Moreover, there is strong eveidence that the quasi-nonstationary of the first difference series is generated by a break in the trend slope of tax revenues two years after the German reunification in 1993. This is taken into account by an additional shift in the growth rates (see stationarity analyses).

Table 6: Wage taxes - short-run

Model	ECM (0,0)
Sample (unadj.)	1970-2009
Estimator	OLS
$\Delta base\_agg^{v}_{t}$	0.90 ***
	9.60
$ec^{tax,v}_{t-1}$	-1.05 ***
	-6.17
c^{v}_{SR}	0.01
	0.95
$reunification_{1990}{}^{v}$	0.09 ***
(impulse)	*4.32*
R²(adj)	0.79
SIC	-4.63
DW	1.96
LM: χ²(1)	0.90
LM: χ²(2)	0.67
LM: χ²(3)	0.79
BPG	0.86
White	0.52
JB	0.34

Note: t-values in italics. Significance on the 10% 5% and 1% level is indicated by *, **, ***. An - refers to an not included term. If the term is not included in the benchmark model, it is also excluded from the models with asymmetries. Whenever there is evidence for serial correlation left in the residuals we used additional lags (up to lag 2) of the endogenous and exogenous variables. In case of heteroscedasticity a White correction of the variance-covariance matrix is applied. p-values are shown for all diagnostic checks on the estimated residuals instead for Durbin-Watson test.

Table 7: VAT - short-run

7 Conclusion

What do we know about dynamic tax revenues elasticities in Germany? In this paper, we estimate short-run and long-run revenue elasticities based on a dynamic empirical model for a new German dataset, which is adjusted for the effects of tax reforms and includes data on the three largest tax categories (wage taxes, VAT and profit-related taxes) from 1970–2009.

With respect to the long run we find the elasticity of profit-related taxes to equal 0.77 - a figure substantially lower than the estimate of most other studies - but can confirm the literature consensus of an elasticity of wage taxes of around 1.75. Our long-run estimate for VAT revenues is 0.79, and thus somewhat lower than the estimates of most other studies.

Simulated impulse-response functions demonstrate that, for value-added taxes, the short-run elasticities differ only very slightly from long-run elasticities. For wage taxes the results indicate a significantly lower short-run elasticity of 1.41 to 1.54 (compared to the long-run elasticity of 1.75), but the system already reaches the long-run elasticity in the first year after the shock.

Dynamic revenue elasticities play the most important role in profit-related taxes. Here we find that the contemporaneous short-run elasticity of 0.43 is substantially and significantly smaller than the long-run elasticity (0.77). At first glance this would speak in favour of low volatility in profit-related tax revenues. However, a closer look at the impulse-response functions shows a rapidly increasing reaction that even leads to some kind of "delayed overshooting" around two years after a shock in the base. From then onwards, the elasticity decreases until it converges to its long-run equilibrium several years after the shock. This pattern might well be explained by the collection lags in the advance-payment system applied to profit-related taxes in Germany.

Taken together, our results therefore indicate that dynamic revenue elasticities play an important role in particular in profit-related taxes in Germany. Policy analysis could potentially benefit from adjusting the currently applied elasticities, which mostly cover only the contemporaneous relationship, with respect to their values as well as with respect to their dynamic structure. Further research could investigate to what extent such adjustments could improve tax revenues forecasts and cyclical adjustment methods in practice.

Appendix

A Results of stationarity tests

Levels	Test	Constant (C) and trend (Tr) (and shift(S))					Constant (C) (and shift (S))			
			Test statistic	t-statistic (C)	t-statistic (Tr)	t-statistic (S)		Test statistic	t-statistic (C)	t-statistic (S)
tax^p	ADF	Lag order					Lag order			
		1	-4.21 **	4.35 **	3.41 ***		2	-2.36	2.46 **	
	PP	Bandwidth					Bandwidth			
		7	-2.77	3.01 ***	2.00 *		6	-2.53	2.48 **	
	LLS(S2001)	Lag order					Lag order			
		1	-2.97 *	209.81 ***	0.45	-8.60 ***	2	-1.40	220.50 ***	-4.75 ***
	LLS(S1991)	Lag order					Lag order			
		1	-2.95 *	204.78 ***	0.39	2.50 **	2	-1.68	221.10 ***	4.84 ***
$income^p$	ADF	Lag order					Lag order			
		1	-1.30	1.41	1.08		1	-1.76	2.06 **	
	PP	Bandwidth					Bandwidth			
		3	-1.01	0.84	0.45		3	-1.73	2.43 **	
	LLS(S1987)	Lag order					Lag order			
		1	-1.97	660.45 ***	0.97	-15.30 ***	0	-2.07	68.86 ***	0.36
							1	-1.85	649.53 ***	-15.66 ***
	LLS(S1991)	Lag order					Lag order			
		0	-1.77	0.14	91.18 ***	-0.09	0	-1.94	68.82 ***	0.61
		1	-2.19	0.90	607.62 ***	-1.49	1	-1.83	581.75 ***	-1.59
First differences	Test	Constant (C) (and shift (S) or impulse (I))					None			
			Test statistic	t-statistic (C)	t-statistic (Tr)	t-statistic (S)		Test statistic		
Δtax^p	ADF	Lag order					Lag order			
		1	-4.52 ***	1.71 *			1	-4.11 ***		
	PP	Bandwidth					Bandwidth			
		9	-2.67 *	1.11			6	-2.75 ***		
	LLS(I2001)	Lag order								
		1	-5.09 ***	5.19 ***	-3.90 ***					
	LLS(I1991)	Lag order								
		1	-5.18 ***	5.02 ***	1.83 *					
$\Delta income^p$	ADF	Lag order					Lag order			
		0	-3.08 **	2.04 **			0	-2.29 **		
		1	-2.61 *	1.89 *			1	-1.85 *		
	PP	Bandwidth								
		3	-3.04 **	2.04 **			0	-2.29 **		
							1	-2.19 **		
	LLS(I1987)	Lag order								
		0	-2.23	0.96	-1.70 *					
		1	-1.97	6.22 ***	-10.84 ***					
	LLS(I1991)	Lag order								
		0	-3.11 **	0.84	-0.21					
		1	-2.72 *	5.61 ***	-1.24					

Note: All tests are performed on the null hypothesis of a unit root. The number of lags in the ADF and LLS tests is based on the Schwarz information criterion (SIC) for a maximum of 3 lags in log levels and 2 lags in 1. differences. Whenever zero lags are indicated by the SIC (which is very restrictive), we additionally used a lag order SIC+1.ndicated values are values of test statistics for the null hypothesis of a unit root in the series. The window length for the PP tests is based on Newey-West (1994) using a Bartlett kernel. Significance at the 10%, 5% and 1%-level is indicated by *, **, ***. The first shown date for a potential structural break is the date indicated by the LLS search procedure. To check for robustness and to analyse the impacts of the German reunification alternative breaks around 1991 are implemented.

Table A.1: Unit root tests for profit-related taxes and tax base: ADF, PP and LLS tests, 1970-2009

Levels	Test	Constant (C) and trend (Tr) (and shift(S))					Constant (C) (and shift (S))			
			Test statistic	*t*-statistic (C)	*t*-statistic (Tr)	*t*-statistic (S)		Test statistic	*t*-statistic (C)	*t*-statistic (S)
tax^w	ADF	Lag order					Lag order			
		2	-1.09	1.27	0.15		2	**-3.09** **	3.34 ***	
	PP	Bandwidth					Bandwidth			
		2	-1.40	2.15 **	0.00			**-4.37** ***	6.82 ***	
	LLS(S1991)	Lag order					Lag order			
		2	-0.51	701.32 ***	**1.87** *	16.72 ***	2	**-2.87** *	6.80 ***	17.65 ***
$income^w$	ADF	Lag order					Lag order			
		1	-1.25	1.31	0.74		1	-1.95	2.10 **	
	PP	Bandwidth					Bandwidth			
		1	0.97	0.57	-0.41		1	**-2.62** *	3.54 ***	
	LLS(S1991)	Lag order					Lag order			
		1	-0.97	1820.54 ***	**2.02** **	39.13 ***	2	-2.17	1783.56 ***	37.98 ***
First differences	Test	Constant (C) (and shift (S) or impulse (I))					None			
			Test statistic	*t*-statistic (C)	*t*-statistic (Tr)	*t*-statistic (S)		Test statistic		
Δtax^w	ADF	Lag order					Lag order			
		0	**-2.69** *	1.65			**0**	**-2.20** **		
		1	-2.55	**1.79** *			1	**-1.82** *		
	PP	Bandwidth					Bandwidth			
		14	**-2.29** **	1.52			34	**-2.02** **		
	LLS(I1991)	Lag order								
		0	-2.18	**4.91** ***	1.96 *					
		1	-2.17	**28.24** ***	12.42 ***					
	LLS(S1992)	Lag order								
		1	**-3.36** **	27.01 ***		-16.33 ***				
	LLS(S1993)	Lag order								
		0	**-3.12** **	4.48 ***		-2.69 **				
		1	**-2.69** *	25.19 ***		-18.35 ***				
$\Delta income^w$	ADF	Lag order					Lag order			
		0	**-2.81** *	**1.96** *			**0**	**-1.95** **		
		1	**-2.96** **	**2.05** **			1	**-2.07** **		
	PP	Bandwidth					Bandwidth			
		3	**-3.15** **	**2.04** *			6	**-2.27** **		
	LLS(I1991)	Lag order								
		0	-2.10	**1.88** *	4.29 ***					
		1	**-2.67** *	**9.37** ***	24.22 ***					
	LLS(S1991)	Lag order								
		0	-1.12	1.30		4.21 ***				
		1	-1.38	**5.02** ***		33.45 ***				
	LLS(S1992)	Lag order								
		0	-1.86	1.29		-4.13 ***				
		1	-2.13	**6.01** ***		-28.15 ***				
	LLS(S1993)	Lag order								
		0	**-3.82** ***	1.09		-1.66				
		1	-1.85	**9.50** ***		-18.84 ***				

Note: All tests are performed on the null hypothesis of a unit root. The number of lags in the ADF and LLS tests is based on the Schwarz information criterion (SIC) for a maximum of 3 lags in log levels and 2 lags in 1. differences. Whenever zero lags are indicated by the SIC (which is very restrictive), we additionally used a lag order SIC+1.ndicated values are values of test statistics for the null hypothesis of a unit root in the series. The window length for the PP tests is based on Newey-West (1994) using a Bartlett kernel. Significance at the 10%, 5% and 1% level is indicated by *, **, ***. The first shown date for a potential structural break is the date indicated by the LLS search procedure. To check for robustness and to analyse the impacts of the German reunification alternative breaks around 1991 are implemented. The LLS search procedure indicates significant level shifts in 1991 due to the reunification. In growth rates impulses in 1991 are indicated. Moreover, a significant shift in the growth rate is indicated in 1993 in tax revenues and 1991 in the income (where we additionally used the 1992 and another 1993 shift).

Table A.2: Unit root tests for wage taxes and tax base: ADF, PP and LLS tests, 1975-2009

Levels	Test	Constant (C) and trend (Tr) (and shift(S))					Constant (C) (and shift (S))			
			Test statistic	*t*-statistic (C)	*t*-statistic (Tr)	*t*-statistic (S)		Test statistic	*t*-statistic (C)	*t*-statistic (S)
tax^v	ADF	Lag order					Lag order			
		0	-1.34	1.50	0.75		0	**-2.80** *	3.50 ***	
		1	-1.20	1.31	0.81		1	-1.81	2.23 **	
	PP	Bandwidth					Bandwidth			
		2	-1.48	1.69	0.75		1	**-2.65** *	3.50 ***	
	LLS(SI990)	Lag order					Lag order			
		0	-0.73	68.32 ***	0.14	2.79 ***	**0**	-2.74 *	52.28 ***	2.77 ***
		1	-0.49	432.17 ***	0.90	15.70 ***	1	-2.14	372.74 ***	8.91 ***
	LLS(SI991)	Lag order					Lag order			
		0	-0.76	67.41 ***	0.14	2.57 **	**0**	**-2.69** *	51.77 ***	2.61 **
		1	-0.57	427.43 ***	0.90	13.91 ***	1	-2.24	371.47 ***	8.40 ***
$base\_agg^v$	ADF	Lag order					Lag order			
		1	-0.91	1.00	0.46		1	-2.06	2.30 **	
	PP	Bandwidth					Bandwidth			
		3	-1.04	1.01	-0.14		3	**-3.13** **	4.86 ***	
	LLS(SI991)	Lag order					Lag order			
		1	0.24	1940.66 ***	**2.82** ***	50.52 ***	1	-2.33	1921.82 ***	49.99 ***
	LLS(SI990)	Lag order					Lag order			
		0	-0.52	133.44 ***	0.19	0.66	0	**-3.86** ***	87.34 ***	1.20
		1	-1.46	1085.73 ***	1.65	-12.71 ***	1	-1.73	1047.81 ***	-13.13 ***
cons	ADF	Lag order					Lag order			
		1	-0.79	0.90	0.20		1	**-2.60** *	2.85 ***	
	PP	Bandwidth					Bandwidth			
		2	-0.90	1.09	-0.28		3	**-3.89** ***	5.94 ***	
	LLS(SI991)	Lag order					Lag order			
		0	0.09	182.32 ***	0.26	5.50 ***	**0**	**-10.54** ***	96.63 ***	3.74 ***
		1	0.31	2247.93 ***	**3.40** ***	57.65 ***	1	**-2.82** *	2241.55 ***	57.48 ***
	LLS(SI990)	Lag order					Lag order			
		0	-0.47	136.43 ***	0.21	0.53	**0**	**-4.84** ***	83.94 ***	1.12
		1	-1.30	1136.96 ***	**1.82** *	-13.42 ***	1	-2.08	1100.27 ***	-13.76 ***
res_inv	ADF	Lag order					Lag order			
		1	-1.94	2.00 *	1.63		1	-1.16	1.31	
	PP	Bandwidth					Bandwidth			
		3	-1.53	1.35	0.21		3	-1.89	2.74 **	
	LLS(SI985)	Lag order					Lag order			
		1	-1.70	324.23 ***	0.88	-12.02 ***	1	-0.97	317.74 ***	-11.50 ***
	LLS(SI990)	Lag order					Lag order			
		1	-1.90	304.32 ***	0.78	-1.04	2	-1.23	308.63 ***	-2.26 **
gov_vat	ADF	Lag order					Lag order			
		0	-1.45	1.57	1.14		**0**	-1.47	1.96 *	
		1	-1.85	1.94 *	1.65		1	-1.04	1.37	
	PP	Bandwidth					Bandwidth			
		2	-1.70	1.67	1.14		0	-1.47	1.96 *	
	LLS(SI991)	Lag order					Lag order			
		1	-1.40	476.61 ***	0.81	38.99 ***	**0**	-1.80	60.03 ***	5.71 ***
							1	-1.65	419.68 ***	32.07 ***
	LLS(SI990)	Lag order					Lag order			
		1	-2.20	337.60 ***	0.72	-6.27 ***	**0**	-1.28	44.50 ***	0.89
							1	-1.15	317.07 ***	-8.92 ***

Table A.3a: Unit root tests for VAT and tax bases (levels): ADF, PP and LLS tests, 1970-2009

First differences	Test	Constant (C) (and shift (S) or impulse (I))					None	
			Test statistic	*t*-statistic (C)	*t*-statistic (I)	*t*-statistic (S)		Test statistic
Δtax^{v}	ADF	Lag order					Lag order	
		0	**-4.93** ***	**3.01** ***			**0**	**-3.54** ***
		1	**-3.79** ***	**2.59** **			1	**-2.58** ***
	PP	Bandwidth					Bandwidth	
		1	**-4.91** ***	**3.01** ***			2	**-3.45** ***
	LLS (I1980)	Lag order						
		0	**-4.74** ***	**2.57** **	1.64			
		1	**-3.25** **	**15.29** ***	11.69 ***			
	LLS (I1990)	Lag order						
		0	**-5.51** ***	**2.32** **	0.71			
		1	**-3.77** ***	**13.90** ***	9.32 ***			
$\Delta base\_agg^{v}$	ADF	Lag order					Lag order	
		0	**-3.30** **	**2.24** **			**0**	**-2.36** **
		1	**-2.71** *	**1.89** *			1	**-1.96** **
	PP	Bandwidth					Bandwidth	
		2	**-3.23** **	**2.24** **			1	**-2.28** **
	LLS (I1991)[1]	Lag order						
		0	-2.37	**6.58** ***	5.59 ***			
		1	-2.09	**40.72** ***	35.40 ***			
	LLS (I1990)	Lag order						
		0	**-2.75** *	**3.49** ***	-1.45			
		1	**-3.10** **	**22.05** ***	-9.73 ***			
$\Delta cons$	ADF	Lag order					Lag order	
		0	**-3.10** **	**2.19** **			**0**	**-2.16** **
		1	-2.36	1.63			1	**-1.79** *
	PP	Bandwidth					Bandwidth	
		1	**-2.99** **	**2.19** **			2	**-2.02** **
	LLS (I1991)[1]	Lag order						
		0	-1.85	**7.43** ***	6.45 ***			
		1	-1.91	**46.24** ***	41.82 ***			
	LLS (I1990)	Lag order						
		0	**-2.60** *	**3.54** ***	-1.52			
		1	**-2.93** **	**22.16** ***	-9.65 ***			
Δres_inv	ADF	Lag order					Lag order	
		0	**-3.31** **	1.21			**0**	**-3.10** ***
		1	**-3.96** ***	1.69			1	**-3.52** ***
	PP	Bandwidth					Bandwidth	
		0	**-3.31** **	1.21			1	**-3.16** ***
	LLS (I1985)	Lag order						
		0	**-3.39** **	**3.08** ***	-1.23			
		1	**-3.77** ***	**19.49** ***	-7.64 ***			
	LLS (I1990)	Lag order						
		0	**-3.48** ***	**2.86** ***	-0.21			
		1	**-3.72** ***	**17.96** ***	-1.49			
Δgov_vat	ADF	Lag order					Lag order	
		0	**-4.85** ***	**2.56** **			**0**	**-3.84** ***
		1	**-4.07** ***	**2.59** **			1	**-2.92** ***
	PP	Bandwidth					Bandwidth	
		1	**-4.87** ***	**2.56** **			2	**-3.79** ***
	LLS (I1991)	Lag order						
		0	**-5.06** ***	**1.91** *	2.95 ***			
		1	**-3.95** ***	**9.55** ***	22.30 ***			
	LLS (I1990)	Lag order						
		0	**-4.09** ***	1.46	-1.14			
		1	**-3.96** ***	**8.14**	-5.96 ***			

Note: All tests are performed on the null hypothesis of a unit root. The number of lags in the ADF and LLS tests is based on the Schwarz information criterion (SIC) for a maximum of 3 lags in log levels and 2 lags in 1. differences. Whenever zero lags are indicated by the SIC (which is very restrictive), we additionally used a lag order SIC+1. The window length for the PP tests is based on Newey-West (1994) using a Bartlett kernel. Significance at the 10%, 5% and 1%-level is indicated by *, **, ***. The first shown date for a potential structural break is the date indicated by the LLS search procedure. To check for robustness and to analyse the impacts of the German reunification alternative breaks around 1991 are implemented. [1] Alternatively, a negative linear trend can be implemented in addition, or the starting point of the sample can be shifted to 1980, to capture weak non-stationarity properties of the series. However, none of the implemented deterministic trends were found significant in this case.

Table A.3b: Unit root tests for VAT and tax bases (1.differences): ADF, PP and LLS tests, 1970-2009

B Results of cointegration tests

Variables	Deterministic specification (MacKinnon, 2010)	Critical values			Test statistic			
		10%	5%	1%	AEG (DOLS)	AEG (DOLS, Shift 1991 in CE)	AEG (DOLS, Shift 2001 in CE)	AEG (DOLS, Shift 1991, Shift 2001 in CE)
tax^p, $income^p$	lag order (A)DF regression by SIC				1	1	1	1
	none in CE or (A)DF regression	-3.04	-3.34	-3.90	**-3.75** **	**-4.19** ***	**-3.59** **	**-4.11** ***
(n=2)	lag order (A)DF regression by SIC				1	1	1	1
	constant in CE or (A)DF regression;	-3.04	-3.34	-3.90	**-3.71** **	**-4.13** ***	**-3.54** **	**-4.05** ***

Note: Augmented Dickey-Fuller regressions and test statistics have to be used, whenever there is serial correlation in the cointegrating resiudals. In case of heteroscedasticity the test statistics do not have to be modified. If a constant or a constant and a trend are already included in the estimation of the cointegrating relation they do not have to be included in the (A)DF regression for the cointegrating residuals, and vice versa. However, if a constant, or a constant and a linear trend is included in, either the cointerating equation, or the ADF (DF) regression, the critical values to be taken are the ones based on the correct deterministic specification. The most reliable one sided critical values can be found in MacKinnon (2010). These values do not take into account additional structural break components. If the lag order is indicated to be zero which we consider as very restrictive an additional test with SIC+1 is performed. Maximum lag order is set to 4.

Table B.1: Profit-related taxes. Residual based cointegration tests:
Null: no cointegration, unadjusted sample 1970-2009.

Variables	Deterministic specification (MacKinnon, 2010)	Critical values			Test statistic			
		10%	5%	1%	AEG (DOLS)		AEG (DOLS, Shift 1991 in CE)	
tax^w, $income^w$	lag order (A)DF regression by SIC (and SIC+1, if 0)				0	1	0	1
	none in CE or (A)DF regression	-3.04	-3.34	-3.90	-2.12	-2.58	**-4.04** ***	**-4.53** ***
(n=2)	lag order (A)DF regression by SIC (and SIC+1, if 0)				0	1	0	1
	constant in CE or (A)DF regression;	-3.04	-3.34	-3.90	-2.10	-2.60	**-3.97** ***	**-4.45** ***

Note: Augmented Dickey-Fuller regressions and test statistics have to be used, whenever there is serial correlation in the cointegrating resiudals. In case of heteroscedasticity the test statistics do not have to be modified. If a constant or a constant and a trend are already included in the estimation of the cointegrating relation they do not have to be included in the (A)DF regression for the cointegrating residuals, and vice versa. However, if a constant, or a constant and a linear trend is included in, either the cointerating equation, or the ADF (DF) regression, the critical values to be taken are the ones based on the correct deterministic specification. The most reliable one sided critical values can be found in MacKinnon (2010). These values do not take into account additional structural break components. If the lag order is indicated to be zero which we consider as very restrictive an additional test with SIC+1 is performed. Maximum lag order is set to 3 (due to the smaller sample for wage tax revenues).

Table B.2: Wage taxes. Residual based cointegration tests:
Null: no cointegration; unadjusted sample 1975-2009.

Variables	Deterministic specification (MacKinnon, 2010)	Critical values			Test statistic			
		10%	5%	1%	AEG (DOLS)		AEG (DOLS, Shift 1990 in CE)	
tax^v $base\_agg^v$	lag order (A)DF regression by SIC (and SIC+1, if 0)				0	1	0	1
	none in CE or (A)DF regression	-3.04	-3.34	-3.90	**-5.80** ***	**-4.41** ***	**-6.22** ***	**-4.86** ***
(n=2)	lag order (A)DF regression by SIC (and SIC+1, if 0)				0	1	0	1
	constant in CE or (A)DF regression;	-3.04	-3.34	-3.90	**-5.72** ***	**-4.34** ***	**-6.13** ***	**-4.79** ***

Note: Augmented Dickey-Fuller regressions and test statistics have to be used, whenever there is serial correlation in the cointegrating resiudals. In case of heteroscedasticity the test statistics do not have to be modified. If a constant or a constant and a trend are already included in the estimation of the cointegrating relation they do not have to be included in the (A)DF regression for the cointegrating residuals, and vice versa. However, if a constant, or a constant and a linear trend is included in, either the cointerating equation, or the ADF (DF) regression, the critical values to be taken are the ones based on the correct deterministic specification. The most reliable one sided critical values can be found in MacKinnon (2010). These values do not take into account additional structural break components. If the lag order is indicated to be zero which we consider as very restrictive an additional test with SIC+1 is performed. Maximum lag order is set to 4.

Table B.3: VAT. Residual based cointegration tests:
Null: no cointegration,; unadjusted sample 1970-2009.

Variables	Deterministic specification (MacKinnon, 2010)	Critical values			Test statistic		
					AEG	AEG (DOLS, Shift 1990 in CE)	
		10%	5%	1%	(DOLS)		
tax^v	lag order (A)DF regression by SIC (and SIC+1, if 0)				1	0	1
cons	none in CE or (A)DF regression	-3.810	-4.096	-4.643	**-5.91** ***	**-7.01** ***	**-5.49** ***
res_inv	lag order (A)DF regression by SIC (and SIC+1, if 0)				1	0	1
gov_vat	constant in CE or (A)DF regression;	-3.810	-4.096	-4.643	**-5.83** ***	**-6.91** ***	**-5.43** ***
(n=4)							

Note: Augmented Dickey-Fuller regressions and test statistics have to be used, whenever there is serial correlation in the cointegrating resiudals. In case of heteroscedasticity the test statistics do not have to be modified. If a constant or a constant and a trend are already included in the estimation of the cointegrating relation they do not have to be included in the (A)DF regression for the cointegrating residuals, and vice versa. However, if a constant, or a constant and a linear trend is included in, either the cointerating equation, or the ADF (DF) regression, the critical values to be taken are the ones based on the correct deterministic specification. The most reliable one sided critical values can be found in MacKinnon (2010). These values do not take into account additional structural break components. If the lag order is indicated to be zero which we consider as very restrictive an additional test with SIC+1 is performed. Maximum lag order is set to 4.

Table B.4: VAT (disaggregated tax base). Residual based cointegration tests: *Null*: no cointegration; unadjusted sample 1970-2009.

C Results for VAT (disaggregated tax base)

Sample (unadj.)	1970-2009	**1970-2009**	1970-2009	1970-2009
Estimator	OLS	**OLS**	DOLS (NW)	DOLS
$cons_t$	0.51 ***	**0.59 *** **	0.59 ***	0.70 ***
	11.21	***10.95***	*8.44*	*5.97*
res_inv_t	0.13 ***	**0.10 *** **	0.09 *	0.08
	3.51	***2.83***	*1.77*	*1.44*
gov_vat_t	0.20 ***	**0.10**	0.18 **	0.00
	3.34	***1.41***	*2.29*	*0.01*
$c^{v,d}_{LR}$	-0.80 ***	**-0.75 *** **	-1.08 ***	-0.93 ***
	-10.06	***-9.65***	*-7.67*	*-4.03*
$reunification_{1990}^{v,d}$		**0.05 ** **		0.07
(shift)		***2.36***		*1.48*
H_0: $cons_t + res\_inv$	0.00	**0.00**	0.00	0.00
R^2(adj)	1.00	**1.00**	1.00	1.00
SIC	-4.42	**-4.48**	-3.93	-3.92
DW	2.16	**2.04**	2.28	2.31
LM: $\chi^2(1)$	0.55	**0.70**	0.35	0.25
LM: $\chi^2(2)$	0.14	**0.25**	0.09	0.24
BPG	0.87	**0.99**	0.56	0.44
White	0.83	**1.00**	0.91	0.48
JB	0.06	**0.51**	0.60	0.90

Note: t -values in italics. Significance on the 10%, 5% and 1% level is indicated by *, **, ***. P-values are shown for all diagnostic checks on the estimated residuals, instead for of Durbin-Watson test. P-values are also presented for the Wald tests. Lags and leads of first differences of the regressors due to DOLS are not presented. - refers to a parameter eliminated due to insignificance. DOLS specifications are obviously overparametrized due to nuisance parameters of each base that have to be taken into account and the small sample that is available. Whenever there is evidence for serial correlation in the residuals, the variance-covariance matrices are corrected by the Newey-West (NW) procedure to get more reliable standard errors.

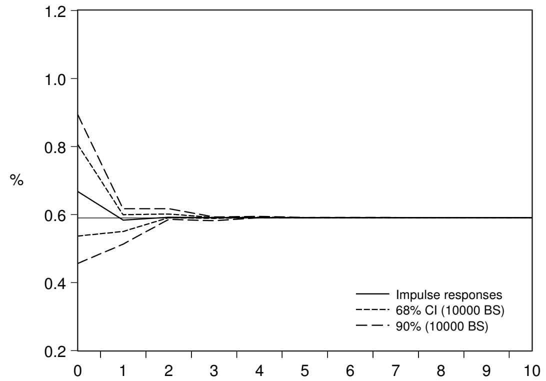
Table C.1: VAT (disaggregated base) - long-run

Model	**ECM (0,0)**
Sample (unadj.)	1970-2009
Estimator	OLS
$\Delta cons_t$	0.67 ***
	4.63
Δres_inv_t	0.14 **
	2.63
Δgov_vat_t	0.07
	1.01
$ec^{tax,v,d}_{t-1}$	-1.09 ***
	-6.65
$c^{v,d}_{SR}$	0.00
	-0.80
$reunification_{1990}^{v,d}$	0.09 ***
(impulse)	*4.24*
R^2(adj)	0.82
SIC	-4.57
DW	2.03
LM: $\chi^2(1)$	0.40
LM: $\chi^2(2)$	0.22
LM: $\chi^2(3)$	0.33
BPG	0.63
White	0.68
JB	0.61

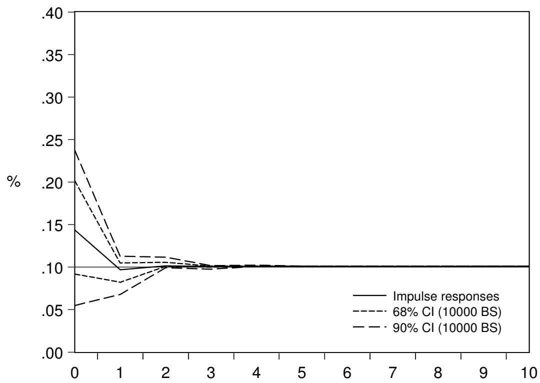
Note: t-values in italics. Significance on the 10%, 5% and 1% level is indicated by *, **, ***. An - refers to an not included term. If the term is not included in the benchmark model, it is also excluded from the models with asymmetries. Whenever there is evidence for serial correlation left in the residuals we used additional lags (up to lag 1) of the endogenous and exogenous variables. p-values are shown for all diagnostic checks on the estimated residuals instead for Durbin-Watson test.

Table C.2: VAT (disaggregated base) - short-run

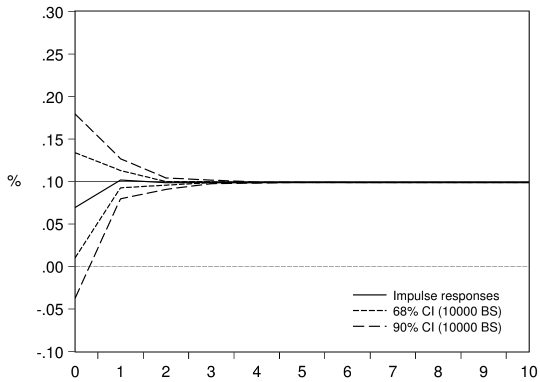
Figure C.1: Impulse responses of VAT (disaggregated tax base)



Notes: 1 percentage point shock in growth rate of private consumption; Benchmark ECM



Notes: 1 percentage point shock in growth rate of residential investment; Benchmark ECM



Notes: 1 percentage point shock in growth rate of government expenditures related to VAT base; Benchmark ECM

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Applicants are requested to send a CV, copies of recent papers, letters of reference and a proposal for a research project to:

Deutsche Bundesbank
Personalabteilung
Wilhelm-Epstein-Str. 14

60431 Frankfurt
GERMANY