Time Varying Fiscal Multipliers in Germany

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Abstract

This paper provides novel evidence on the time varying impact of government spending shocks on output in Germany over the years 1970 to 2013. In a first step, I use an expectations-augmented vector autoregressive model with time varying parameters (TVP-VAR) to show that fiscal multipliers are not stable over time but exhibit a u-shaped pattern. While multipliers fluctuate around 2 at the beginning and end of the sample, they are much smaller in between. In a second step, I discuss which factors determine the magnitude of German multipliers and hence explain the observed variation. It turns out that fiscal policy is more effective when business uncertainty is high but less in periods of financial market stress, while the state of the business cycle is minor important. Moreover, I find that fiscal sustainability is a crucial determinant of the multipliers and that these are about 1 euro higher since the loss of monetary policy autonomy due to the adoption of the euro. And finally, I conclude that policy recommendations based on average multipliers are misleading.

Keywords: Fiscal Multipliers, State Dependence, Germany
Expectations-Augmented TVP-VAR

JEL-Codes: C11, E32, E62

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"It seems to me that the German people - pointedly - can withstand a 5% price increase better than 5% unemployment." - Chancellor Helmut Schmidt, Süddeutsche Zeitung, July 28, 1972, p. 8

"We will cut back state benefits, promote personal responsibility and have to request a greater contribution from each individual." - Chancellor Gerhard Schröder, Government Declaration, March 14, 2003

"We do not want to simply survive this crisis. [...] We want to use this crisis as an opportunity. [...] These are signals that should not be overlooked, and that create reasons for action. [...] Because of this, doing nothing is not an option." - Chancellor Angela Merkel, Government Declaration, January 14, 2009

Original quotes are in German. Own translation.[1]

1 Introduction

The attitude of German policymakers towards the role of government in general and fiscal stimulus in particular has changed several times over the past decades. During the 1970s Keynesian stabilization policy was in vogue and fiscal authorities believed that discretionary government spending is a good thing, even if it comes at the cost of higher inflation. While the government spending share of output was about 15% at the beginning of the 1970s, it had been risen to more than 20% at the end of the chancellorship of Helmut Schmidt in 1982 (see Figure 1).[2] Inspired by American Reaganomics and British Thatcherism, the Kohl administration conducted a different policy and the share fell throughout the 1980s, until German reunification in 1990 called again for a stronger role of government. In March 2003 Gerhard Schröder gave a famous government declaration and more or less redefined the role of the German welfare state. Thanks to generous state benefits, public spending had reached unsustainable levels, so the tenor of his speech. The declaration was followed by a series of supply-side reforms, including a deregulation of the labor market and lower unemployment benefits (so-called *Agenda 2010* and *Hartz I to IV* reforms). With the outburst of the global financial and economic crisis in fall 2008, discretionary

[1]The original quotes in German are available here: de.wikipedia.org/wiki/Phillips-Kurve#cite_note-4 (Helmut Schmidt), www.documentarchiv.de/brd/2003/rede_schroeder_03-14.html (Gerhard Schröder), dip21.bundestag.de/dip21/btp/16/16198.pdf (Angela Merkel).

[2]I use the ratio of nominal government consumption and nominal gross domestic product (GDP). See Section 2.1 and Appendix A for a detailed description of the data.

government spending was back at the top of the political agenda, or as Angela Merkel put it "[...] doing nothing is not an option". In November 2008 and February 2009, the German parliament passed two deficit-financed stimulus packages summing to 74.5 billion euro or 3.1% of GDP to counteract the economic downturn (so-called *Konjunkturpaket I & II*).[3]

But were these stimulus packages effective? And if yes, why? In this paper I address these and a few other questions that come into mind when considering the German fiscal episodes of the past decades. In particular, I quantify the degree of fiscal activism and explore whether it has changed over time. Moreover, I investigate if the effectivity of discretionary government spending, i.e. government spending shocks, has varied across periods. Finally, I discuss which factors determine the effectivity of changes in spending. Addressing these questions is not only interesting in its own right and a contribution to the recent debate on the economic effects of fiscal stimulus packages,[4] but also a prerequisite for sound policy recommendations.

To study the time varying impact of government spending shocks on output in Germany, I proceed in two steps. In a first step, I run a vector autoregressive model with time varying parameters (TVP-VAR) on government spending and output. The model is the appropriate framework to address the questions of interest since it allows for smooth and permanent changes in the structure of the economy via drifting coefficients, while accounting for the possibility that the size of spending shocks is not stable over time.[5] In contrast to the regime-switching models of Auerbach and Gorodnichenko (2012a,b), the TVP-VAR is more flexible since it is not restricted to only two states of the economy (recession vs. expansion, for example). Moreover, I add professional forecasts for government spending and output to control for anticipation effects and avoid nonfundamentalness.[6] The spending shock is identified with a recursive scheme and impulse responses are used to calculate fiscal multipliers as a measure of policy effectivity.

In a second step, I discuss which factors determine the size of German multipliers and explain the observed variation. To that end I regress the series of multipliers from the TVP-VAR on a broad set of possible determinants, including cyclical, structural, and institutional factors. The

[3] See Gemeinschaftsdiagnose (2009), p. 49, Table 3.11, for an exact composition of both packages.

[4] See for example Coenen, Straub, and Trabandt (2013) for an analysis of the European Economic Recovery Plan (EERP) in the European Union, or Cogan, Cwik, Taylor, and Wieland (2010) for the American Recovery and Reinvestment Act (ARRA) in the United States.

[5] Applications of the TVP-VAR framework to fiscal policy include Pereira and Lopes (2010) for the U.S., Rafiq (2010, 2014) for the U.K., and Kirchner, Cimadomo, and Hauptmeier (2010) for the euro area.

[6] Nonfundamentalness arises in situations in which the information set of the econometrician is smaller than that of the economic agents (see, e.g., Lippi and Reichlin, 1994, among others). Ramey (2011) emphasizes that neglecting anticipation effects in fiscal VARs can render impulse responses biased and proposes to include news about future fiscal policy to overcome this potential problem.

choice of these factors is motivated by standard economic models and the findings of the related empirical literature. This paper hence fits into the growing literature on the state dependence of fiscal policy multipliers (see, e.g., Auerbach and Gorodnichenko, 2012a,b; Bachmann and Sims, 2012; Corsetti, Meier, and Müller, 2012; Hristov, 2012, 2013; Born, Juessen, and Müller, 2013; Ilzetzki, Mendoza, and Végh, 2013; Müller, 2014; Rafiq, 2014, among others).

The results are: First, I find that the degree of fiscal activism has declined over time. While the size of spending shocks varies across periods, their posterior standard deviation is about 30% lower these days than at the beginning of the 1970s. Second, fiscal stimuli have a limited and short-lived impact on German output, but tend to increase the government spending share of output over longer horizons. Third, their impact is not stable over time, but exhibits a u-shaped pattern. While multipliers fluctuate around 2 at the beginning and end of the sample, they are much smaller in between. Fourth, I obtain evidence that German fiscal policy is more effective when business uncertainty is high but less in periods of financial market stress, while the state of the business cycle is minor important. Furthermore, I find that fiscal sustainability is a crucial determinant of the multipliers and that these are much higher since the loss of monetary policy autonomy due to the adoption of the euro. Other factors, such as exchange rate flexibility, the degree of import penetration, private households' access to credit, or German reunification appear to be less relevant. In the light of these findings, I conclude that policy recommendations based on average multipliers are misleading, but should take the state dependence of the spending shocks into account. Moreover, I believe that this paper tells a cautionary tale for fiscal policy to stimulate output in Germany.

The remainder of this paper is organized as follows. Section 2 explains the empirical strategy and the data used. Section 3 documents the evidence on the time varying impact of government spending shocks on German output. Section 4 presents a few extensions and robustness checks. Section 5 discusses the determinants of the fiscal multipliers and offers an explanation for the observed variation. Section 6 provides a summary of the results and concluding remarks.

2 Methodology and Data

In this section I outline the TVP-VAR model that is used to explore the time varying impact of government spending shocks on output in Germany. The model allows for both time variation in the coefficients and stochastic volatility. In addition, I include professional forecasts for the variables of interest to control for anticipation effects. Furthermore, I describe the data used, explain the identification strategy and present different measures of fiscal policy effectivity.

2.1 Expectations-Augmented TVP-VAR

Consider the TVP-VAR model

$$Y_t = c_t + B_{1,t}Y_{t-1} + ... + B_{p,t}Y_{t-p} + u_t = X_t'B_t + u_t, \tag{1}$$

where Y_t is a 4×1 vector of endogenous variables including forecasted government spending growth ($\Delta g^f_{t|t-1}$), forecasted output growth ($\Delta y^f_{t|t-1}$), actual government spending growth (Δg_t), and actual output growth (Δy_t) in that order; c_t is a 4×1 vector of time varying intercepts; $B_{i,t}$ are 4×4 matrices of time varying coefficients; $i = 1, ..., p$ denotes the lags included; u_t is a 4×1 vector of residual terms with zero mean and time varying covariance matrix Ω_t; and data are available for $t = 1, ..., T$. Let $X_t' = I_4 \otimes \left[1, Y_{t-1}', ..., Y_{t-p}'\right]$ and $B_t = \text{vec}\left([c_t, B_{1,t}, ..., B_{p,t}]'\right)$, where $\otimes$ denotes the Kronecker product and vec $(\cdot)$ is the column stacking operator, respectively. The system in (1) is labelled an expectations-augmented TVP-VAR model since Y_t includes professional forecasts for the variables of interest Δg_t and Δy_t to control for anticipation effects. I estimate the model using Bayesian methods as in Primiceri (2005), which are explained in detail in Appendix B.

For actual government spending growth I use the annualised (log) change in real government consumption and for actual output growth the annualised (log) change in real GDP. Both series are streamed from the OECD Economic Outlook database. The corresponding forecasts are obtained from the respective vintage of the OECD Economic Outlook, which is prepared twice a year in July and December, providing predictions for real government consumption growth and real GDP growth over the following half year. The availability and timing of these forecasts hence dictate the frequency and definition of the series used to estimated the TVP-VAR model. For that reason I consider semi-annual data from 1970:1 to 2013:1. A detailed description of all series used in this paper is provided in Appendix A. Unfortunately, forecasts for real government investment growth are not available for all periods, and government spending is hence measured by government consumption only. However, I do not regard this data limitation as a disadvantage since government investment is only a small fraction of overall spending. Finally, I follow common practice and fix the lag length at the frequency of the data, i.e. $p = 2$.[7]

The validity of the expectations-augmented TVP-VAR approach depends on the quality of the forecasts used. It should be ensured that these are not biased in any direction. In Figure 2 it is shown that forecasted government spending growth closely tracks movements in actual spending growth over time, showing no systematic deviations. This visual inspection is con-

[7]The results are not sensitive to alternative choices for p.

firmed by Figure 3, which plots actual government spending growth againts its corresponding forecasts together with a regression line obtained by regressing the former on the latter and a constant (Mincer-Zarnowitz regression).[8] While there is a strong positive correlation between both series, the estimated coefficients indicate that the forecasts are both unbiased and efficient. I can neither reject the null hypothesis that the constant is equal to zero (point estimate: 0.77; standard error:[9] 0.47) nor that the slope is equal to one (point estimate: 0.78; standard error: 0.25) at conventional significance levels (p-values: 0.102 and 0.378, respectively). In fact, the joint null has a p-value of 0.196 using a standard F-Test. Similar conclusions can be drawn for the output growth forecasts that are depicted in Figures 4 and 5 together with their corresponding actual values. While both series display a strong positive correlation, the regression analysis also points to unbiasedness and efficiency of the forecasts. The estimated constant is 0.57 (standard error: 0.64) and the slope is 0.64 (standard error: 0.25), with p-values above conventional significance levels (0.375 and 0.153, respectively). The joint null has a p-value of 0.233.

Taken together, I conclude that forecasts for government spending and output growth from the OECD Economic Outlook perform well in terms of Mincer-Zarnowitz regressions, showing no systematic bias in any direction, and including them into an otherwise standard TVP-VAR model seems to be a reasonable way to control for anticipated movements in both variables.

2.2 Identifying Government Spending Shocks

Consider the following structural representation of the TVP-VAR model in Equation (1):

$$Y_t = X_t' B_t + \Xi_t \epsilon_t, \quad E\left[\epsilon_t \epsilon_t'\right] = I_4, \tag{2}$$

where Ξ_t maps the structural shocks ϵ_t into the residual terms. If Ξ_t contains six restrictions for any $t = 1, ..., T$, the system is just identified. In order to identify government spending shocks, I follow Auerbach and Gorodnichenko (2012a,b), assuming a recursive ordering of the variables in $Y_t = \left[\Delta g^f_{t|t-1} \; \Delta y^f_{t|t-1} \; \Delta g_t \; \Delta y_t\right]'$ and calculate Ξ_t as the lower triangular Cholesky factor of Ω_t. The structural government spending shock is the innovation to government spending growth, i.e. $\epsilon_{3,t}$. No structural interpretation is attached to the remaining shocks.

[8]See Mincer and Zarnowitz (1969). The idea is the following. First, estimate $\Delta g_t = \beta_0 + \beta_1 \Delta g^f_{t|t-1} + u_t$ by ordinary least squares (OLS). Second, test $H_0 : \hat{\beta}_0 = 0$ and $\hat{\beta}_1 = 1$. If one cannot reject the null hypothesis at conventional significance levels, $\Delta g^f_{t|t-1}$ is called unbiased and efficient, implying that the forecast error $(\Delta g_t - \Delta g^f_{t|t-1})$ is white noise.

[9]I use White heteroskedasticity-consistent standard errors.

Imposing a lower triangular structure on Ξ_t amounts to imposing the following restrictions on the contemporaneous response of the variables to a government spending shock. First, forecasted government spending growth and forecasted output growth are not affected by a surprise innovation to government spending growth in period t. This assumption is trivial since both forecasts are made in $t-1$ and are hence predetermined. Observe that by controlling for expected changes in government spending and output growth, $\epsilon_{3,t}$ is indeed a surprise innovation to government spending growth and not mixed up with an anticipated increase in Δg_t. Second, output growth reacts immediately to a government spending shock, while government spending growth does not respond to an innovation in output growth. The latter assumption is standard in the related literature and reflects the delays that are inherent in the political system (see, e.g., Blanchard and Perotti, 2002, among others).[10]

Finally, I compute impulse responses at horizon k as the difference between two conditional expectations with and without the government spending shock:

$$\mathrm{IRF}_{t+k} = \mathrm{E}\left(y_{t+k}|\mathrm{I}_t, \epsilon_{3,t} = 1\right) - \mathrm{E}\left(y_{t+k}|\mathrm{I}_t\right), \tag{3}$$

where I_t is the current information set. When calculating these conditional expectations I follow Koop, Leon-Gonzalez, and Strachan (2009) and fix coefficient and covariance states at their period t values, assuming constant parameters over the response horizon, which is equivalent to setting all shocks to the model between period t and k to their expected values of zero.[11]

2.3 Measuring Fiscal Policy Effectivity

In order to assess the effectivity of fiscal policy, I follow common practice in the related literature and rescale the impulse responses of output to a government spending shock by the government spending share of output to put them in euro terms. The size of the output response may then be interpreted as a fiscal policy multiplier, i.e. $\partial y/\partial g$. There is, however, no such thing as a fiscal multiplier *per se*, and I thus consider the four prevalent measures of the related literature.

[10]While this assumption seems natural for quarterly time series, one may argue that it is too restrictive in case of semi-annual data since fiscal policy may easily respond to the state of the economy within six months via discretionary changes in spending. However, Born and Müller (2012) test this restriction and find that even annual spending is predetermined. See also Beetsma, Giuliodori, and Klaassen (2009).

[11]An alternative would be to simulate the future path of the coefficients and the covariance matrix, hence taking into account all potential sources of uncertainty arising from changes in lagged coefficients, contemporaneous relations, and additive innovations (see, e.g., Koop, 1996; Koop, Pesaran, and Potter, 1996, among others). As Koop himself emphasizes, however, such simulations can be computationally intense and often lead to impulse responses that are similar to those setting future shocks to zero (see Koop et al., 2009). Therefore I do not follow this avenue.

The measures have their pros and cons and computing all of them therefore allows for a robust assessment of fiscal policy effectivity. Let $y_{k,t}$ denote the output response at horizon k in period t, $g_{k,t}$ the government spending response, and $(g/y)_t$ the government spending share of output. The fiscal multipliers considered are:

Impact Multiplier The first measure relates the output response to the impact size of the government spending shock (see, e.g., Blanchard and Perotti, 2002, among others):

$$\mathrm{IM}_{k,t} = \frac{y_{k,t}}{g_{0,t}} / (g/y)_t \,. \tag{4}$$

Maximum Multiplier The second measure is similar to the first one, with the exception that the maximum output response over a k period horizon is divided by the maximum government spending response over the same horizon (see, e.g., Bachmann and Sims, 2012, among others):

$$\mathrm{MM}_{k,t} = \frac{\max\ (y_{k,t})}{\max\ (g_{k,t})} / (g/y)_t \,. \tag{5}$$

Present Value Multiplier The third measure considers the entire path of the output and government spending response up to horizon k:

$$\mathrm{PVM}_{k,t} = \frac{\sum_{j=0}^{k} (1+i_t)^{-j}\ y_{j,t}}{\sum_{j=0}^{k} (1+i_t)^{-j}\ g_{j,t}} / (g/y)_t \,, \tag{6}$$

where i_t is the nominal interest rate, meaning that multipliers are expressed in terms of period $k = 0$ euros (see, e.g., Mountford and Uhlig, 2009, among others).

Cumulative Multiplier The fourth measure is similar to the third one, but abstracts from discounting, i.e. $i_t = 0$ for all t (see, e.g., Auerbach and Gorodnichenko, 2012b, among others):

$$\mathrm{CM}_{k,t} = \frac{\sum_{j=0}^{k} y_{j,t}}{\sum_{j=0}^{k} g_{j,t}} / (g/y)_t \,. \tag{7}$$

While the four multipliers are different ways to measure fiscal policy effectivity, it should be noted that they are identical in the period the spending shock materializes, i.e. $k = 0$.

3 Evidence on Time Variation

In this section I present the evidence on the time varying impact of government spending shocks on output in Germany for the period 1970:1 to 2013:1. While the main focus is on changes in the transmission mechanism, i.e. the output response to spending shocks of equal size, I begin by documenting if and how the size of the shocks itself has varied across periods. Then I present impulse responses to a 1 percent increase in spending that are used to compute fiscal multipliers. Finally, I discuss the time variation in multipliers, thereby providing an assessment of how the effectivity of German fiscal policy has changed. Some robustness checks and extensions to the baseline model are reported in Section 4, while I discuss possible determinants of the observed variation in multipliers in Section 5.

3.1 Size of Spending Shocks

Figure 6 documents how the standard deviation of spending shocks has evolved over time. The figure shows the median of the posterior distribution (solid line) together with a 68 percent error band (dashed line).

The evolution of the shock size squares well with the fiscal episodes outlined in the introduction, supporting the plausibility of the identification strategy. While the posterior standard deviation is large during the period of Keynesian stabilization policies in the 1970s, it is steadily falling thereafter. Fiscal policy activism is particularly low during the first term of the Kohl administration around 1985 and again in the mid 2000s. With German reunification in 1990, the posterior standard deviation increases remarkably and stays high for a few years, but sharply falls again in the late 1990s. The response of the Merkel administration to the Great Recession in 2008/09 is reflected by a modest but temporary rise in the standard deviation.

In sum, I detect large swings in the size of spending shocks which mark important episodes of German fiscal policy. However, I also find that the degree of fiscal activism has declined over time, with a posterior standard deviation that is about 30% lower these days than at the beginning of the 1970s.

3.2 Impulse Responses to Spending Shocks

In Figure 7 I plot the impulse responses to spending shocks in the baseline model which are the basis for the fiscal multipliers that are discussed below. The size of the shocks is normalized to 1 percent. To obtain the impulse responses for forecasted government spending, forecasted output, government spending and output, I cumulate the responses coming from their respective growth rates. Each three-dimensional (3D) graph shows the posterior median at horizons 0 to 20 for the period 1970:1 to 2013:1. The x-axis plots the horizon, the y-axis denotes the year, and the z-axis shows the response in percent.

The figure displays a hump-shaped response for government spending across all periods, which settles after five years at 1.4 to 1.6 percent. The response is larger at the beginning and end of the sample than in between, but always above zero, meaning that a shock permanently raises spending. Not surprisingly, forecasted government spending shows a similar pattern, though its magnitude is lower than that of actual spending. In Section 2.1 I show, however, that this difference is not statistically significant.

With respect to output I detect substantial variation across periods. The impact response shows a u-shaped pattern, being roughly 0.3 percent before 1985 and after 2005 but is smaller in between. In all periods, the response declines over time and varies between -0.4 and 0.2 percent after five years. Taken together with the permanent increase of government spending, this finding implies that the spending share of output rises following a positive shock to spending, which may explain why the fiscal stimuli of the 1970s are associated with a permanent shift in the spending to GDP ratio (see Figure 1). In addition, I find that the behavior of forecasted output is consistent with that of actual output.

All in all, I conclude that the transmission of spending shocks to German output is not stable across periods. In the next subsection I discuss how this finding affects the fiscal multipliers and hence the effectivity of fiscal policy.

3.3 Fiscal Multipliers

Figure 8 shows the posterior median for the fiscal multipliers at horizons 0 to 20 for the period 1970:1 to 2013:1 in euro terms. Since the 3D plots do not account for the uncertainty surrounding the multipliers, I document the posterior median for $k = 0$ together with a 68 percent error band in Figure 9. Remember that the four multipliers are identical in that period. Similarly, I show the multipliers at $k = 20$ in Figure 10. While for the impact multipliers the initial period is particularly interesting, the remaining multipliers (maximum, present value and cumulative) are most informative when the entire path of responses is considered.

It turns out that the multipliers display substantial time variation for $k = 0$. An increase in spending of 1 euro lifts output by more than 2 euro at the beginning of the sample. This value decreases thereafter and is about zero at the end of the 1980s, meaning that extra demand generated by fiscal policy is completely counteracted by a fall in private absorption and/or net exports in that time. At the beginning of the 1990s, multipliers start to rise and fluctuate again around 2 since the early 2000s. Moreover, the error band largely supports positive multipliers for the 1970s and since about 2000, but not for the period in between.

For $k = 20$, all multipliers show the same u-shaped pattern as for $k = 0$. Not surprisingly, impact multipliers are never significantly positive, meaning that an initial 1 euro increase in spending does not lead to a permanent rise in output. The maximum multipliers look similar to the multipliers at $k = 0$, but are smaller, which is the result of the fact that the maximum response for output is always obtained in the initial period, while that of spending is delayed. Finally, I find that present value and cumulative multipliers are negative most of the time, except for the early 1970s and since 2000. Both are, however, never significantly different from zero.

Taken together, this evidence suggests that (a) spending shocks have a short-lived and limited impact on German output; and (b) that impact is not stable over time, but might be state dependent.

4 Robustness and Extensions

Before I turn to a detailed analysis on which factors determine the size of fiscal multipliers and hence the effectivity of fiscal policy in Germany, I discuss a few extensions to the baseline model, which allow me to explore the robustness of the previous findings. Furthermore, extending the model to variables other than spending and output may provide some valuable insights about the transmission mechanism. To fix ideas, let $Y_t = \left[\Delta g^f_{t|t-1}\ \Delta y^f_{t|t-1}\ \Delta g_t\ \Delta y_t\ x_t\right]'$ be the baseline TVP-VAR model augmented by a scalar x_t, which contains an additional variable beyond spending and output. In order to keep the estimation procedure tractable, I add only one series at a time and repeat the exercise for each additional variable separately. In particular, I consider net exports, a real exchange rate, and a real interest rate.[12] The latter is included to account for possible crowding-out effects, while the former two variables are regarded as important in an open economy context (see, e.g., Enders, Müller, and Scholl, 2011; Born et al., 2013, among others). Estimation and identification are as before. Since x_t is ordered last in Y_t, the additional variables are allowed to respond contemporaneously to a spending shock.

In Figure 11 I show the impulse responses to a 1 percent increase in spending for net exports, the real exchange rate, and the real interest rate (left column) together with the corresponding output responses (right column).[13] The following findings are worth mentioning. First, the output responses appear to be robust across specifications. Adding net exports, the real exchange rate, or the real interest rate to the baseline TVP-VAR has little to no impact on their magnitude and shape. Second, I obtain a decline in net exports around 1990, which is consistent with the previous finding that fiscal multipliers were low at that time. The additional income generated

[12]The variables are constructed as follows. Net exports is nominal exports of goods and services minus nominal imports of goods and services divided by nominal GDP. The real exchange rate is the real effective exchange rate based on the consumer price index (CPI). The real interest rate is the nominal interest rate less actual CPI inflation. See Appendix A for a detailed description of the series used.

[13]The full set of results for the extended models is available on request from the author.

by fiscal policy has presumably been used to buy foreign rather than domestic goods, thereby limiting the stimulating impact on German output. Moreover, I find that the real exchange rate shows a stronger increase, i.e. appreciation, around the same time, which might have dampened net exports as well. And finally, I obtain a larger positive response for the real interest rate in the second part of the sample than in the first one, which is consistent with the general tendency of central banks to react stronger to inflationary pressures since the mid 1980s compared to the 1970s. There is, however, no evidence that this increased monetary policy activism has significantly limited the effectivity of fiscal policy.

To sum up, I find that the results of the previous sections still hold when the baseline TVP-VAR model is extended to control for relevant transmission channels.

5 Determinants of the Multipliers

In the previous sections I have shown that German fiscal multipliers vary across periods. Yet, it is unclear what lies behind that variation. In this section I discuss which factors determine the effectivity of fiscal policy in Germany. To that end I regress the series of multipliers on a set of possible determinants that can be broadly grouped into three categories:

Cyclical Factors First, I include the following cyclical factors: recession dates, a measure of business uncertainty, and a financial market stress index. While there is evidence for both the United States (see, e.g., Auerbach and Gorodnichenko, 2012a,b; Bachmann and Sims, 2012, among others) and Germany (see, e.g., Baum and Koester, 2011; Baum, Poplawski-Ribeiro, and Weber, 2012, among others) that fiscal policy is more effective during recessions than expansions, the literature has neglected so far a role for business uncertainty. Using U.S. micro data, Vavra (2013) advocates that monetary policy is less effective when business uncertainty is high since it leads to an increase in aggregate price flexibility. In contrast, Bachmann, Born, Elstner, and Grimme (2013) find this effect to be negligible when using German micro data. For fiscal policy, no evidence has been documented yet. It could well be, however, that an increase in spending lowers uncertainty among entrepreneurs about future orders and revenues, which in turn stabilizes the economy by stimulating private investment.

For periods of financial market stress, it is often argued that fiscal policy could help lessen financial market frictions, thereby lifting fiscal multipliers (see, e.g. Corsetti et al., 2012; Rafiq, 2014, among others). However, if financial market stress coincides with fiscal stress, i.e. situations in which investors are concerned about the sustainability of public debt, increased spending may well be less effective since risk premia are likely to rise.

The recession dates are from the German Council of Economic Experts (*Sachverständigenrat*) and include five periods of severe underutilization of production capacities.[14] To obtain a measure for business uncertainty, I rely on the foreward-looking question of the Ifo Business Climate Survey. Each month, the survey polls a representative sample of about 5,000 firms in the manufacturing sector on their expected production activities for the next three months.[15] The answer to this question falls into one of three qualitative categories: increase, decrease, and stay the same. Following Bachmann, Elstner, and Sims (2013), I proxy for uncertainty with forecast disagreement and construct the business uncertainty index as $\sqrt{QE_t^+ + QE_t^- - \left(QE_t^+ - QE_t^-\right)^2}$, where QE_t^+ (QE_t^-) is the fraction of firms expecting an increase (decrease) in production. While this index is a reasonable measure for uncertainty among entrepreneurs, I also consider a financial market stress index that measures the uncertainty among investors. The composite index is provided by the Kiel Institute for the World Economy (IfW Kiel) and comprises, among others, bank lending conditions, coporate bond and credit spreads, or stock market volatility.[16]

Figure 12 depicts the business uncertainty and financial market stress index together with the recession dates. For better comparability, both indices are rescaled to have zero mean and unit variance. The uncertainty measures undergo large swings during the sample period and are countercyclical. The correlation between them is 0.43. While positively correlated, the figure also reveals that business uncertainty and financial market stress move in opposite directions during several periods, hence justifying the usage of both concepts.

Structural Factors Second, I consider several structural factors: a measure of exchange rate flexibility, the degree of import penetration, a measure of fiscal sustainability, and private households' access to credit. In contrast to the cyclical factors, these determinants change smoothly over time and their choice can be motivated by standard models.

Exchange rate flexibility is measured by the absolute change in the CPI-based real effective exchange rate and allows me to test the prediction of standard models that multipliers are larger when the exchange rate cannot adjust quickly to a spending shock (see, e.g., Corsetti et al., 2012; Born et al., 2013; Ilzetzki et al., 2013, among others). Similarly, I add the import penetra-

[14]See Sachverständigenrat (2009). The recession dates are: 1973:2 to 1975:2, 1979:4 to 1982:4, 1991:1 to 1993:3, 2001:1 to 2005:2, and 2008:1 to 2009:2. Whenever these quarterly periods do not fully coincide with a half year, I assume that the German economy was in recession for the entire half year that the respective quarter corresponds to.

[15]The survey question reads as: "*Expectations for the next three months: Our domestic production activities with respect to product X will (without taking into account differences in the length of months or seasonal fluctuations) increase, roughly stay the same, decrease.*"

[16]See van Roye (2014) for a detailed description of the index methodology.

tion rate since these models also suggest that fiscal policy is more effective when only a small share of domestic absorption falls on imports.[17] To measure fiscal sustainability, I include the government interest payment to GDP ratio, which is a summary statistics of all factors that are relevant when assessing the sustainability of public debt, i.e. gross debt, the interest rate, and nominal GDP. If public finances are weak, concerns about future tax rises or even government solvency are likely to dampen the impact of spending shocks on output (see, e.g., Corsetti et al., 2012; Corsetti, Kuester, Meier, and Müller, 2013; Müller, 2014, among others). Finally, I use the ratio of household credit and disposable income to proxy for access to credit. Galí, López-Salido, and Vallés (2007) show in a standard model that multipliers depend positively on the share of credit constraint households that are not able to insure against future tax rises to smooth their consumption.

Institutional Factors Finally, I take two institutional factors into account. First, I add a dummy that takes on unity from 1970:1 to 1991:2 and zero otherwise, hence controlling for the fact that the data for the first part of the sample are for West Germany only. While it is unclear though if, and in what direction, the inclusion of the former communist part of Germany has affected fiscal policy effectivity, it may nevertheless be useful to account for this institutional change. Second, I control for the adoption of the euro and include a dummy that takes on unity from 1999:1 to 2013:1 and zero otherwise. In a currency union, monetary policy is restricted since it cannot fully counteract country-specific shocks and fiscal multipliers are hence expected to be larger (see, e.g., Galí and Monacelli, 2008; Illing and Watzka, 2014, among others).[18]

Table 1 shows the results from the regression analysis. The coefficient estimates are obtained by regressing the series of multipliers from the TVP-VAR on the set of possible determinants and a constant using OLS. The impact multipliers are measured at $k = 0$, while the remaining multipliers are evaluated at $k = 20$. To avoid reversed causality, I include all variables, except for the recession dates and the institutional dummies, one period lagged. The respective standard errors are given in parantheses below coefficient estimates. I denote significance at the 1, 5, and 10 percent level by ***, **, and *, respectively. While I am aware about the limitations of such reduced-form regressions, I nevertheless think that they may reveal some interesting insights about the determinants of fiscal policy effectivity in Germany.

[17] The import penetration rate is calculated as the ratio of nominal imports of goods and services and nominal GDP less net exports.

[18] See for example Christiano, Eichenbaum, and Rebelo (2011), Eggertsson (2011), Woodford (2011), or Wieland (2012) for a similar argument when monetary policy is constrained by the zero lower bound on nominal interest rates.

The table reveals that the results are similar across multipliers. While the signs of the coefficients and significance levels are identical, I also obtain small differences in the absolute size of the estimates. It appears that the differences between the multipliers are largely absorbed by the constant terms. Thus I concentrate on the impact multipliers in the following.

With respect to the cyclical factors, the following results emerge from the regression analysis. First, I obtain a small coefficient estimate for the recession dates. During recessions the multiplier is 0.085 euro larger than in expansions. This number is smaller than those reported in the related literature and not significantly different from zero. In contrast, I find that business uncertainty is strongly and significantly correlated with the size of the multipliers. If uncertainty rises by one standard deviation, the multipliers increase by 0.227 euro. This finding suggests a stimulating role for fiscal policy via a reduction in business uncertainty, which in fact is independent of the state of the business cycle. Second, I find that the coefficient estimate for financial market stress significantly points into the opposite direction. In periods of stress, fiscal policy is less effective than in normal times (-0.168 euro), which is consistent with the idea that financial market and fiscal stress often coincide.

Furthermore, I do not obtain support for the hypotheses that exchange rate flexibility, import penetration, or households' access to credit are connected to the size of the multipliers. For all three variables, coefficient estimates are small in absolute value and insignificant. However, I find a strong and significantly negative correlation between fiscal sustainability and multipliers. A 1 percent increase in the government interest to GDP ratio lowers the impact multipliers by 0.850 euro. Given a time series standard deviation for that ratio of 0.73, an increase of one standard deviation hence reduces the multipliers by about 0.62 euro, suggesting that the estimated effect is of economic significance and larger than that for business uncertainty. Taken together with the negative impact of financial market stress, I conclude that sound public finances are an important prerequisite for fiscal policy to be effective.[19]

The dummy for West Germany is positive but small and insignificant, suggesting that, after controlling for other channels, the transmission of spending shocks to output has not been different before reunification than after. Finally, I obtain a positive coefficient estimate for the currency union dummy that is highly significant. The introduction of the euro and hence the loss of monetary policy autonomy has lifted the impact multiplier by 0.944 euro, which underlines the prominent role monetary policy has in the transmission of government spending

[19]When I drop the financial market stress index from the baseline regression, the coefficient estimate for the government interest payment to GDP ratio declines from 0.850 to 0.904, supporting the notion that both variables relate to fiscal stress.

shocks to output. Multipliers may be large if monetary policy can only partially accommodate a discretionary increase in spending.[20]

In order to check the robustness of these findings, I report the outcome of alternative regressions in Table 2. First and foremost I explore whether the insignificant coefficient estimate for the recession dates is due to the fact that other variables are also correlated to the business cycle, thereby lowering the impact of the dates. To that end I consecutively drop business uncertainty, financial market stress, and finally all structural factors from the regression. While both uncertainty measures are strongly correlated with the business cycle, the latter are to a lesser extent. It turns out that the coefficient estimates for the recession dates are hardly affected by removing these variables. Across all three alternative regressions, the estimated coefficients are again small in absolute value and insignificant, hence providing no support for the hypothesis that fiscal multipliers in Germany depend on the state of the business cycle. However, I find that the coefficient estimates for the government interest payment to GDP ratio and the currency union dummy are robust over all regressions. For the latter I obtain estimates that are even larger than in the baseline regression (up to 1.493 compared to 0.944).

In addition, I run a regression on only those factors that seem to be relevant in determining the effectivity of fiscal policy in Germany. It turns out that these factors show again plausible and significant coefficient estimates that are also of economic relevance. Moreover, I obtain an adjusted R^2 that is marginally lower than that in the baseline regression (respectively, 0.84 and 0.85), suggesting that the removed variables explain little of the variation in multipliers.

Finally, I provide a decomposition of the fitted values from the baseline regression into the contribution of, respectively, business uncertainty, financial market stress, government interest payment, and the currency union dummy in Figure 13. In each plot the impact multipliers are included in deviation from their estimated constant. Since the series are correlated, the plots should not be interpreted as a counterfactual simulation, but to provide some intuition about the contribution of a variable in a particular period. The figure reveals that the decrease in fiscal policy effectivity during the 1970s and 80s can be largely attributed to a deterioration in public finances, while the decline in business uncertainty is also relevant in the second half of the 80s. The contribution of financial market stress is modest across all periods, except for the years after

[20]It should be stressed that the currency union also brought along a decrease in exchange rate flexibility by about one third compared to the period before. And when dropping the currency union dummy from the baseline regression, I indeed observe that the coefficient estimate for exchange rate flexibility declines from -0.013 to -0.018 and is now signifcantly different from zero at a 10 percent level. Despite a time series standard deviation of about 3.33, this estimated effect is, however, still small, suggesting that the loss of monetary policy autonomy is more important in the context of a currency union than the decreased exchange rate flexibility.

the outburst of the global crisis in 2008 in which it contributes strongly negatively. In contrast, business uncertainty shows a positive impact during that period. And as already discussed, the introduction of the euro shifts the multipliers by nearly 1 euro in 1999.

To sum up, I obtain evidence that German fiscal policy is more effective when business uncertainty is high but less in periods of financial market stress, while the state of the business cycle is minor important. Furthermore, I find that fiscal sustainability is a crucial determinant of the multipliers and that these are on average higher since the loss of monetay policy autonomy due to the adoption of the euro. Other factors, such as exchange rate flexibility, the degree of import penetration, private households' access to credit, or German reunification appear to be less relevant. Taken together, these results provide an explanation for the observed time profile of fiscal multipliers.

6 Summary and Conclusion

In this paper I investigate the time varying impact of government spending shocks on output in Germany during the period 1970:1 to 2013:1 in two steps. In a first step, I use an expectations-augmented TVP-VAR model to establish that fiscal multipliers are not stable across periods but exhibit a u-shaped pattern. While multipliers fluctuate around 2 at the beginning and end of the sample, they are much smaller in between. I demonstrate that this pattern is obtained regardless of the definition of the multipliers and robust to alternative model specifications. In addition, I document that the size of spending shocks has declined over time and that the observed profile squares well with important fiscal episodes.

In a second step, I discuss which factors determine the size of German multipliers and hence explain the time variation. It turns out that fiscal policy is more effective when business uncertainty is high but less in periods of financial market stress, while the state of the business cycle is minor important. Furthermore, I find that fiscal sustainability is an important determinant of the multipliers and that these are much higher since the loss of monetary policy autonomy due to the adoption of the euro.

Given the evidence of this paper, I conclude that policy recommendations based on average fiscal multipliers may be misleading. Considering cyclical, structural, and institutional factors appears to be important to predict the impact of a surprise increase in government spending on output. Moreover, I find that independent of the state of the economy, the impact of spending shocks is limited and short-lived, suggesting that fiscal stimuli tend to increase the government spending share of output over longer horizons. In sum, these findings tell a cautionary tale for fiscal policy to stimulate output in Germany.

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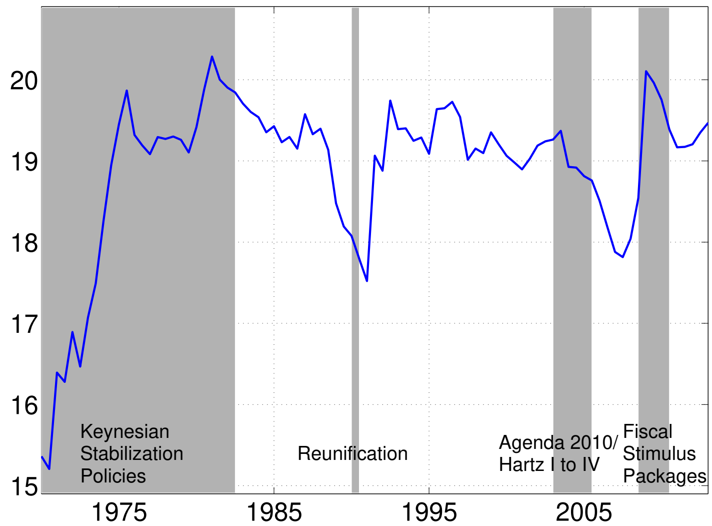

Figure 1: Government Spending with Fiscal Episodes. Notes: Shows the government spending to GDP ratio (solid line) together with important fiscal episodes (shaded area). Government spending is measured by government consumption. x-axis: year; y-axis: percent.

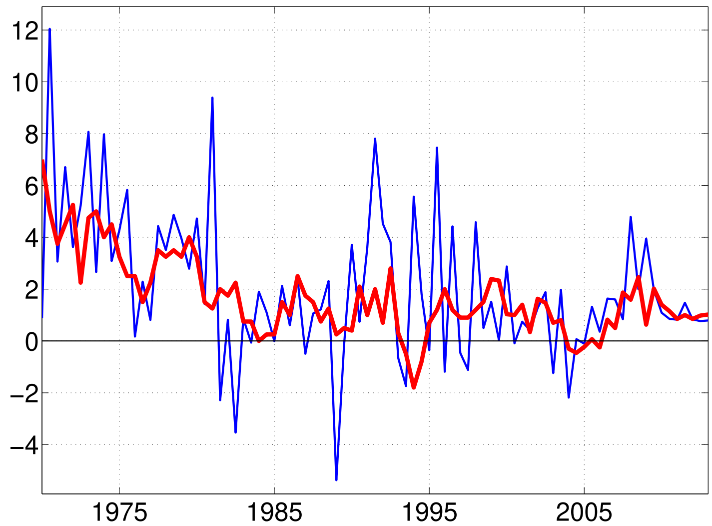

Figure 2: Government Spending Growth and Forecast - Time Series. Notes: Shows actual government spending growth (thin line) together with forecasted government spending growth (thick line). x-axis: year; y-axis: percent.

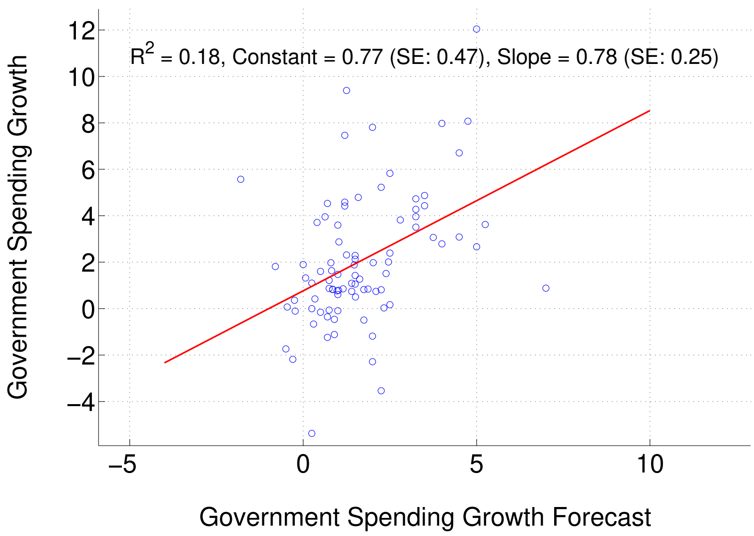

Figure 3: Government Spending Growth and Forecast - Scatterplot. Notes: Plots actual government spending growth against forecasted government spending growth together with a regression line obtained by regressing the former on the latter and a constant. x and y-axis: percent.

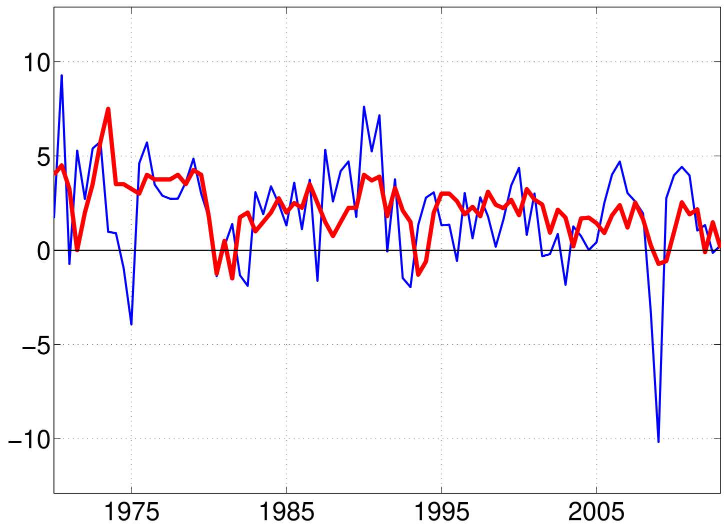

Figure 4: Output Growth and Forecast - Time Series. Notes: Shows actual output growth (thin line) together with forecasted output growth (thick line). x-axis: year; y-axis: percent.

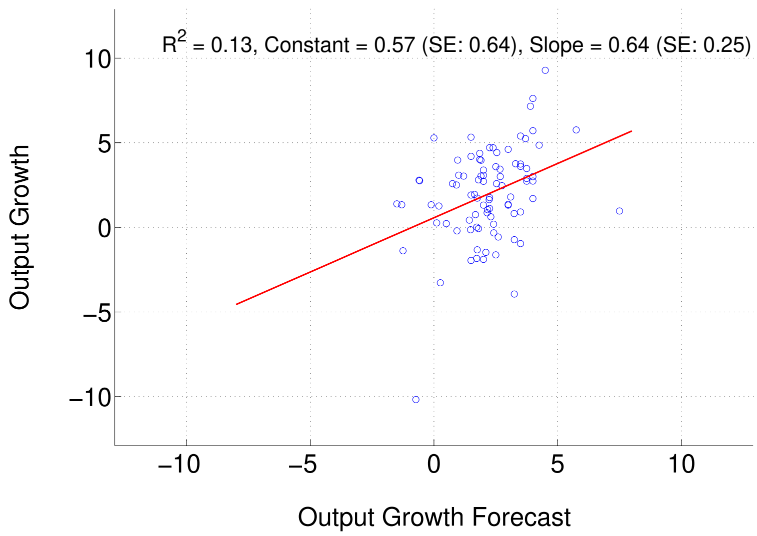

Figure 5: Output Growth and Forecast - Scatterplot. Notes: Plots actual output growth against forecasted output growth together with a regression line obtained by regressing the former on the latter and a constant. x and y-axis: percent.

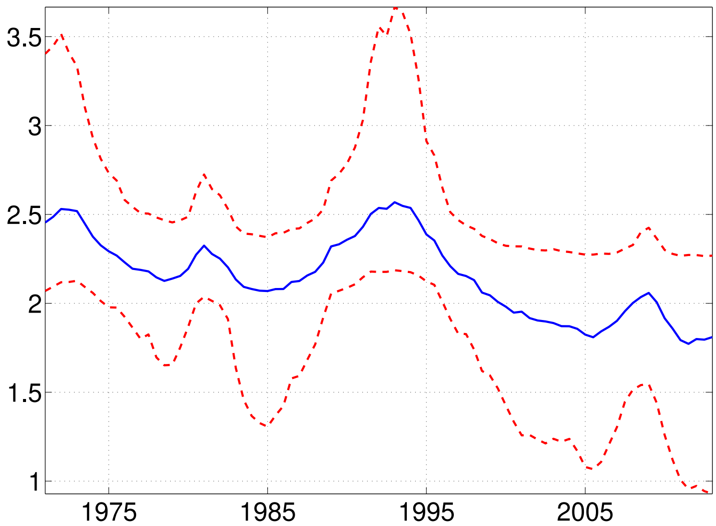

Figure 6: Standard Deviation of Government Spending Shocks. Notes: Shows the posterior median (solid line) together with a 68 percent error band (dashed line). x-axis: year; y-axis: percent.

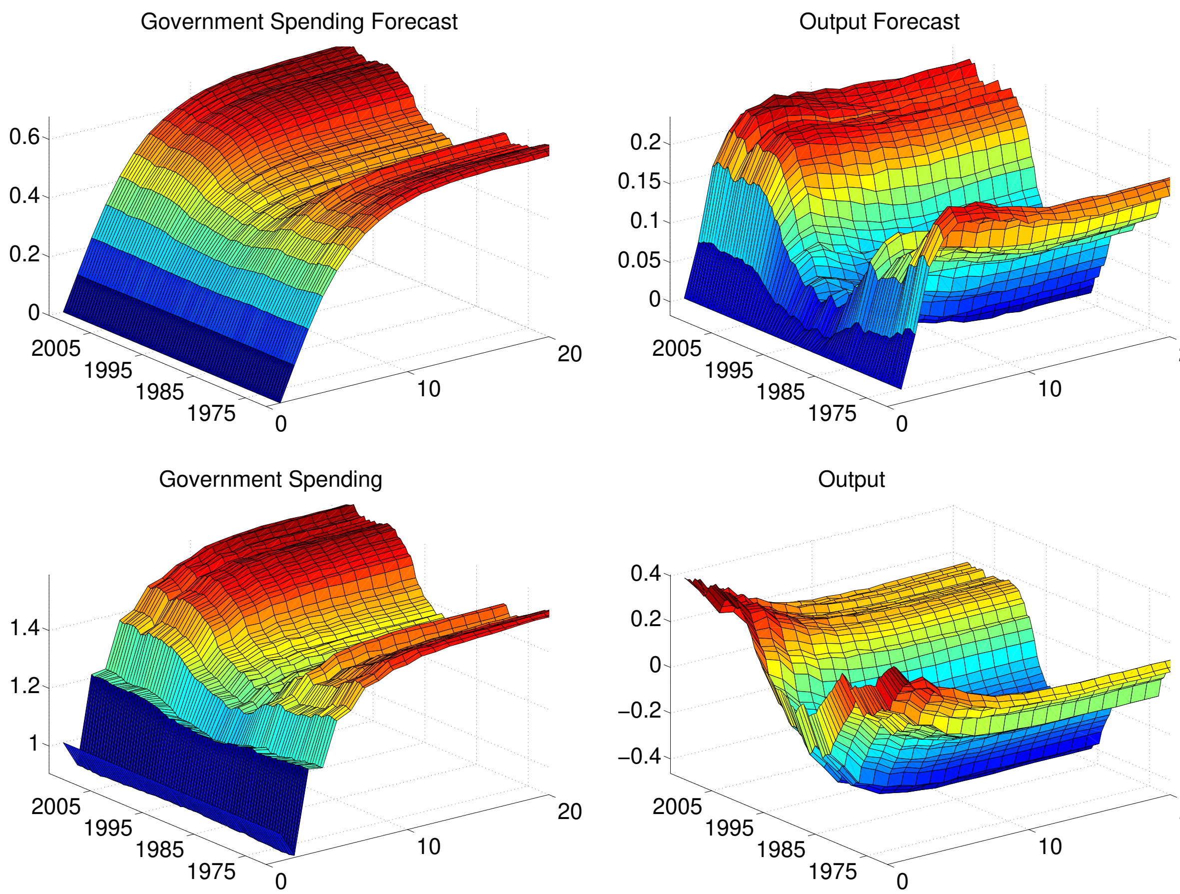

Figure 7: Impulse Responses to Government Spending Shocks - Baseline. Notes: Shows the posterior median. The size of the shocks is 1 percent. x-axis: horizon; y-axis: year; z-axis: percent.

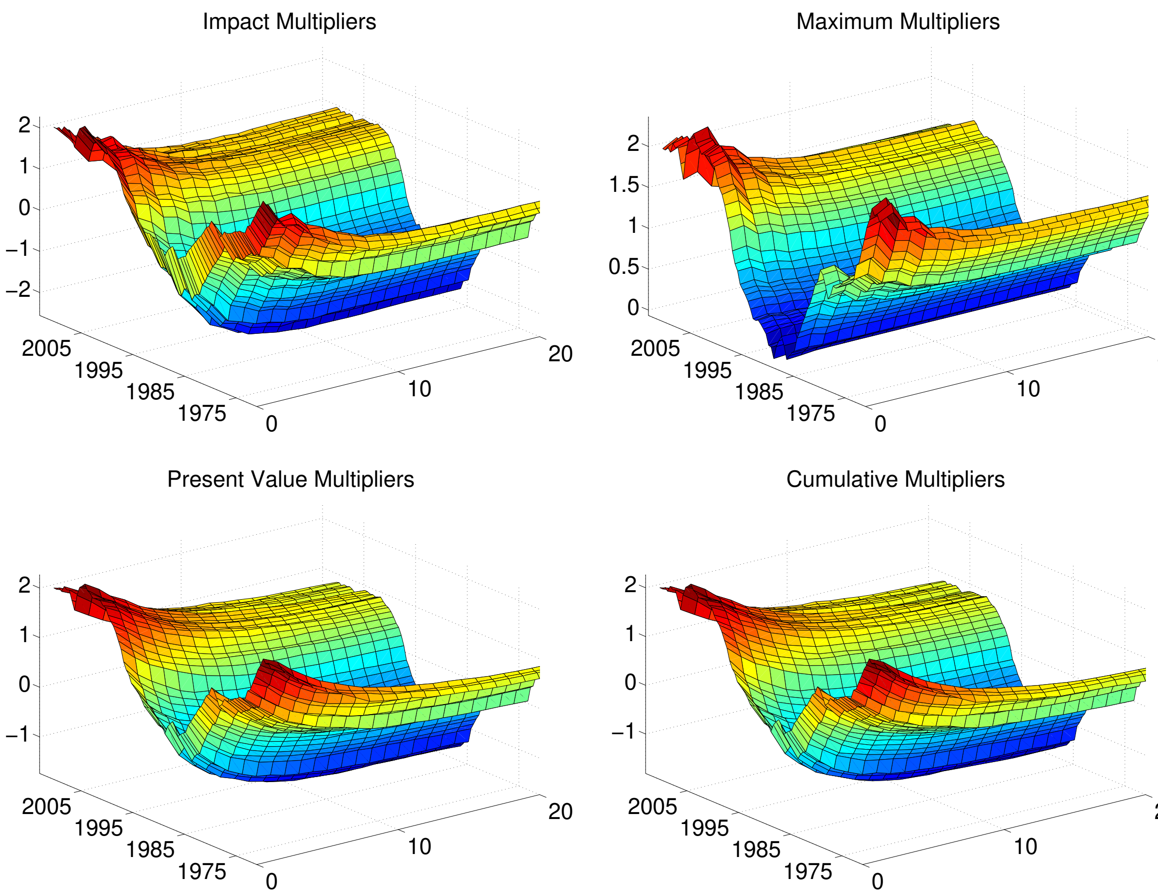

Figure 8: Fiscal Policy Multipliers. Notes: Shows the posterior median. x-axis: horizon; y-axis: year; z-axis: euro.

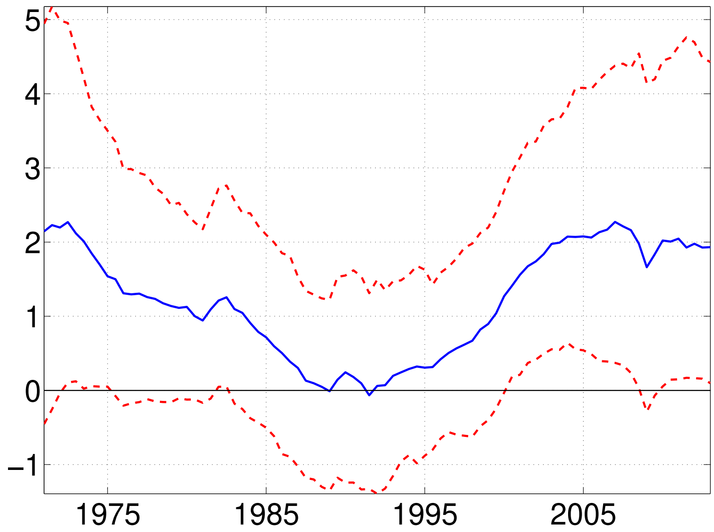

Figure 9: Fiscal Policy Multipliers after 6 Months. Notes: Shows the posterior median (solid line) together with a 68 percent error band (dashed line). x-axis: year; y-axis: euro.

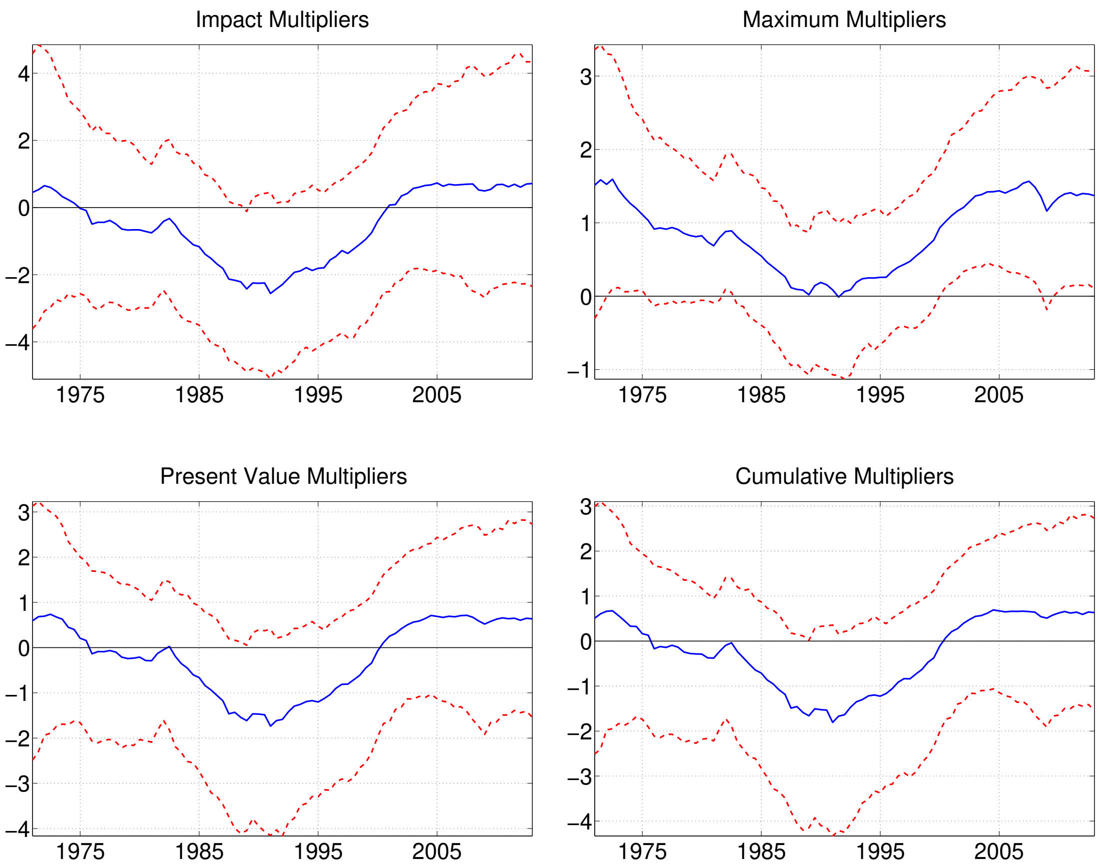

Figure 10: Fiscal Policy Multipliers after 10 Years. Notes: Shows the posterior median (solid line) together with a 68 percent error band (dashed line). x-axis: year; y-axis: euro.

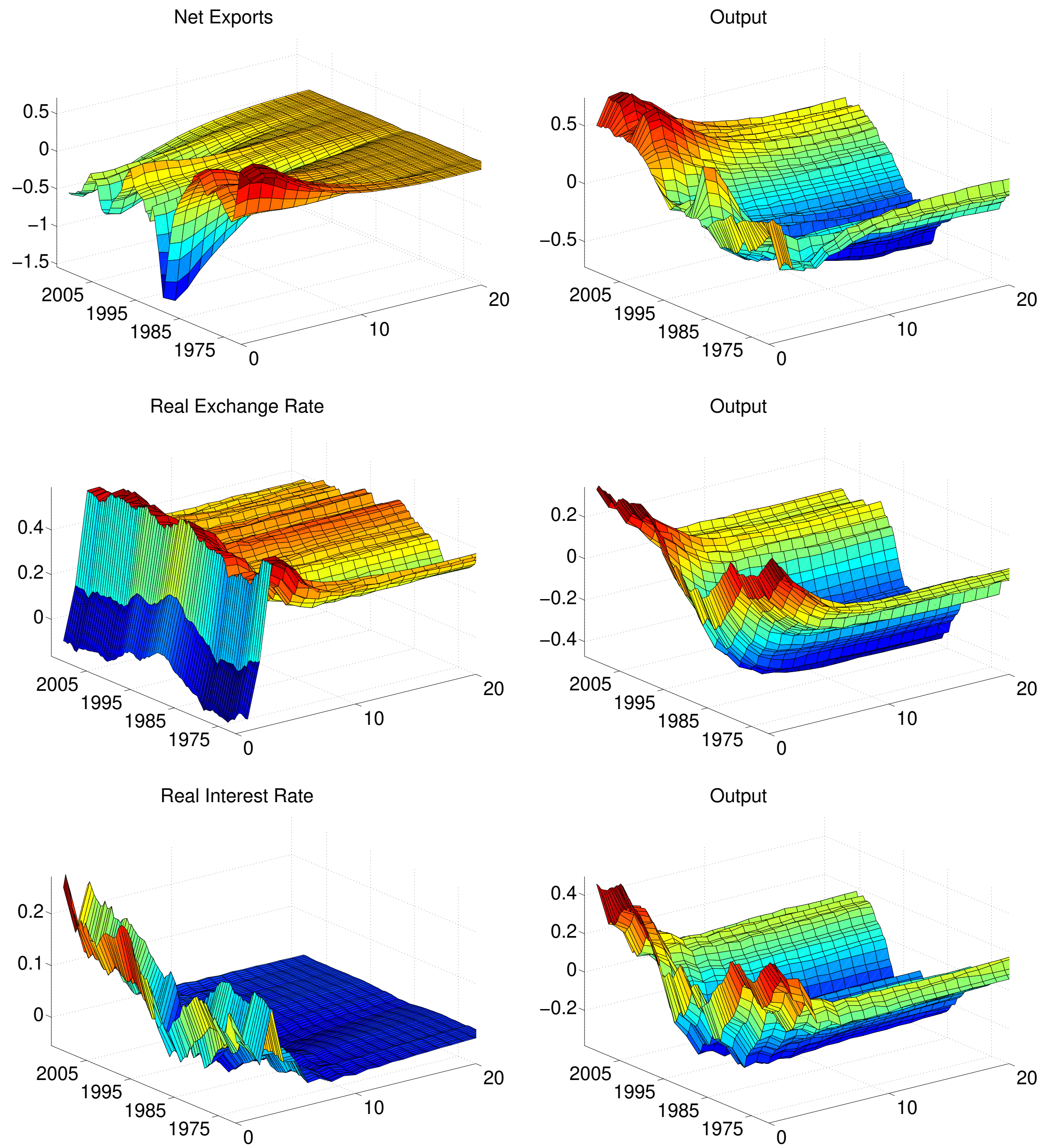

Figure 11: Impulse Responses to Government Spending Shocks - Extensions. Notes: Shows the posterior median. The size of the shocks is 1 percent. x-axis: horizon; y-axis: year; z-axis: percent/percentage points.

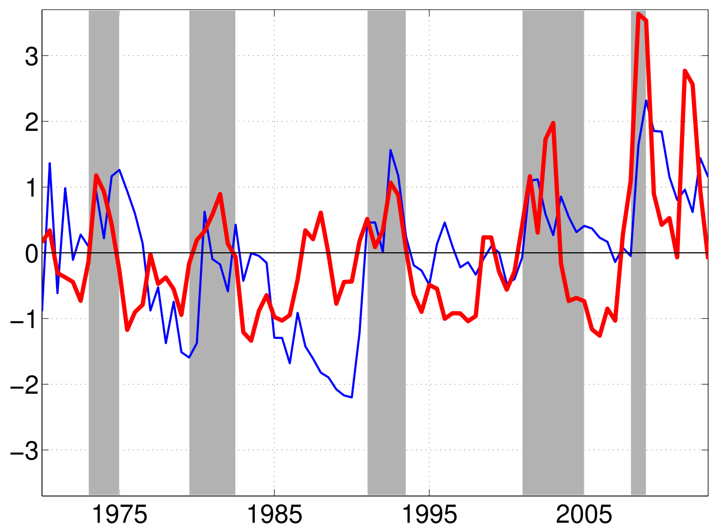

Figure 12: Uncertainty Measures with Recession Dates. Notes: Shows the Ifo Business Uncertainty (thin line) and the IfW Financial Market Stress Index (thick line) together with recession dates from the German Council of Economic Experts (shaded area). Both uncertainty measures are rescaled to have zero mean and unit variance. x-axis: year; y-axis: standard deviation.

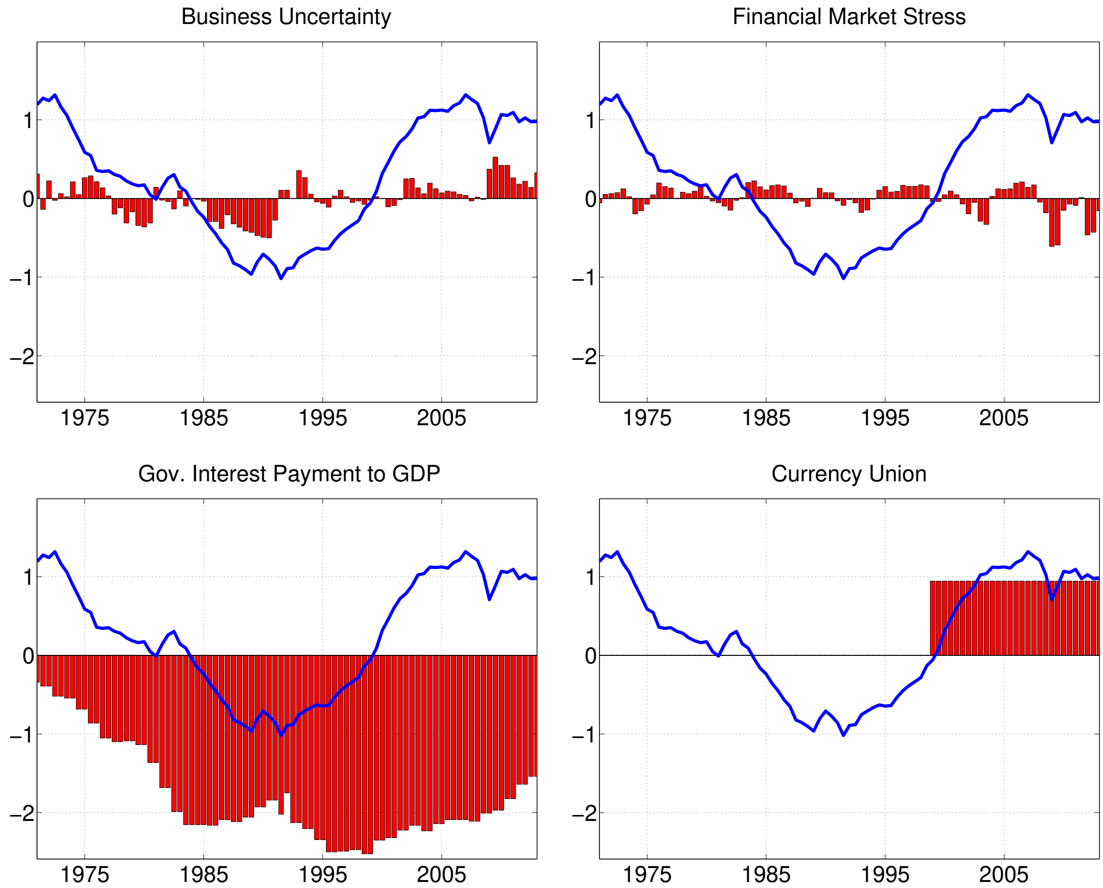

Figure 13: Decomposition of Fitted Values. Notes: Shows a decomposition of the fitted values from the baseline regression (bars) together with the impact multipliers in devation from their estimated constant (solid line). x-axis: year; y-axis: euro.

Table 1: Determinants of the Multipliers - Baseline

Method: OLS with White Standard Errors
Sample: 1971:1 to 2013:1

	Dependent Variable: Fiscal Multipliers			
Independent Variables	Impact	Maximum	Present Value	Cumulative
Recession Dates	0.085	0.046	0.117	0.091
	(0.082)	(0.056)	(0.100)	(0.100)
Business Uncertainty	0.227^{***}	0.149^{***}	0.269^{***}	0.275^{***}
	(0.043)	(0.030)	(0.050)	(0.050)
Financial Market Stress	-0.168^{***}	-0.109^{***}	-0.167^{***}	-0.163^{***}
	(0.032)	(0.022)	(0.035)	(0.035)
Exchange Rate Flexibility	-0.013	-0.009	-0.007	-0.009
	(0.010)	(0.007)	(0.012)	(0.012)
Import Penetration Rate	0.008	0.005	0.008	0.008
	(0.009)	(0.006)	(0.009)	(0.009)
Gov. Interest Payment to GDP	-0.850^{***}	-0.566^{***}	-0.741^{***}	-0.724^{***}
	(0.183)	(0.123)	(0.221)	(0.221)
Household Credit Ratio	0.016	0.010	0.011	0.011
	(0.010)	(0.007)	(0.012)	(0.013)
West Germany	0.121	0.080	0.261	0.262
	(0.182)	(0.126)	(0.221)	(0.219)
Currency Union	0.944^{***}	0.640^{***}	1.140^{***}	1.144^{***}
	(0.412)	(0.203)	(0.373)	(0.376)
Constant	0.953^{*}	0.735^{*}	-0.397	-0.473
	(0.552)	(0.379)	(0.689)	(0.694)
Adjusted R^2	0.85	0.84	0.82	0.82
Observations	85	85	85	85

Notes: Shows the estimated coefficients obtained by regressing the median multipliers from the TVP-VAR model on a set of explanatory variables and a constant. The respective White standard errors are given in parenthesis. ***, **, and * denotes significance at the 1, 5, and 10 percent level, respectively.

Table 2: Determinants of the Multipliers - Robustness

Method: OLS with White Standard Errors
Sample: 1971:1 to 2013:1

	Dependent Variable: Impact Multipliers			
Independent Variables	1	2	3	4
Recession Dates	0.075	-0.013	0.132	
	(0.090)	(0.086)	(0.108)	
Business Uncertainty				0.140^{***}
				(0.036)
Financial Market Stress	-0.134^{***}			-0.156^{***}
	(0.037)			(0.032)
Exchange Rate Flexibility	-0.002	-0.007		
	(0.010)	(0.010)		
Import Penetration Rate	0.005	-0.000		
	(0.010)	(0.010)		
Gov. Interest Payment to GDP	-0.804^{***}	-0.855^{***}		-0.679^{***}
	(0.223)	(0.231)		(0.048)
Household Credit Ratio	0.003	0.009		
	(0.011)	(0.012)		
West Germany	-0.106	-0.114	0.702^{***}	
	(0.211)	(0.126)	(0.129)	
Currency Union	1.259^{***}	1.135^{***}	1.493^{***}	1.311^{***}
	(0.362)	(0.376)	(0.101)	(0.091)
Constant	2.060^{***}	1.927^{***}	0.312^{***}	2.194^{***}
	(0.579)	(0.598)	(0.081)	(0.090)
Adjusted R^2	0.81	0.79	0.51	0.84
Observations	85	85	85	85

Notes: Shows the estimated coefficients for some robustness checks. See also notes to Table 1.

A Data

The table below provides a description of the series used. The format is as follows: series label, series mnemonic in Datastream (if available), series market, the original data source (OECD Economic Outlook = EO; OECD Main Economic Indicators = MEI; Bank for International Settlements = BIS), and the frequency of the series (Monthly = M; Quarterly = Q; Semi-Annual = S; Annual = A). The last column indicates if a series is seasonally adjusted (sa). I consider all series at semi-annual frequency for the period 1970:1 to 2013:1. Series that are available at monthly or quarterly frequency are converted by taking averages across periods. Series that are available at annual frequency only are interpolated, assuming no change within the year. Series for West and reunified Germany are linked in 1991:2. Forecasts for real government consumption growth and real GDP growth are collected from the respective vintage of the OECD Economic Outlook. Business expectations for the manufacturing sector are provided by Sigrid Stallhofer (Ifo Institute), while the financial market stress index comes from Björn van Roye (IfW Kiel). Moreover, I use recession dates from the German Council of Economic Experts (*Sachverständigenrat*) that are available in: "*Die Zukunft nicht aufs Spiel setzen - Jahresgutachten 2009/10*", Ch. 7, p. 260.

Label	Mnemonic	Market	Source	Freq.	sa
Nominal Government Final Consumption Expenditure	WGOCFCGGB	West	EO	Q	x
Nominal Government Final Consumption Expenditure	BDOCFCGGB	Germany	EO	Q	x
Nominal Gross Domestic Product	WGOCFGPNB	West	EO	Q	x
Nominal Gross Domestic Product	BDOCFGPNB	Germany	EO	Q	x
Real Government Final Consumption Expenditure	WGOCFGCND	West	EO	Q	x
Real Government Final Consumption Expenditure	BDOCFGCND	Germany	EO	Q	x
Real Government Consumption Growth Forecast		West/Germany	EO	S	x
Real Gross Domestic Product	WGOOFGDPD	West	EO	Q	x
Real Gross Domestic Product	BDOCFGDPD	Germany	EO	Q	x
Real GDP Growth Forecast		West/Germany	EO	S	x
3-Month FIBOR	BDQIR076R	West/Germany	MEI	Q	
Nominal Exports of Goods and Services	WGOCFXGSB	West	EO	Q	x
Nominal Exports of Goods and Services	BDOCFXGSB	Germany	EO	Q	x
Nominal Imports of Goods and Services	WGOCFMGSB	West	EO	Q	x
Nominal Imports of Goods and Services	BDOCFMGSB	Germany	EO	Q	x
Real Effective Exchange Rates - CPI based	BDQCC011H	West/Germany	MEI	Q	x
CPI All Items	BDQCP009F	West/Germany	MEI	Q	x
Business Expectations: Manufacturing Sector		West/Germany	Ifo	M	x
Financial Market Stress Index		West/Germany	IfW	M	
Net Government Interest Payments as % of GDP	WGOCFDB%	West	EO	A	x
Net Government Interest Payments as % of GDP	BDOCFDB%	Germany	EO	A	x
Nominal Credit to Households	BDBLCAHAA	West/Germany	BIS	Q	x
Nominal Disposable Income	BDPERDISB	West/Germany	Bundesbank	Q	x

B Markov Chain Monte Carlo (MCMC) Estimation

In this appendix I explain the Bayesian estimation of the TVP-VAR model and provide diagnostics on the convergence of the Markov chain. For further details, I refer to Primiceri (2005). See Baumeister, Durinck, and Peersman (2008) as well as Baumeister and Peersman (2013) for a similar outline.

B.1 Model

Consider the TVP-VAR model in (1):

$$Y_t = X_t' B_t + u_t, \quad \Omega_t = E\left[u_t u_t'\right]. \tag{B.1}$$

The covariance matrix Ω_t can be decomposed as follows[21]

$$\Omega_t = A_t^{-1} \Sigma_t \Sigma_t' \left(A_t'\right)^{-1}, \tag{B.2}$$

where A_t is a lower triangular matrix which models the contemporaneous interactions among variables and Σ_t is a diagonal matrix which contains the stochastic volatilities

$$A_t = \begin{bmatrix} 1 & 0 & 0 & 0 \\ \alpha_{21,t} & 1 & 0 & 0 \\ \alpha_{31,t} & \alpha_{32,t} & 1 & 0 \\ \alpha_{41,t} & \alpha_{42,t} & \alpha_{43,t} & 1 \end{bmatrix}, \qquad \Sigma_t = \begin{bmatrix} \sigma_{1,t} & 0 & 0 & 0 \\ 0 & \sigma_{2,t} & 0 & 0 \\ 0 & 0 & \sigma_{3,t} & 0 \\ 0 & 0 & 0 & \sigma_{4,t} \end{bmatrix}.$$

Let α be the vector of non-zero and non-one elements of A_t (stacked by rows), σ_t be the vector of the diagonal elements of Σ_t, and B_t be the vector containing all the coefficients of the TVP-VAR stacked. The time varying parameters are assumed to evolve as follows

$$B_t = B_{t-1} + \nu_t, \qquad \nu_t \sim N(0, Q), \tag{B.3}$$

$$\alpha_t = \alpha_{t-1} + \xi_t, \qquad \xi_t \sim N(0, S), \tag{B.4}$$

$$\log \sigma_t = \log \sigma_{t-1} + \eta_t, \qquad \eta_t \sim N(0, W), \tag{B.5}$$

where the innovation terms have zero mean, are normally distributed and independent of each other. The elements of B_t and A_t are thus modelled as driftless random walks, while the stochastic volatilities in Σ_t follow a geometric random walk. The random walk assumption reduces the

[21] This decomposition ensures that the covariance matrix is positive definite.

number of parameters significantly and hence allows for an efficient estimation of the model. To ensure stationarity, I follow Cogley and Sargent (2002, 2005) and discard all draws for the coefficient vector that lead to an explosive solution of the model. In particular, I check for each draw whether the roots of the associated VAR polynomial are outside the unit circle and attribute zero prior weight to it if they are not.

Finally, it is also assumed that S has a block-diagonal structure of the following form:

$$S = \mathrm{Var}\left(\xi_t\right) = \begin{bmatrix} S_1 & 0_{1\times 2} & 0_{1\times 3} \\ 0_{2\times 1} & S_2 & 0_{2\times 3} \\ 0_{3\times 1} & 0_{3\times 2} & S_3 \end{bmatrix},$$

where $S_1 = \mathrm{Var}\left(\xi_{21,t}\right)$, $S_2 = \mathrm{Var}\left([\xi_{31,t}, \xi_{32,t}]'\right)$, and $S_3 = \mathrm{Var}\left([\xi_{41,t}, \xi_{42,t}, \xi_{43,t}]'\right)$ with $\mathrm{Var}\left(\cdot\right)$ denoting the variance operator, implying that the coefficients evolve independently in each equation.

B.2 Priors

In contrast to the related literature, I do not preserve a training sample to calibrate the prior distributions for the initial states, but run a constant parameter version of the model on the full sample from 1970:1 to 2013:1 using OLS. In situations in which the total number of observations is relatively small (here 87 semi-annual observations), this procedure is a valid alternative to training sample priors (see, e.g., Kirchner et al., 2010). Following Primiceri (2005), I assume that the initial states for the coefficients (B_0), the contemporaneous relations (α_0), the stochastic volatilities (σ_0) and the hyperparamters (Q, S, W) are independent of each other. For the coefficients and contemporaneous relations I specify normal priors $p\left(\cdot\right)$ of the following form: $p\left(B_0\right) = N\left(\hat{B}, \hat{V}_{\hat{B}}\right)$ and $p\left(\alpha_0\right) = N\left(\hat{\alpha}, \hat{V}_{\hat{\alpha}}\right)$, where the mean values of B_0 and α_0 are set to their corresponding OLS point estimates. The variance for B_0 is chosen to be four times the variance in a constant parameter version of the model. Moreover, I follow Benati and Mumtaz (2007) and set $\hat{V}_{\hat{\alpha}} = 10 \cdot \mathrm{diag}\ \widehat{|\alpha|}$. While this choice for the variance of α_0 is arbitrary, it accounts for the different magnitude of the elements. Finally, I assume a log-normal prior for the stochastic volatilities: $p\left(\log\sigma_0\right) = N\left(\log\hat{\sigma}, 10 \cdot I_4\right)$. I set the mean value for σ_0 to the corresponding OLS point estimate and the variance to ten times the identity matrix.

Let $IW\left(\Psi, m\right)$ denote the inverted Wishart distribution with scale matrix Ψ and m degrees of freedom. The priors for the hyperparameters Q and W are specified as follows: $p\left(Q\right) = IW\left(0.003^2 \cdot 36 \cdot \hat{V}_{\hat{B}}, 36\right)$ and $p\left(W\right) = IW\left(0.01^2 \cdot 5 \cdot I_4, 5\right)$, where the scale matrices are constant fractions of the variances from a time invariant model multiplied by the degrees of freedom, while the latter are set to one plus the dimension of the B_0 and σ_0 matrix, respectively. The value for the scaling parameter in $p(Q)$ is the same as in Primiceri (2005) and conservative with respect to the prior belief about time variation in the coefficients. Finally, I consider the following priors for the blocks of S: $p(S_1) = IW\left(0.1^2 \cdot 2 \cdot \hat{V}_{\hat{\alpha_1}}, 2\right)$, $p(S_2) = IW\left(0.1^2 \cdot 3 \cdot \hat{V}_{\hat{\alpha_2}}, 3\right)$ and $p(S_3) = IW\left(0.1^2 \cdot 4 \cdot \hat{V}_{\hat{\alpha_3}}, 4\right)$, where $\hat{\alpha_1}, \hat{\alpha_2}$ and $\hat{\alpha_3}$ are the corresponding blocks to S_1, S_2 and S_3 of $\hat{\alpha}$. The degrees of freedom are again set to one plus the number of corresponding entries in α_0, the minimum number for the inverted Wishart distribution to be proper. Specified in this way, the prior is diffuse and at best weakly informative, and hence soon dominated by the information in the data.

B.3 Gibbs Sampling

To simulate the joint posterior distribution of $(B^T, A^T, \Sigma^T, Q, S, W)$, I use a Gibbs sampling algorithm. The Gibbs sampler is a MCMC method and is carried out by sequentially drawing time varying coefficients (B^T), contemporaneous relations (A^T), stochastic volatilities (Σ^T) and hyperparamters (Q, S, W), given the data and the rest of the parameters. The approach allows for an efficient estimation of the model since it treats all parameters as separate blocks and does not require to write down a complicated likelihood for the model. The superscript $(\cdot)^T$ indicates that the complete data is used in estimation. The Gibbs sampler thus produces smoothed estimates of the parameters using all the information available in the data, as opposed to filtered estimates that exhaust only the information contained in a particular subsample.

The steps are:

Step 1: Initialize A^T, Σ^T, s^T, Q, S, and W.

Step 2: Sample B^T from $p\left(B^T | Y^T, A^T, \Sigma^T, Q, S, W\right)$.

Conditional on all other parameters and the data, the observation equation $y_t = X_t' B_t + u_t = X_t' B_t + A_t^{-1} \Sigma_t e_t$, with $e_t \sim N(0, I)$, is linear and has Gaussian innovations. Draws for $B_t = B_{t-1} + \nu_t$ are obtained from $N\left(B_{t|t+1}, P_{t|t+1}\right)$, where $B_{t|t+1} = E\left(B_t | B_{t+1}, Y^T, A^T, \Sigma^T, Q, S, W\right)$ and $P_{t|t+1} = \text{Var}\left(B_t | B_{t+1}, Y^T, A^T, \Sigma^T, Q, S, W\right)$, using the algorithm of Carter and Kohn (1994).

Step 3: Sample A^T from $p\left(A^T | Y^T, B^T, \Sigma^T, Q, S, W\right)$.

The system of equations $y_t = X_t' B_t + A_t^{-1} \Sigma_t e_t$ can be written as $A_t (y_t - X_t' B_t) = A_t \hat{y}_t = \Sigma_t e_t$, where, conditional on B^T, $\hat{y}_t$ is observable. Since A_t is lower triangular with ones on the main diagonal, the system of equations is given by

$$\hat{y}_{1,t} = \sigma_{1,t} e_{1,t}, \tag{B.6}$$

$$\hat{y}_{i,t} = -\hat{y}_{[1,i-1],t} \alpha_{i,t} + \sigma_{i,t} e_{i,t}, \quad i = 2, ..., 5 \ , \tag{B.7}$$

where $e_{i,t}$ is the i-th element of e_t and $\hat{y}_{[1,i-1],t}$ denotes the row vector $[\hat{y}_{1,t}, \hat{y}_{2,t}, ..., \hat{y}_{i,t}]$. Given that S is block-diagonal, the algorithm of Carter and Kohn (1994) can be applied equation by equation to obtain draws for $\alpha_{i,t}$ from $N\left(\alpha_{i,t|t+1}, \Lambda_{i,t|t+1}\right)$, where $\alpha_{i,t|t+1} = E\left(\alpha_{i,t} | \alpha_{i,t+1}, Y^T, B^T, \Sigma^T, Q, S, W\right)$ and $\Lambda_{i,t|t+1} = \text{Var}\left(\alpha_{i,t} | \alpha_{i,t+1}, Y^T, B^T, \Sigma^T, Q, S, W\right)$.

Step 4: Sample Σ^T from $p\left(\Sigma^T | Y^T, A^T, B^T, Q, S, W, s^T\right)$.

Consider the system of non-linear measurement equations $A_t (y_t - X_t' B_t) = y_t^* = \Sigma_t e_t$, where, conditional on B^T and A^T, y_t^* is observable. Squaring and taking logarithms of each element converts the system into a linear one:

$$y_t^{**} = 2 \ h_t + g_t, \tag{B.8}$$

$$h_t = h_{t-1} + \eta_t, \tag{B.9}$$

where $y_{i,t}^{**} = \log \left[\left(y_{i,t}^* \right)^2 + 0.001 \right]$; the constant (0.001) makes the estimation procedure more robust; $h_{i,t} = \log \ \sigma_{i,t}$; and $g_{i,t} = \log \left(e_{i,t}^2 \right)$. Though linear, the system is non-Gaussian since the innovations in the measurement equations are distributed as log $\chi^2(1)$. I follow Kim, Shepard, and Chib (1998) and use a mixture of seven normal densities with component probabilities q_j, means $m_j - 1.2704$, and variances v_j^2 to transform the system into a Gaussian one. The parameters $\left(q_j, m_j, v_j^2\right)$ are chosen to match the moments of the log $\chi^2(1)$ distribution:

Let $s^T = [s_1, ..., s_T]'$ be the matrix of indicator variables selecting the member of the mixture, $j = 1, ..., 7$, used for each element of e. Conditional on B^T, A^T, Q, S, W, and s^T, the system is approximately Gaussian and the algorithm of Carter and Kohn (1994) can be used to draw h_t from $N\left(h_{t|t+1}, H_{t|t+1}\right)$, where $h_{t|t+1} = E\left(h_t | h_{t+1}, Y^T, A^T, B^T, Q, S, W, s^T\right)$ and $H_{t|t+1} = \text{Var}\left(h_t | h_{t+1}, Y^T, A^T, B^T, Q, S, W, s^T\right)$. As has been pointed out by

Table B.1: Mixing distributions as in Kim et al. (1998)

j	q_j	m_j	v_j^2
1	0.00730	-10.12999	5.79596
2	0.10556	-3.97281	2.61369
3	0.00002	-8.56686	5.17950
4	0.04395	2.77786	0.16735
5	0.34001	0.61942	0.64009
6	0.24566	1.79518	0.34023
7	0.25750	-1.08819	1.26261

Del Negro and Primiceri (2013) it is important that the indicator variables s^T are sample before the stochastic volatilities.

Step 5: Sample Q, S, W from $p\left(Q|Y^T, A^T, B^T, \Sigma^T\right)$, $p\left(S|Y^T, A^T, B^T, \Sigma^T\right)$, and $p\left(W|Y^T, A^T, B^T, \Sigma^T\right)$, respectively.

Conditional on Y^T, A^T, B^T, and Σ^T, the hyperparameters Q, S, W have inverted Wishard posterior distributions from which draws can be directly obtained, see Gelman, Carlin, Stern, and Rubin (1995).

Step 6: Go to step 2.

In total, I perform 100,000 iterations of the Gibbs sampler, discarding the first 50,000 for convergence and keep one for every 50 of the remaining 50,000 draws to economize storage space and to further reduce autocorrelation among them. Since the Gibbs sampler is a dependence chain algorithm, posterior draws are correlated. The remaining 1,000 draws are used for inference. Below I present inefficiency factors, showing that the Markov chain has indeed converged to its ergodic distribution. Moreover, I have inspected recursive means for some parameters, started the Gibbs sampler at distinct initial conditions, and considered chains of different length. All these experiments indicate that posterior draws come from the same distribution.

B.4 Convergence

In order to check for the convergence of the Markov chain, I follow Primiceri (2005) and calculate inefficiency factors (IFs) for the time varying coefficients B^T (3,060 in total), the free elements

Table B.2: Distribution of Inefficiency Factors

Parameter/ Statistic	Mean	Median	Min.	16^{th} Prct.	84^{th} Prct.	Max.
Coefficients	10.76	9.37	4.22	5.34	15.53	33.96
Contemporaneous Relations	7.36	7.06	3.55	5.48	8.76	19.75
Stochastic Volatilities	47.16	38.70	5.61	14.93	81.26	129.66
Hyperparameter Q	11.98	11.91	4.09	8.93	15.16	21.33
Hyperparameter S	9.66	9.90	5.48	6.10	11.84	15.57
Hyperparameter W	80.50	79.65	54.41	60.34	100.84	116.19

of the contemporaneous relations A^T (510 in total), the stochastic volatilities Σ^T (340 in total), the distinct elements of the hyperparameters Q and W (666 and 10 in total, respectively), as well as the free and distinct elements of the hyperparameter S (10 in total). The IF is defined as $1 + 2\sum_{s=1}^{\infty} \rho_s$, where ρ_s is the estimated autocorrelation of the chain at lag s. Since independence sampling produces an IF that is equal to one and Gibbs sampling typically produces an IF greater than one, the IF quantifies the relative efficiency loss in the computation of posterior draws from dependent versus independent samples. In practice, values around 20 are regarded as efficient (see, e.g., Primiceri, 2005, among others), meaning that the econometrician needs to draw 20 times as many MCMC draws as from uncorrelated samples.

Following Benati and Mumtaz (2007) as well as Baumeister and Benati (2013), I calculate the IFs as the inverse of the relative numerical efficiency measure (RNE) of Geweke (1992):

$$\text{RNE} = (2\pi)^{-1} \frac{1}{\text{S}(0)} \int_{-\pi}^{\pi} \text{S}(\omega)\, d\omega, \tag{B.10}$$

where $\text{S}(\omega)$ denotes the spectral density of the sequence of draws at frequency ω. I estimate the spectral densities by smoothing the periodograms in the frequency domain using a 4 percent tapered window as in Primiceri (2005).

Figure B.1 plots the IFs for all 4,596 parameters, while Table B.2 provides some summary statistics for the distribution of the IFs. Except for the stochastic volatilities and their hyperparameters W, the 84^{th} percentile is below or even well below 20 for all sets of parameters. The IFs are exceptionally low for the contemporaneous relations and their covariance matrix S for which all of the IFs are below 20. The distribution of the stochastic volatilities and their covariance matrix W is centered around, respectively, 39 and 80, meaning that drawing from the posterior distribution is less efficient for these parameters. Overall, the IFs are comparable to those in Primiceri (2005), suggesting that posterior draws come from the ergodic distribution.

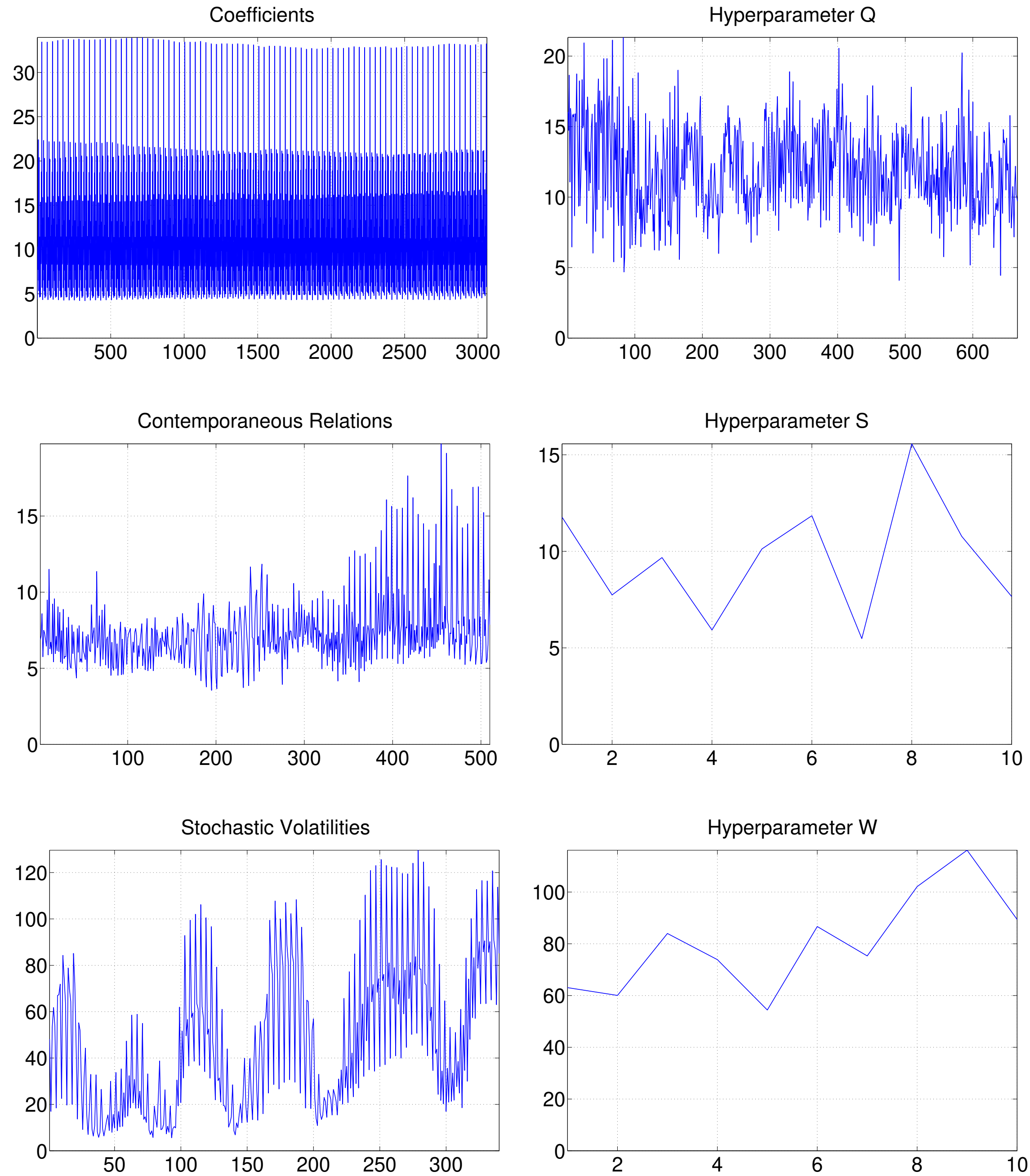

Figure B.1: Inefficiency Factors. Notes: Shows the inefficiency factors for all states (left column) and hyperparameters (right column) of the TVP-VAR model to check for the convergence of the Markov chain. x-axis: parameter; y-axis: inefficiency factor.