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PUBLIC DEBT, MONEY AND CONSUMER PRICES: A VECTOR ERROR CORRECTION MODEL FOR GERMANY

DŁUG PUBLICZNY, PIENIĄDZE I CENY KONSUMENCKIE: WEKTOROWY MODEL KOREKTURY BŁĘDÓW DLA NIEMIEC

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Summary: In the paper, the authors analyse the interaction between public debt and inflation including the mutual impulse response. The European sovereign debt crisis brought once again a focus onto the consequences of government debt in combination with an expansionary monetary policy for the development of consumer prices. Public deficits can lead to higher inflation rates if the money supply is expansionary. The high level of national debt, not only in the Euro-crisis countries, and the strong increase in the total assets of the European Central Bank, as a result of the unconventional monetary policy, have caused fears of inflating government debt. The transmission from public debt to inflation through money supply and long-term interest rate will be shown in the paper. Based on these theoretical thoughts, the variables: public debt, consumer price index, money stock m3 and long-term interest rate will be analysed within a vector error correction model. In the empirical part of this article, quarterly data for Germany from 1991 to 2014 are to be examined.

Keywords: public debt, inflation, Germany, VECM.

Streszczenie: Przedmiotem niniejszego artykułu jest związek między długiem publicznym a inflacją. Kryzys wywołany zadłużeniem krajów europejskich na nowo skupia zainteresowanie badaczy na konsekwencjach długu publicznego i ekspansjonistycznej polityki pieniężnej dla rozwoju cen konsumenckich. W artykule najpierw omawia się teoretyczne drogi przeniesienia, jakie wiodą od długu publicznego przez podaż pieniądza i stopy długoterminowe do rozwoju cen konsumenckich. Następnie zmienne dotyczące zadłużenia państwa, indeksu cen konsumenckich, podaży pieniądza M3 i stóp długoterminowych bada się w ramach wektorowego modelu korektury błędów. W analizie empirycznej wzięte zostały pod uwagę dane kwartalne tychże zmiennych dla Niemiec od 1991 do 2004 roku. Z pomocą procedury Johansena oceniono stosunki kointegracji i parametry wektorowego modelu korektury błędów, pozwalające na interpretację wzajemnych związków między zadłużeniem, polityką pieniężną i cenami.

Słowa kluczowe: dług publiczny, inflacja, Niemcy, wektorowy model korektury błędów.

1. Introduction

Governments in collaboration with central banks stabilised the global financial and banking system during the global financial crisis in 2008 and 2009. They started global bank rescue programmes worth billions of dollars. Moreover, economic recovery plans slowed down the strong and fast economic fall in 2009. However, the economic stimulus packages and bank bailout programmes led to an acceleration of getting into debt in many countries. The European sovereign debt crisis has also increased the level of public debt. Since 2010, Germany and the other euro area countries have lent Greece in total 198 billion euros by using the temporary crisis resolution mechanism, European Financial Stability Facility (EFSF) and bilateral credits. In the latter case, Germany's sovereign debt increased directly. As a consequence, the level of government debt in Germany according to the Maastricht criteria reached a record high at the end of the fourth quarter in 2012 [Eurostat 2013], which was nearly 82 per cent of the gross domestic product. Furthermore, public debt is threatened by additional burdens from the European Stability Mechanism (ESM) and Target2-credits from the Deutsche Bundesbank against the Euro system.

The general reason for sovereign debt is that governmental expenditures were higher than public revenues in most countries and periods. There is a natural tendency for government deficit in recession, whereas government borrowing decreased only slightly during boom times in the last two decades. The special reasons for the strong increase in German debt are the costs of German reunification, the financial support for the extensive social security system, several economic stimulus packages, bank bailout programmes and a the lack of political intention for consolidation [Wagschal et al. 2009]. Figure 1 shows that the sovereign debt problem has been worse since the early 1990s and strengthened at the beginning of the latest financial crisis. However, the debt accumulation process was not explosive.

The high level of national debt, not only in the Euro crisis states, could lead to an apprehension of a debt restructuring caused by a sovereign default. Greece is a current example of a partial default. An alternative is to inflate the government debt away. Fiscal adjustment-austerity by spending cuts and tax increases would be accompanied with the resistance of lobbies and large sectors of the population. Eliminating debt overhangs by economic growth is time consuming and difficult to achieve. Consequently, inflation could be an attractive solution for the government debt problem. Reinhart and Rogoff [2009], have shown that governments around the world tried to devalue their real debt by inflation. This discussion will be expanded by the theory of financial repression. It describes how public regulation in combination with an expansionary monetary policy leads to a negative real interest rate and may conduce a debt relief of states [Reinhart, Sbrancia 2011].

The concern about inflation in Germany will be strengthened by the strong expansion of the money base caused by the low interest rate policy and the unconventional monetary policy (quantitative easing) by the central banks in many

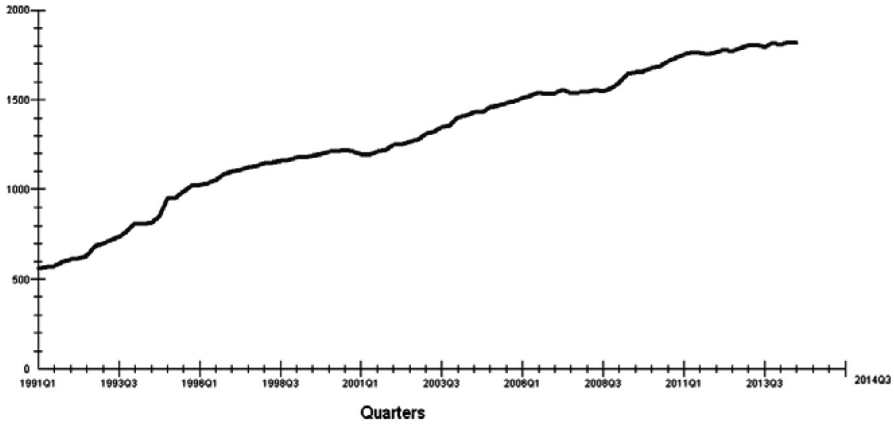

Fig. 1. Public debt (in billion euros) in Germany after reunification

Source: Deutsche Bundesbank.

countries. Furthermore, the lists of eligible securities were continuously extended (qualitative easing) and so the criteria for deposit capable securities were reduced significantly. The central banks of a number of countries purchased assets, mainly long-term government bonds, from the private sector. The European Central Bank (ECB) has bought public bonds of the crisis countries and lowered their government yield payment. The first public bond purchase programme (SMP) started at the peak of the European sovereign debt crisis in May 2010 and ended in February 2012. In total, it had a nominal volume of 219 billion Euros. A second public bond purchase programme (OMT) was decided in September 2012 and covers the unlimited purchase of government bonds under certain conditions, but it has not been used yet. In 2014 the ECB's main refinancing operation fixed rate reached a historical low rate (0.05%) and the deposit facility was set to a negative value (–0.2%). An expanded asset purchase programme was started in March 2015 after achieving the zero lower bound. The programme combines monthly asset purchases of sovereign bonds up to an amount of 60 billion euros, and it encompasses the existing private sector asset purchase programmes (ABSPP, CBPP3) in order to address the risks of a too prolonged period of low inflation in the euro area [ECB 2015]. An excessively prolonged period of low inflation or deflation could put a strain on the sustainability of private and public debt.

The sovereign debt reduction and the current low increase in consumer prices and monetary aggregates in Germany could still indicate a mutual relationship between these important economic variables. The low consumer price increase in 2014 (+0.9%) was attended with a surplus in the government budget (+0.6% of GDP) and a moderate growth rate of money m3 in October 2014 (+2.5%). In this article, the following questions will be theoretically and empirically examined:

- Does an increasing level of public debt cause an inflationary process?
- What is the impact of inflation on public debt?

A main point will be the investigation of the role of the monetary policy by central banks in this interaction. Public deficits can lead to inflation if the money supply is expansionary. We provide an overview of the empirical studies about the relationship between government debt and inflation. Moreover, we show the main transmission channels. The two questions will be analysed empirically for Germany after reunification within a co-integration framework. We estimate a vector error correction model. This means the included variables are considered endogenous. The variables in the model are tested for cointegration relations and estimated with the ML-estimator according to the Johansen approach. Afterwards the generalised impulse response analysis is applied to the data.

2. Transmission mechanisms between public debt and inflation

That large budget deficits can drive inflation higher over the medium or longer-term has been described by different theoretical economic models. Sargant and Wallace [1981], Leeper [1991] and Sims [1994], emphasise that not only public debt by itself, but the interaction between fiscal and monetary policy determinates the impact of public deficit on inflation. If the monetary policy controls inflation and ergo determines the seigniorage, fiscal policy has to ensure the stabilisation of national debt by increasing taxes or cutting governmental spending (monetary dominance). In contrast, the *fiscal theory of the price level* (FTPL) maintains that the price level is determined by the budgetary policy of the fiscal authority. The weak-form of the FTPL supposes that fiscal policy predetermines the path of budget surpluses/deficits and forces the monetary policy to generate the seigniorage needed to maintain sovereign solvency and avoid a default (fiscal dominance). Thus, the fiscal policy is assumed to be exogenous, while money supply is endogenous. Compared with this, the strong-form of the FTPL describes that fiscal variables such as the level of sovereign debt directly affect the price level and the path of inflation, but independent of future money growth [Belke, Polleit 2010, p. 376f]. This theory posits that higher government debt increases household wealth and under rational expectations as well as households' inflation expectations, and hence their demand for goods and services which causes upward pressure on consumer prices. Both monetary and fiscal policies are given exogenously and prices are adjusted to ensure solvency.

Following the *classical-neoclassical theory* a debt-financed government spending does not lead to an increasing output. There is only a displacement from private sector demand to the government (crowding out). The higher demand for capital will cause higher interest rates and crowd out private consumption and corporate investment, especially building activity. If private-sector demand is highly sensitive to interest rates, the crowding-out effect can be substantial. In the long run

the private capital stock will be substituted by public capital stock and the flow of income will be reduced. Additionally, higher taxes to finance more debt are clearly lowering welfare in the future.

Corresponding to the *Ricardo-Barro-equivalence theorem,* debt-financed government expenditures with the consideration of a public budget restriction has no effect on output and inflation. Considering the fact that private households' act rationally, the present public borrowing is equal to higher taxes in the future. The private sector fully internalises the public sector budget's constraint.

In contrast, the *Keynesian theory* supposes that deficit spending has an expansionary effect on output. Thus, the cyclical development in the short-term is determined by macroeconomic public and private demand. The economy is characterised by imperfectly flexible wages and prices. Government spending can affect output through shifting the aggregate demand. Countercyclical fiscal policy may be a corrective device to keep the output near the trend growth path, and if debt is incurred to finance investment that could boost future output and could create budget surpluses. Furthermore, the *New Keynesian theory* assumes the positive impact of government spending on private consumption in the short-run.

According to the *monetarist view,* public spending, debt-financed with the help of the central bank, leads to a greater monetary base and corresponding to the quantity theory of money, and the price level will increase in the long-run. Inflation equals the sum of the growth rate of money stock and the trend growth in the economy. Changes in output are independent of changes in money supply. Furthermore, higher interest rates could cause a reduction in private individuals' cash balance and thus the velocity of money rises. As a result, there is an additionally upward pressure on prices.

The *I theory of money* [Brunnermeier, Sannikov 2014], provides a framework for analysing the interactions between price and financial stability and emphasises the crucial role of financial institutions in creating money. A high level of public debt increases the probability of sovereign default and thus reduces the value of government bonds. As a consequence, the capitalisation of the banking system deteriorates and lending to the private sector will shrink which affects the economic situation negatively. An accommodative monetary policy by lowering interest rates or bond purchase programmes could increase the value of bonds and recapitalise the intermediaries.

Public debt and consumer prices are connected within a two-way relationship over different transmission channels (Figure 2). The analysis of the transmission from debt to inflation has to consider the impact on money supply and aggregate demand and the role of the central bank:

- Debt-financed government spending stimulates macroeconomic demand in the short-term and inflation will rise in the medium or long-term, i.e.
  - directly through the purchase of public bonds by the central bank or
  - indirectly through the demand of public bonds by the private sector with a simultaneous expansionary monetary policy to stabilise the increasing interest rate,

– also indirectly through the demand of public bonds by the banking sector,
– and through the inflation expectation of the economic subjects.
• Monetary easing could lead to an exchange-rate depreciation and thus cause higher import prices and ergo inflation.
• Permanent public deficits have a negative impact on economic efficiency, and hence on the process of price formation.

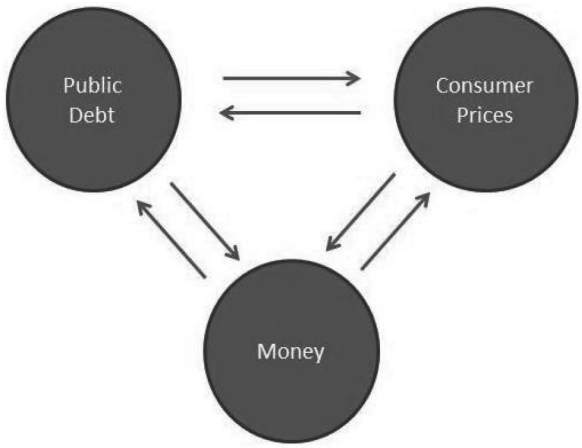

Fig. 2. Interaction between public debt, money and consumer prices

Source: own graph.

These seven factors could lead to an increasing price level in the medium or long-term. Bonds buying programmes increase the monetary base. The result is debt monetisation. Financing a persistent budget deficit by money creation will lead to faster money growth and higher inflation rates [Burda, Wyplosz 2009, p. 549]. However, the quantity theory of money explains inflation only in the long run and it is notable that broad money matters for inflation. The multiplication of the monetary base crucially depends on money creation by financial intermediaries. This transmission is influenced by the economic cycle and the health of the banking system. By applying quantitative easing, central banks try especially to reduce the long-term interest rates. This may stimulate private investment and consumption. The purchases also may decrease the default risk and enhance liquidity [Fender 2012, p. 208]. In addition, business and consumer expectations will be enhanced. Furthermore, monetary easing also fosters exchange rate depreciation, which supports external demand and output growth. As a consequence, higher import prices cause an upward pressure on the domestic price level.

The relationship between public debt and inflation does not only exist through the money supply and macroeconomic demand. The inflation expectations of the economic subjects can influence the current price development. A high budget deficit

or a high level of sovereign debt could lead to increasing inflation expectations. As a result, the nominal wages claims, and later the de facto wages, rise. The higher wage level affects consumer prices and could start an inflationary process. This channel describes the link between fiscal and monetary policy. If there is a high debt level and high nominal interest rates, the bonding of the inflation target within the inflation expectations of the economic subject would be more difficult. As a consequence, central banks are interested in stabilising economic subjects' inflation expectations.

National debt would be a burden for future generations, which comes in the form of a reduced flow of income caused by a lower capital stock [Modigliani 1961]. The reduced output growth in the medium and long-run lowers the government's capacity to pay its creditors. The higher the level of public debt, the bigger the drop for a given size of shock to the economy. The government has to pay a large proportion of public revenue to the creditors. As a consequence, there are fewer resources for education and public investments. A high debt-to-GDP ratio can signal an unsustainable level of debt. The greater probability of a default on debt obligations can cause interest rates to rise, as creditors need to be compensated for the risk of default. The higher interest rates also influence negatively private investment and consumption. The capital stock is at least partially crowded out. The negative impact of high debt on output growth is called the debt-relief Laffer curve [Miles et al. 2012, p. 469f]. This curve suggests that there is a point where outstanding debt is so large that it reduces output growth and lowers the probability of debt repayment. On the other hand, a positive effect of sovereign debt on growth may be possible when debt is used to finance productive public capital formation. In general, economic growth is an important determinant of managing debt. The instrument of government debt allows fiscal authorities under certain conditions to stabilise the macroeconomy and smooth taxes in the face of variable public expenditures [Cecchetti et al. 2011, p. 3]. Government debt used for financing investment can also help to smooth consumption across generations and can raise society's inter-temporal welfare. However, beyond a certain point, the sovereign debt is expected to influence output growth negatively.

The transmission from inflation to public debt is given by

- the seigniorage as a part of the central bank profits: money creation is an easy way to finance sovereign debt,
- the eroding of the real value of (nominal) public debt by inflation (inflation tax). If the nominal value is given, an increasing price level leads to a decreasing real value of nominal debt,
- the short-term stimulation of economic growth caused by an expansionary monetary policy, leading to rising public revenues and decreasing public spending,
- a progressive tax system, because a high inflation rate leads to higher tax revenues–also with zero real economic growth.

These four factors could reduce government debt in the short or medium-term. Higher money growth increases seigniorage only to the extent that it does not reduce real money holdings more than proportionally. Seigniorage and inflation tax are

closely interconnected. If the inflation rate equals the growth rate of money stock, then seigniorage and the inflation tax are equivalent. Money creation leads to an increasing money stock and with a lag to inflation. The result of the higher inflation is a declining through the inflation tax of the real public debt. The impact of this channel depends on the maturity structure, the interest rate response to higher inflation and the currency denomination of the debt. The government benefits from the inflation tax because the public debt is rarely indexed. But, if the inflation rate increases, the private buyers of government bonds will require a higher nominal interest rate. They will also prefer short repayment terms. If the debt process onward is unstable, the government (i.e. the central bank) will extend the money stock again and therefore inflation could accelerate strongly. The consequences are higher nominal interest rate requirements for public bonds and that generates an additional push in the necessary inflation. The result of this development could be hyperinflation.

3. Brief overview on empirical studies

The relationship between public debt and inflation in developed countries is disputed in the empirical literature. Compared with this, public deficits were positively correlated with inflation in developing economies. Giannitsarou and Scott [2006] and Sill [2005], could not find a significant relationship between public debt and inflation in the industrial countries since the 1960s. Opposing that, Sill [2005] and Catão and Terrones [2005], estimated a definite influence from national debt on inflation in the emerging market economies for the period from 1960 to 2000. Independent central banks and the high reputation from the capital market players contribute to a more stable financial position in the developing countries, so that public deficits predominantly do not lead to high inflation rates.

Kliem et al. [2013], show that the positive long-run relationship between public deficits and inflation in the USA suddenly diminished after 1979 and has remained insignificant ever since. The strongest correlation was found for the period from the mid 1960s to 1979. Tagavi [2000], examined the relation between inflation and the debt ratio for the period from 1970-1997 for Germany, Italy, France and the United Kingdom. Cointegration was not found in the sample, but the debt ratio was Granger-causal to inflation with a time lag of between three and five years. The impulse-response functions showed that a shock in the debt ratio caused a significant reaction on inflation. However, the direction and the strength were very different. Bleaney [1996], applied a correlation analysis for the public debt level and inflation. The result was a positive mean correlation of 0.36 between the two variables for 15 OECD-countries in the period 1973-1982. In contrast, the correlation was negative (–0.19) during the period 1983-1989. Akitoby et al. [2014], investigated by the use of simulation for the G7-countries and found that higher inflation could help reduce the public debt-to-GDP ratio. Raising the average inflation rate to 6% annually would

cause a debt reduction of about 12 percentage points for Germany, although inflation is not able to solve the government debt problem and would raise marked risks.

High levels of public debt can be expected to be detrimental to countries' growth prospects, as has also been widely analysed in the respective literature. Reinhart and Rogoff [2010], measured the negative correlation between sovereign debt and output growth in a sample of 20 developed countries over a period of two centuries (1790–2009) when the debt-to-GDP ratio is over 90%. Cecchetti et al. [2011], obtained a similar result for 18 OECD-countries when debt is at around 85% of GDP. However, high debt may itself be the result of low growth, or it could reflect a third factor that at the same time increases debt and reduces growth (e.g. a financial crisis). Checherita and Rother [2010], found for a panel of 12 euro area countries that government debt-to-GDP ratios above 90% and 100% would have a negative impact on economic growth. However, public debt ratios were not determining the long-term interest rate. Paesini et al. [2006], showed that for Germany, Italy and the USA, public debt accumulation leads at least temporarily to higher long-term interest rates. Bildiric and Ersin [2007], found that for a panel of emerging and developing countries which experience high inflation, the inflationary process fed on the increasing costs of domestic debt. The increasing debt-to-GDP ratios led these countries to borrow at higher interest rates and with lower maturity rates.

Höppner [2001], estimated the effects of fiscal policy on output and consumption in Germany. The main findings are the negative reaction of GDP to tax shocks and the positive reaction to public expenditure shocks. Moreover, the structural vector autoregressive (SVAR) model (without a public debt variable) indicates a crowding in of private consumption by government expenditures. Tenhofen et al. [2010], obtained a similar result for the unified Germany. Government expenditure shocks are found to increase output and private consumption on impact.

Dwyer and Hafer [1999], identified a positive relationship between inflation and money growth for many countries. Mandler and Scharnagl [2013], found empirical evidence for strong co-movement between money growth and inflation at low frequencies with money growth as the leading variable in the euro area. De Grauwe and Polan [2005], showed that the mutual relationship between money and consumer prices depends critically on the level of inflation. Thus, money growth is only significant for periods of time with a high-level inflation.

4. Econometric methods

The public debt/inflation function to be estimated later in this paper is considered as a kind of long-run equilibria or cointegrating relations. Cointegration may be characterised by two or more integrated variables indicating a common long-run development. However, transitory fluctuations are possible. This defines a statistical equilibrium which can be interpreted as a long-run economic relation. Equation (1) shows a vector error correction model (VECM) with the order (p):

$$\Delta \mathbf{x}_t = \boldsymbol{\mu} + \mathbf{A}\mathbf{B}^t \mathbf{x}_{t-1} + \sum_{i=1}^{p} \boldsymbol{\Gamma}_i \Delta \mathbf{x}_{t-i} + \mathbf{u}_t \quad (1)$$

with a deterministic shift vector $\boldsymbol{\mu}$. $\boldsymbol{\Gamma}_i$ are $(n \times n)$ parameter matrices of the lagged stationary differences, **B** being the $(n \times r)$ matrix of r n-dimensional cointegrating vectors containing the coefficients of r linear cointegrating relations (equilibria) between the n cointegrated variables, and **A** the corresponding $(n \times r)$ matrix of adjustment coefficients. As a whole, the matrix $\boldsymbol{\Pi} = \mathbf{AB}$' represents the impact of the lagged long-term relations between the individual variables x_{nt} in $\mathbf{x}_t$ on the change of $\mathbf{x}_t$. $\mathbf{B}'\mathbf{x}_{t-1}$ are r stationary linear combinations (for more details see [Hansen, Johansen 1998, pp. 59-70]).

This VECM is equivalent to a vector autoregression (VAR $(p + 1)$) presentation of the levels $\mathbf{x}_t$. In a VAR-model each variable can be taken as endogenous. The changes in a selected target variable in period t depend on the deviations from a specific equilibrium in the previous period and the short-term dynamics. The VECM allows us to estimate the long-term effects and to analyse the short-term adjustment process within one model. Actually, the variable vector $\mathbf{x}_t$ is assumed to be vector integrated of order 1 (I(1)), i.e. $\Delta\mathbf{x}_t$ should be vector stationary. For the purpose of this paper, it will be sufficient to test each individual variable independently for integration or stationarity respectively by the augmented Dickey-Fuller-test (ADF).

An intercept can be included in cointegrating relations alternatively, as well as a deterministic time trend. The maximum lag p can be found by applying the Adjusted LR test or the Schwarz information criterion. The number r of cointegrating vectors (lines in **B**') can be determined as the rank of the matrix $\boldsymbol{\Pi} = \mathbf{AB}$' by the test of maximum eigenvalue of $\boldsymbol{\Pi}$ or the trace statistics [Hansen, Johansen 1998, pp. 125-128]. Under rather general conditions, the coefficient matrices **A, B** and $\boldsymbol{\Gamma}_i$ can be estimated by least squares (LS), generalised least squares (GLS) and maximum likelihood (ML). In the following sections of this paper, the ML method will be used as proposed in the Johansen procedure presented in the software MICROFIT [Pesaran, Pesaran 2009, pp. 496-511].

Generalised Impulse Response Functions

Following the paper by Koop et al. [1996], concerning impulse response functions in nonlinear econometric models, Pesaran and Shin [1998], developed generalised impulse response functions because of the lack of unambiguity of the orthogonal shock analysis. Orthogonal impulse response functions depend on the sequence of the elements within the vector of jointly dependent variables. There are n! different sequences of n economic variables in the VAR model. There are no unambiguous criteria for the choice of an optimal sequence[(Pesaran, Shin 1998, p. 20]. In contrast, the generalised impulse response functions for the individual variables are unambiguous, i.e. invariant towards the chosen order of variables within vector $\mathbf{x}_t$.

Under the assumption that the variables in $\mathbf{x}_t$ are I(1), that is they have stationary first differences, the latter can be written in the infinite version of a moving average (MA) presentation [Pesaran, Shin 1998, p. 5] with certain coefficient matrices $\mathbf{C}_k$ as long-term multipliers after k periods:

$$\Delta \mathbf{x}_t = \sum_{k=0}^{\infty} \mathbf{C}_k \mathbf{u}_{t-k} \,. \tag{2}$$

Then the generalised impulse response function in a cointegrated VAR measures the effect after k periods onto vector $\Delta \mathbf{x}_t$ of a single impulse in the j-th equation. The effect for the i-th equation is given by:

$$\psi^{G}_{\Delta x,ij}(k) = \frac{\mathbf{e}_i^T \mathbf{C}_k \boldsymbol{\Sigma}_{\mathbf{u}} \mathbf{e}_j}{\sqrt{\sigma_{jj}}}, \tag{3}$$

where the $\mathbf{C}_k$ are taken from the infinite MA representation (2), $\mathbf{e}_j$ = (0,0, ..., 1,0, ..., 0)' is the j-th unit vector for the purpose of selecting the j-th element, and σ_{jj} is a diagonal element of the variance-covariance matrix $\boldsymbol{\Sigma}_{\mathbf{u}}$ of the shock variables $\mathbf{u}_t$, i.e. the variance σ_j^2 of shocks u_j in x_j.

The cumulative effect of a one-standard-deviation shock on $\mathbf{x}_{t+k}$ results in:

$$\psi^{G}_{x,j}(k) = \frac{\mathbf{D}_k \boldsymbol{\Sigma}_{\mathbf{u}} \mathbf{e}_j}{\sqrt{\sigma_{jj}}} \quad \text{with} \quad \mathbf{D}_k = \sum_{j=0}^{k} \mathbf{C}_j \quad \text{and} \quad \mathbf{D}_0 = \mathbf{C}_0 = \mathbf{I}_n \,. \tag{4}$$

5. Statistical dataset

In the following section we present the data sources and describe the executed transformation procedures.

Public debt

The public debt series includes total government debt (central, state and local debt) corresponding to the Public Finance Statistics except for the debt of state-owned hospitals with commercial accounting. The series also includes the debt of the 2008 established Special Financial Market Stabilisation Fund (SoFFin) and the debt of the Investment and Repayment Fund. The dataset are quarterly stocks at the end of the quarter measured in billion euros. Source: Deutsche Bundesbank time series database.

Consumer price index

Despite the consumer price index not being inflation itself, but in the framework of this study it is used as the main indicator for the more complex phenomenon of inflation. The index includes all goods and services in the economic region if they are part of the consumer spending of private households. The monthly dataset is seasonally adjusted by Census-X-12-ARIMA. The monthly data were transformed into a quarterly period by applying the arithmetic mean. The series is standardised to 100 for the year 2000. Source: Deutsche Bundesbank time series database.

Money stock m3

This series is the German contribution to the outstanding amounts at the end of the month (stock) of monetary aggregate m3 (from January 2002, excluding currency in circulation). By using the stock at the end of the quarter, the monthly series is transformed to a quarterly periodicity. M3 is also seasonally adjusted with the Census-X-12-ARIMA and will be measured in billion euros. Source: Deutsche Bundesbank time series database.

Long-term interest rate

The long-term interest rate will be measured by the yields on debt securities outstanding issued by residents as a monthly average in per cent. The arithmetic mean was applied to transform the monthly data into a quarterly series. Source: Deutsche Bundesbank time series database.

In the following section, we present empirical research which is based on aggregate time series for the unified Germany for the period 1991, quarter 1, to 2014, quarter 3. This period includes the effects of the latest global financial and economic crisis.

6. Empirical results

The data are analysed within the framework of a vector error correction model and the variables will be tested for cointegrating relations. Further on, the results of the generalised impulse response analysis are shown.

6.1. The econometric model

The analysis of the relationship between public debt and consumer prices uses the following variables vector

$$\mathbf{x}_t' = \begin{bmatrix} \ln D_t & \ln P_t & \ln M_t & I_t \end{bmatrix},$$

where D_t is the public debt in quarter *t*, P_t the consumer price index, M_t the money stock m3 and I_t the long-term interest rate. The natural logarithm is marked by "ln". This approach may differ from other ways of exploration in empirical literature in that the authors of this paper focus on the role of the level of public debt, instead of the budget deficit or the debt-to-GDP ratio, in determining consumer prices.

The estimation of the determinants of consumer prices in Germany is based on the following log-linear macroeconomic function:

$$\ln P_t = \alpha + \beta \ln D_t + \gamma \ln M_t + \delta I_t + u_t . \tag{5}$$

Equation (5) implies a linear relationship between the four variables in $\mathbf{x}_t$. Because of applying the natural logarithm, the coefficients α, β and γ are to be interpreted as elasticity. However, the coefficient δ is a semi-elasticity of the interest rate. Equivalent to the consumer price function, a public debt equation can be estimated:

$$\ln D_t = \alpha + \beta \ln P_t + \gamma \ln M_t + \delta I_t + u_t . \tag{6}$$

The mutual relationship between these variables is estimated within a vector error correction model, wherein public debt, consumer prices and money m3 are considered as endogenous variables and the long-term interest rate as an exogenous I(1)-variable. The latter was tested as weakly exogenous in a previous estimation, and we decided to drop it as an endogenous part of the system. Before estimating the VECM, we need to ensure that the variables investigated are in fact integrated, I(1).

6.2. Results of test on integration

The variables will be tested with the Dickey-Fuller test or the augmented Dickey-Fuller test. The Schwarz information criterion suggests the order of ADF regression be selected. The results are presented in Table 1.

Table 1. Results of Augmented Dickey-Fuller Tests

Variables	Regression	Lags	Test-statistic	95% critical value	
ln*D*	C,T	2	–3.2747	–3.4586	ns
ln*P*	C	1	–2.3971	–2.8929	ns
ln*M*	C,T	1	–2.9768	–3.4581	ns
I	C,T	2	–3.2545	–3.4586	ns
Δln*D*	C	1	–5.0153	–2.8929	s
Δln*P*	C	0	–6.8527	–2.8925	s
Δln*M*	C	0	–12.1564	–2.8925	s
Δ*I*	C	1	–7.1475	–2.8929	s

Notes: Dickey-Fuller regressions include an intercept (C) or a linear trend (T).
ns – non-stationary, s – stationary

Source: own elaboration.

Unit root tests confirm, at a level of 5% significance, that national debt, money stock, consumer price index and long-term interest rate are integrated in order one. The results indicate that each of the series is non-stationary when the variables are defined in log-levels (the interest rate is expressed in percentages). But first-differencing removes the logarithmic levels to stationary growth rates.[1]

6.3. Results of test on cointegration

Because we have four I(1)-variables in the model, there is a possibility of having more than one cointegrating vector. Therefore, the cointegration rank must be estimated. First, the order of the VECM needs to be selected. For that to happen, an unrestricted VAR in (log)-levels will be estimated. The model includes a trend and a constant. In the case of quarterly data we recommend using 4 as the maximum order of the VAR. The results are shown in Table 2.

Table 2. Results of testing the appropriate lag length of the VAR

Order	Schwarz criterion	Adjusted LR test
4	823.4079	–
3	836.1013	**$\chi^2(9) = 12.87$ [.169]**
2	843.1319	$\chi^2(18) = 35.32$ [.009]
1	**853.5520**	$\chi^2(27) = 52.04$ [.003]
0	581.7718	$\chi^2(36) = 546.3$ [.000]

Notes: (ML version in Microfit); *p*-value in [ ].

Source: own elaboration.

The Schwarz information criterion suggests a VAR of order one, which equals a VECM of order zero. The Adjusted LM test prefers the VAR(3) model. Given that we have a relatively small sample size, a lag length of two periods for the VAR in levels, respectively one period for the VECM is selected to capture the main short-term dynamics in a parsimonious way.

Besides the lag length of the VAR model, choosing the appropriate deterministic components in the multivariate system is crucial for the determination of cointegration. Johansen [1992], discussed a procedure to determine jointly the cointegration rank and the deterministic components of the VECM. According to the so-called Pantula principle, we estimate and test sequentially different relevant model specifications. In our case, there are linear trends in the level of the variables in $\mathbf{x}_t$. Therefore the model-selection procedure should comprise moving from a more restrictive model

[1] The change (ΔI_t) of I at period t is defined as ($I_t - I_{t-1}$). In comparison, the log growth rates ($\Delta \ln X_t$) of the other three variables are defined as ($\ln X_t - \ln X_{t-1}$) which is approximately equal to $(X_t - X_{t-1})/X_{t-1}$, if the percentage change is small.

(model 1: intercept in the error correction equations, but no trend in the cointegration equation) and the number of cointegration vectors is zero to a less restrictive model (model 2: linear trend in the cointegration equation, and an intercept in the VAR) and r is n–1. The procedure continues until the preferred model is identified by the first time when the null hypothesis is not rejected.

We use the trace test for searching for the cointegration rank of the two models. The trace test is applied to test different values of the rank r as shown in Table 3. However, we correct the trace statistic for a small sample bias suggested by Cheung and Lai [1993]. The correction factor is $(T - np)/T$, where T is the number of observations, n is the number of variables and p is the number of lags used.

Table 3. Results of Johansen Cointegration Tests

	H_0	Trace-test statistic	Corr. trace-test statistic	Critical value (95 %)
Model 1	$r = 0$	67.06	64.89	38.93
	$\boldsymbol{r \leq 1}$	19.49	**18.86**	23.32
	$r \leq 2$	0.29	0.28	11.47
Model 2	$r = 0$	89.48	86.00	49.36
	$r \leq 1$	34.82	33.67	30.77
	$\boldsymbol{r \leq 2}$	6.65	**6.44**	15.44

Note: r denotes the number of cointegrating vectors.

Source: own elaboration.

The trace test suggests for model 1 that there is one single cointegrating relation between public debt, consumer prices and money stock in Germany after reunification. In contrast, the trace test indicates $r = 2$ for model 2. These considerations demonstrate that selecting the appropriate deterministic is essential for determining the number of cointegrating vectors. The first time that the null hypothesis is not rejected is for model 1. As a consequence of the Pantula principle, we include an unrestricted intercept in the cointegrated VAR, but not a trend in the cointegrating relation. If we restrict the rank of the long-term matrix **Π** to be equal to one, we can estimate the cointegrating vector and the error correction models by maximum likelihood, following the Johansen procedure.

The estimated single cointegrating vector is $\hat{\mathbf{B}}_t = \begin{bmatrix} -1.0543 \\ 4.2669 \\ -0.7188 \\ 0.0217 \end{bmatrix}$.

To identify the cointegration relationship, we normalise the cointegrating vector to a coefficient of government debt of –1. As a result, we can interpret equation (7)

as a public debt function. Then estimating the vector error correction model yields the following long-term relationship for public debt:[2]

$$\hat{d}_t = \underset{(1.56)}{4.05}\, p_t - \underset{(0.59)}{0.68}\, m_t + \underset{(0.02)}{0.02}\, I_t . \tag{7}$$

As we can see in equation (7), consumer prices have a significant (5%) positive effect on sovereign debt in Germany. If the consumer price index increases by 1%, public debt rises by 4% on average, ceteris paribus. Higher consumer price level did not contribute to lower (nominal) public debt in the long run. Especially in the period after reunification in the early 1990s, the strong increase in government debt was linked to the comparatively high inflation rates in Germany. The money stock and the long-term interest rate had no significant (5%) influence on public debt. Alternatively, we can also normalise the other coefficients to one. As with the earlier a debt function, we then get equations for money stock and consumer prices. The corresponding estimated equation after standardising the cointegration vector for the coefficient of consumer price level to –1 is:

$$\hat{p}_t = \underset{(0.10)}{0.25}\, d_t + \underset{(0.07)}{0.17}\, m_t - \underset{(0.005)}{0.005}\, I_t . \tag{8}$$

In the sample period the effect of sovereign debt on consumer prices is significantly positive. A 1% rise in national debt corresponds to a 0.25% increase in the consumer price index. As described in section 2, a higher debt level could lead to increasing consumer prices by different transmission channels. However, the quantity of the public debt effect is moderate for Germany. National debt does not lose the explanatory power for the consumer prices, when money and interest rates are controlled. Moreover, we estimated a rectified relationship between money stock and consumer prices. We proved that inflation in Germany after reunification was also a monetary phenomenon in the long run. The results provide empirical evidence to characterise the cointegrating relation as a consumer price function rather than a debt function.

In the long term, trends in public debt are closely related to trends in consumer prices and money stock. Public debt deviates from this long-term equilibrium in the short term, but will tend to gradually revert to equilibrium over time. This process is modelled as an error correction mechanism. The estimated vector error correction model is the following:

$$\begin{aligned}
\Delta\hat{d}_t &= \underset{(0.087)}{-0.58} + \underset{(0.092)}{0.04}\,\Delta d_{t-1} \underset{(0.437)}{-1.62}\,\Delta p_{t-1} \underset{(0.068)}{+0.19}\,\Delta m_{t-1} + \underset{(0.005)}{0.008}\,\Delta I_{t-1} + \underset{(0.014)}{0.09}\, ecm_{t-1} \\
\Delta\hat{p}_t &= \underset{(0.023)}{-0.06} + \underset{(0.025)}{0.01}\,\Delta d_{t-1} + \underset{(0.118)}{0.22}\,\Delta p_{t-1} + \underset{(0.018)}{0.003}\,\Delta m_{t-1} - \underset{(0.001)}{0.001}\,\Delta I_{t-1} + \underset{(0.004)}{0.01}\, ecm_{t-1} \\
\Delta\hat{m}_t &= \underset{(0.134)}{-0.24} - \underset{(0.143)}{0.24}\,\Delta d_{t-1} + \underset{(0.674)}{0.43}\,\Delta p_{t-1} - \underset{(0.105)}{0.28}\,\Delta m_{t-1} - \underset{(0.007)}{0.003}\,\Delta I_{t-1} + \underset{(0.021)}{0.04}\, ecm_{t-1}
\end{aligned} \tag{9}$$

with $ecm_t = -1.05 d_t + 4.27\, p_t - 0.72 m_t - 0.02 I_t$ being the error correction term.

[2] The asymptotic standard errors of the coefficients can be found in the brackets. The lower case notation denotes natural logarithms.

After estimating the ECMs we need to proceed with tests of weak exogeneity. Testing for weak exogeneity with respect to the long-term parameters is equivalent to testing which of the rows of **A** in equation (1) are equal to zero [Hansen, Johansen 1998, p. 92]. In our case we test for a zero restriction of the error correction term in (9). If a variable is found to be weakly exogenous, we can drop it as an endogenous part of the system. The significance (5%-level) of the error correction term in all three equations indicates that public debt, consumer prices and money stock are endogenous in the system.

The dynamic specification exhibits significant error correction coefficients in all three equations. However, the value of the ECM-coefficient in the consumer price growth equation appears to be very low. That means the speed of return to the equilibrium price level after a shock is quite slight. Furthermore, changes in consumer prices in the previous quarter indicate the restraining effect on public debt growth in the short-term. The government profits from high inflation only in the short term, whereas in the long run a mutual relationship was observed. The error correction model for the consumer prices shows that m3 money growth is not a good indicator for consumer price growth in the short term.

6.4. Results of the impulse response analysis

In the following graphs, the results of the cumulative effects of the variable (or equation) specific shocks for the variables in $\mathbf{x}_t$ are shown. Figure 3 demonstrates the impact of a one standard-error shock in the equations for public debt, consumer price index and money stock on the variables under consideration.

Using the generalised impulse response, the impact effect of a unit shock to consumer prices on sovereign debt is significant at the 5% level, and is in fact slightly larger than the effect on prices itself. A consumer price shock generates directly a decreasing reaction on government debt and in the medium and long-term an increasing effect on government debt. This supports the VECM results in the previous section. The rise in inflation could push up nominal interest rates, which may influence private investment negatively and increases government interest spending. The response of money stock to a consumer price impulse is significantly positive after one year. The impacts of the debt shock and the money supply shock on consumer prices are not significant. The money supply shock causes a slightly contractive effect on government debt after four quarters. A higher money stock could indicate a better economic situation and thus could lead to an improving fiscal situation.

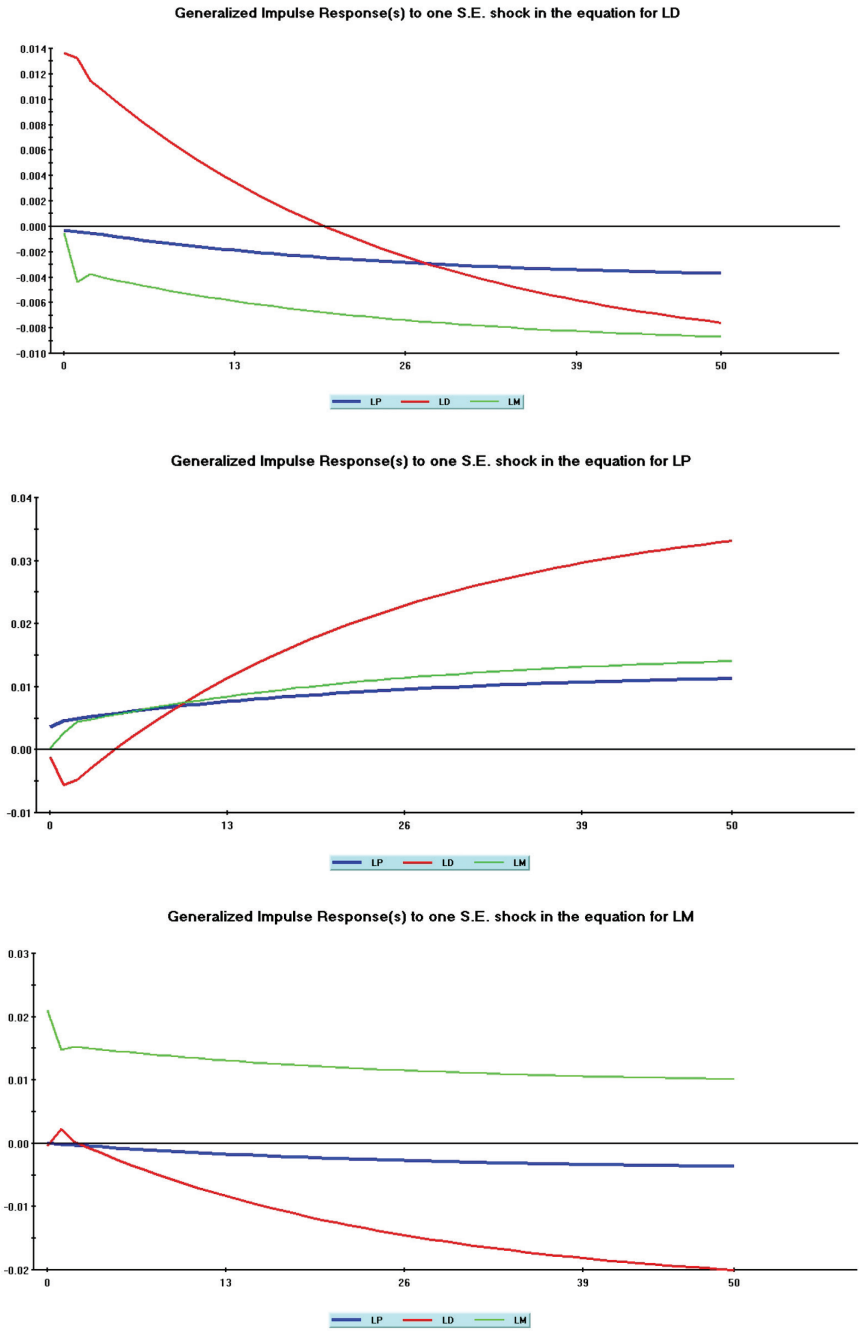

Fig. 3. Generalised impulse responses in the equations for public debt, consumer price and money stock

Source: own elaboration.

7. Conclusion and policy implications

Public debt and inflation are mutually connected through several channels. Public deficits can lead to higher inflation if the money supply is expansionary. The liquidity condition of the banking sector and the institutional framework such as the independency of the central bank determine the relationship between government debt and inflation. The lower the level of independence the higher the potential of debt-caused inflationary processes. In this context, it is important where (domestic or abroad) and from whom (private or institutional investors) the government lends money and how the investors evaluate the public bonds. A high proportion of short-term debt lowers the incentives to use inflation to erode the real value of sovereign debt. An essential factor is also the government's solvency, which means on the one hand the ability to repay and on the other hand the readiness to repay. This is shown currently by the example of Greece. An unsustainable evaluated public debt level could lead to a loss in financial standing and cut access to the credit markets.

The inflation tax applies only to debt issued in local currencies. In addition, the tax works only if consumer price inflation is unexpected. When debt-holders anticipate inflation, they demand a nominal interest rate in line with the expected inflation. In that case, there is no gain for government. Notable exceptions are long-maturity assets. The nominal interest rate cannot be modified during the term of the contract by the bond-holders. Additionally, the central bank's bonds purchase programmes could impede the increase in nominal interest rates or instruments of financial repression such as the capital regulation of banks and the insurer could prescribe buying public bonds. To sum up, monetary financing of public deficits is just another form of taxation: reducing the real value of the monetary base and the public debt. It also redistributes wealth from borrowers to lenders, when the assets are nominal.

Empirical literature[3] has shown that government debt had an effect on macroeconomy, especially in emerging market economies. The regression results[4] of the empirical analysis for Germany signal the strong positive relationship between the public debt level and the consumer prices after reunification, after controlling for money supply and long-term interest rates. For this paper, the authors estimated a significant mutual long-term relationship. On the contrary, the short-term changes of the consumer price index indicated the restraining effect on public debt growth. The government profits from higher inflation only in the short term, whereas in the medium and long-term a mutual relationship was observed. Moreover, consumer prices were significantly positively affected by the sovereign debt level in the long term. That means government debt statistically causes inflation and vice versa. Furthermore, a stable connection between money stock and consumer prices was

[3] See Chapter 3.

[4] See equation (7) and (8) in Section 6.3.

detected in Germany, but money growth is not a good indicator for inflation in the short run.

The central banks of some highly indebted countries (FED, Bank of England, Bank of Japan) have purchased a huge amount of government bonds since 2008 to lower the public and private refinancing costs. The returns on public bonds were successfully kept under the inflation rate in these countries. The uncertainty on the bonds markets as a result of the European sovereign debt crisis also has led to negative real interest rates, not only in Germany. The real interest rates are remaining in a negative range and contribute to the short-term debt relief of countries with high solvency. Considering the high level of public debt and the fragile economic situation, some central banks additionally announced to fix the interest at a low level for a considerable time (forward guidance). The ECB also decided to speed up the money supply. However, the impact of the ECB's government bond purchase programme on output and inflation in the euro area is expected to be weaker than in the US and the UK. The funding of Anglo-Saxon companies is more capital-market-based and the wealth effects are generally greater [Nastansky 2012, p. 182f].

Quantitative easing is assumed to be a powerful instrument of monetary policy to influence long-term interest rates, output and inflation. Besides, De Grauwe [2011], argues that in case of a disturbance of the bond market (e.g. liquidity crisis and domino effects) central banks should purchase extensively government bonds. The monetary policy has to counteract the crisis of confidence. So the central bank takes the role as lender of the last resort also for governments. But that means the monetisation of a part of the public debt and a higher risk in the central bank's balance sheets. The negative consequences of debt monetisation are different: the assets of the bond owner and depositors will be devalued in real terms in the long run. The central banks should also take into account the possible moral hazard behaviour of the crises states after the purchase of public bonds. Lower yields on government bonds could reduce the market pressure and subsequently the governments could expand the fiscal deficits again. This development happened in Italy in the summer of 2011. Quantitative easing is more a financial stabilisation policy rather than a growth policy. Large deficits in some countries within a monetary union could cause negative external effects (increasing risk premiums) on the other member states. Furthermore, a long-lasting low level of interest rates could encourage the development of speculative bubbles on the bond, stock, real estate and commodity markets. As a consequence, the capital accumulation of the economic subjects could be distorted. Higher asset prices increase the wealth especially of rich people and strengthen the inequality in distribution of wealth. Moreover, persistent budget deficits can limit the fiscal policy to acting as a stabilising instrument. A high level of sovereign debt can strengthen the fear of inflation by economic subjects and unsettle their inflation expectations. This could lead the monetary policy authorities to keep short-term interest rates higher than would otherwise be necessary. The national

central banks will become the most important creditors to their governments, which might put the independence of monetary policy at risk.

A monetary policy strategy focussed on price stability, depends on the public-debt level as well as on the balance-sheet management of the financial intermediary. The latest financial crisis has shown that sound fiscal debt policy is crucial for financial stability. Banks and insurers are the most important creditors for the governments. In spite of the growing national debt in many euro area countries, the deleveraging of banks, the weak credit demand and the economic downturn as yet has impeded an upward pressure on prices. The crisis of the banking industry and the new regulatory capital requirements have forced the financial sector to multiply the increasing central bank money base, and thus to start an inflationary process. So the following question arises: will an accelerated inflation development, such as in the 1970s, come back in the medium or long term? This fear will be intensified by the debt problem of Greece. Economically stable countries such as Germany supported the crises-affected countries by implementing the bailout funds, EFSF and ESM. This can increase the incentive to depreciate debt in real terms in the future. For precisely this reason, independent central banks with a focus on price stability are an important factor to limit the inflation potential caused by a high level of sovereign debt. In a growing economy, governments can run deficits quite consistently. But, if the interest rate on public debt is persistently higher than the nominal output growth rate, the sovereign debt position could become unsustainable. Inflation as a solution for ensuring sovereign solvency could lead to an undesirable macroeconomic outcome.

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