The Effect of Public Capital on Aggregate Output

– Empirical Evidence for 22 OECD Countries –

by JAN-ERIK WESSELHÖFT*

Abstract

Based on new estimates of public and private capital stocks for 22 OECD countries we study the dynamic effect of public capital on the real gross domestic product using a vector autoregression approach. Whereas most former studies put effort on examining the effects of public capital in a single country, this paper covers a large set of OECD countries. The results show that public capital has a positive effect on output in the short-, medium- and long-run in most countries. In countries where the effect is negative, possible explanations as the different productivities of investments, crowding out or high growth rates of government debt are analyzed. (JEL: C32; E60; H54. Keywords: *Public capital stock; VAR model; Cointegration; OECD countries*)

1. Introduction

The public capital stock consists of a wide range of physical assets such as transportation networks (e.g. roads, highways, railways and airports), energy networks, telecommunication networks, public buildings (e.g. schools, universities, hospitals, police and fire departments, courthouses). The reason why many states invest in their public capital stocks is that public sector capital is generally regarded as an important prerequisite for a well-functioning and growing economy. To further increase their growth prospects, even already well-developed countries invest a considerable share of their gross domestic product in their public capital stocks. Moreover, building up a public sector capital stock is often seen as one of the primary means to spur growth in underdeveloped countries. The UNITED NATIONS MILLENNIUM PROJECT (2005), the COMMISSION FOR AFRICA (BLAIR COMMISSION) (2005) and the WORLD BANK (2005) all advocated to foster the process of public sector investments in developing countries by debt relief and foreign aid programs. A quick modernization of the public capital stock was also seen as the best way of achieving similar living conditions

* Helmut-Schmidt-University Hamburg, Chair for Political Economy & Empirical Economics, Holstenhofweg 85, 22043 Hamburg/Germany, Phone: 0049+40+65412616,
E-mail: jan-erik.wesselhoeft@hsu-hh.de.

Review of Economics, 64. Jg., 51–72, ISSN 0948-5139

in East Germany in the process of German Reunification. A considerable amount of the transfers from West to East Germany has been used for this purpose.

Whether public capital in fact contributes to economic growth is an empirical question.[1] The empirical literature on this issue starts out with ASCHAUER's (1989) study of the growth effect of public capital in the United States. Using a production function approach, he finds a strong positive effect of the public capital stock. He finds the elasticity of the gross domestic product with respect to public capital to be as large as 0.39. A similar result was reported by MUNNELL (1990). In the aftermath, studies for many different countries were conducted. Initially, these studies primarily relied on some variation of the production function approach.[2] However, this approach has two serious shortcomings. First, it violates standard productivity theory.[3] Second, the production function approach fails to take into account that not only public capital might have an influence on aggregate output but output might also influence public capital.[4] As BATINA (1999) argues, the production function approach therefore overestimates the effects of public capital on economic growth. Many recent papers therefore apply the vector autoregression approach (VAR) which can adequately account for endogeneity problems.[5] Most of the existing VAR evidence is related to single countries. Since the data employed in these studies often comes from national sources, the calculation methods of the public capital stock differ from study to study. Moreover, the employed macroeconomic variables also differ from study to study. As a consequence, the results of these studies are hardly comparable. Studies covering various countries and using the same set of control variables and the same data and calculation method of public capital stocks are yet very rare.[6]

In this paper we contribute to the literature by constructing public capital stock data for 22 OECD countries using the same data source and the same methodology. We then study the effect of shocks of the public capital stock in a vector autoregression approach.

We find very different effects of public capital shocks on GDP, depending on the country and the existing level of the public stock of capital.

---

1 For reviews of the empirical literature see STURM, KUPER and DE HAAN (1998) and ROMP and DE HAAN (2007).

2 ROMP and DE HAAN (2007) report as many as 24 studies following some kind of production function approach.

3 Some studies tackled the first problem by employing a cost-function approach. See, e.g., CANALETA et al. (1998), DEMETRIADES and MAMUNEAS (2000) or COHEN and MORRISON PAUL (2004).

4 KAMPS (2005b) shows impulse response functions for shocks of output on the stock of public capital and finds for the vast majority of countries significant effects. In our empirical analysis we find similar effects. Therefore a dynamic VAR model seems to be the appropriate framework to deal with the reverse causation problem.

5 See e.g. MITTNIK and NEUMANN (2001) or BELLOC and VERTOVA (2006).

6 To the best of our knowledge, the only existing multi-country study covering more than 10 countries is the one by KAMPS (2004).

The paper is organized as follows: Section 2 summarizes the existing literature on the topic. We thereby concentrate on approaches employing the vector autoregression approach. Special attention is given to the few studies covering multiple countries. Section 3 briefly describes the vector autoregression methodology, which is used in the empirical analysis. Section 4 presents the used data while section 5 specifies the model. In section 6 we discuss the empirical results. Section 7 concludes.

2. Literature

In the beginning, the empirical literature on the effects of public capital on economic growth was dominated by the production and the cost function approach. However, in the recent past the popularity of the VAR approach has increased significantly. The primary reason for this increasing popularity is that the VAR approach does not make any a-priori assumptions on causalities and thus allows dealing with the case of possible endogeneity in an adequate way. Most of the existing studies refer to single countries and are based on quite different data sources.[7] The results are thus hardly comparable.

Only a few studies cover more than one country. MITTNIK and NEUMANN (2001) analyze the dynamic relationship of public investment and output for six industrialized countries[8] using quarterly data from the OECD Quarterly National Accounts. The authors analyzed the effect of a shock on public capital in a VAR framework[9] and a VECM with four variables: public investment, public consumption, private investment and GDP. The resulting impulse responses show that the very short-run reaction is positive for all sample countries. In the case of Great Britain the result is insignificant. For Canada and France the significant results in the short-run become insignificant in later years. In the long-run only the Netherlands and Germany have significant positive results. The elasticities of output with respect to public investment are, with the exception of Canada where the elasticity is 0.15, lower than 0.1. The authors conclude that public investments might influence real GDP and can therefore be a source of endogenous growth.

In order to overcome the problem of non-comparable capital stock data KAMPS (2005a) constructed a new database of private and public capital stock data for 22 OECD countries. In order to do so he applies the perpetual inventory method to OECD data.[10] In his follow-up study KAMPS (2005b) uses this dataset to analyze and compare the dynamic effects of public capital for these 22 OECD countries.[11] More precise, KAMPS (2005b) estimates a VAR model including four endogenous vari-

[7] See e.g. PEREIRA (2000) which investigates the effect of public investment on private-sector performance in the US. Other sources for single country studies are e.g. BATINA (1998), MAMATZAKIS (1999) or OTTO et al. (1996).

[8] Canada, France, Great Britain, Japan, the Netherlands and Germany for 1955–1994.

[9] The VAR was estimated in first differences.

[10] For a description of the method see e.g. BERLEMANN and WESSELHÖFT (2012).

ables.[12] Because the employed time-series mostly turn out to be non-stationary but cointegrated for most of the sample countries[13] vector error correction models (VECM) are used. KAMPS (2005b) argues that most prior studies did not provide any confidence intervals indicating the uncertainty and significance of the impulse responses. In order to fill this gap he reports confidence intervals derived from bootstrapping.[14]

KAMPS (2005b) concludes that for the majority of the 22 countries the output effect of a shock to public capital is significantly positive. However, for some countries the effect of public capital on economic growth is negative at all horizons (Ireland, Japan and Portugal). For a few countries (Canada, Iceland, Norway, Spain and the United Kingdom) the short-term effect is negative but changes its sign in the medium-term perspective. The long-run effect is significantly positive in 9 countries, insignificantly positive in another 10 and negative in the remaining 3 out of 22 sample countries. When comparing his results to those derived from production function approaches[15] KAMPS (2005b) concludes that the effects of shocks to public capital on real GDP turn out to be much smaller in the VAR approach. He suggests this to be due to the neglected second round effect from output to public capital. Another interesting finding of the analysis is that a shock of public capital has typically no statistically significant effect on employment in the sample countries.

Another study from PEREIRA and PINHO (2006) with data from the Statistical Annex of the European Economy and the OECD covers twelve countries[16] for the period 1980-2003. This paper also applies the VAR approach to catch dynamic feedbacks and to analyze the budgetary and economic effect of public investment. They also set up a model with four variables.[17] In contrast to KAMPS (2005b) the authors did not calculate capital stocks. PEREIRA and PINHO (2006) used the capital formation data itself. All variables in log-levels are determined as stationary in first differences and not cointegrated. Because the Engle-Granger test is applied here, a possibility of more than one cointegration relations is neglected. Therefore the authors estimated a standard VAR model.

---

[11] The study includes Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom and the United States for the period of 1960 to 2001.

[12] The VARs include the public net capital stock, the private net capital stock, employment and the real gross domestic product.

[13] For New Zealand and Portugal no cointegration relations could be found. Therefore, for these two countries a simple VAR model was estimated.

[14] See BENKWITZ, LÜTKEPOHL and NEUMANN (2000) for possible problems in calculating confidence intervals in VAR models.

[15] See e.g. PEREIRA (2000).

[16] The sample countries are: Austria, Belgium, Finland, France, Greece, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain.

[17] Private and public investment, employment and output.

Contrary to KAMPS (2005b), a result of their estimation is that public investment has a positive effect on employment and private investment in most of the covered countries. In Austria, Belgium, Luxembourg, the Netherlands and in Greece public investment crowds out employment in the long-run. Especially Ireland, Italy, Portugal, Spain and Germany benefit most from public investments with respect to employment effects.

Regarding possible crowding in or out effects on private investment, the results show positive effects on private investments.

The authors also found that public investment has a strong positive effect on long-term output for eight of the twelve observed countries. PEREIRA and PINHO (2006) therefore come to the conclusion that a cut in public investment will affect output negatively in the long-run. For Luxembourg and the Netherlands the elasticity is negative, for Austria and Belgium the effect on output is very small.

3. *VAR methodology*

Following the earlier reported line of argument we employ vector autoregressive regression models (VAR) to study the effects of public capital on economic growth. The VAR approach, originally introduced by SIMS (1980), makes it possible to analyze and describe the relationship between several variables of interest. All included variables are treated as being (at least a priori) endogenous. In a VAR approach every variable is regressed on its own lags and the lags of all other variables. The mathematical form of a VAR is

$$(1) \qquad y_t = A_1 y_{t-1} + A_2 y_{t-2} + \ldots + A_p Y_{t-p} + Bx_t + \varepsilon_t = \sum_{i=1}^{p} A_i y_{t-i} + Bx_t + \varepsilon_t$$

where y_t is a $(k \times 1)$ vector of endogenous variables, x_t is a vector of exogenous variables, A_i and B are matrices of autoregressive coefficients to be estimated, and ε_t denotes a vector of unobservable innovations. The error terms might be contemporaneously correlated with each other. However, it is assumed that there is no correlation with the own lags and also no correlation with all of the other right-hand side variables.

In our study, we include variables for the public net capital stock (KGV), the private net capital stock (KPV), employment (N) and the real gross domestic product (GDP).[18] The nature of the considered variables implies that the variables are non-stationary. As a consequence, estimating an unrestricted VAR using OLS might lead to inconsistent impulse responses and forecast error variance decompositions at long horizons.[19] However, when the non-stationary variables are cointegrated, the model

[18] We refrain from adding more endogenous variables to the model since doing so would end up in insufficiently degrees of freedom.

[19] See PHILLIPS (1998).

can be estimated as a vector error correction model (VECM). Assume a system with two variables and one cointegrating equation

(2) $$y_{2,t} = \beta y_{1,t}$$

When this expression is used as error-correction term in the VECM as error correction term, the model can then be interpreted as a restricted VAR that has cointegration restrictions built into the specification[20]

(3) $$\begin{aligned} \Delta y_{1,t} &= \gamma_1 (y_{2,t-1} - \beta y_{1,t-1}) + \varepsilon_{1,t} \\ \Delta y_{2,t} &= \gamma_2 (y_{2,t-1} - \beta y_{1,t-1}) + \varepsilon_{2,t} \end{aligned}$$

The specification, which is relevant for our problem, assumes a linear trend in y_t and a constant which is left unrestricted.[21] Thus, we have

(4) $$\begin{aligned} \Delta y_{1,t} &= \delta_1 + \gamma_1 (y_{2,t-1} - \beta y_{1,t-1} - \mu) + \varepsilon_{1,t} \\ \Delta y_{2,t} &= \delta_2 + \gamma_2 (y_{2,t-1} - \beta y_{1,t-1} - \mu) + \varepsilon_{2,t} \end{aligned}$$

To analyze the reaction of the dynamic system in response to exogenous shocks, it is usual to calculate the impulse response functions for all endogenous variables. The impulse responses show how a specific shock works through the system of endogenous equations when a one-standard-deviation shock in one equation occurs. Such a shock not only affects the variable which is described by the referring equation. Because of the dynamic structure the shock is typically transmitted to all other endogenous variables. Following KAMPS (2005b) we report confidence intervals for the impulse responses. The reported 95% confidence-intervals are calculated with a bootstrap methodology[22] and should be interpreted with some caution.[23]

4. Data

For our empirical analysis we are in need of comparable data on private and public capital stocks. However, no official database with a satisfying number of observations is available. We therefore apply the Perpetual Inventory Method to investment data to construct adequate capital stock data. The only database providing disaggregated investment data for a larger number of countries in a comparable manner is the OECD database.[24] The database comprises data on public investments, private resi-

[20] There are no lagged differences included on the right-hand side to keep this example simple.
[21] See KAMPS (2005b).
[22] We report 95%-confidence-intervals with $n = 1000$ repetitions (see SIMS 1987). The confidence intervals were calculated with JMulTi (KRÄTZIG 2004) and the Efron bootstrap methodology.
[23] See e.g. KRÄTZIG (2004).
[24] The data is available in the Economic Outlook of the OECD.StatExtracts (www.stats.oecd.org).

dential investments and private non-residential investments. We extracted this data for all included 22 countries for the longest period available (1970 to 2010).

The basic idea behind the Perpetual Inventory Method is to calculate an initial capital stock for the period in which the available time series of investment starts. For each subsequent period investments are added and a fraction of the already existing capital stock is subtracted (capital stock depreciation). The capital stock in period $t+1$ is then given by

$$(5) \qquad K_{t+1} = (1-\delta_t)^t K_1 + \sum_{i=0}^{t-1} (1-\delta_t)^i I_{t-1}$$

where K_1 is the initial capital stock, δ_t is the depreciation rate and I_t the investment flow at time t. For the calculation of K_1 different methods have been in use.[25]

In this paper we apply the method proposed by KAMPS (2005a). His approach of estimating the initial capital stock bases on the idea to construct a long synthetic time series of investment data for the years preceding the first year for which investment data is available. This investment series for the period 1860–1959 is constructed for each country by assuming that investment increased by 4 percent a year during this period, finally reaching its observed level in 1960.[26] He then applies formula (5) to this synthetic data[27] while setting the capital stock in the initial period to zero. Whenever the time series is sufficiently long,[28] the effect of the initial period is negligible small. As the result, KAMPS (2005a) ends up with an estimator of the initial capital stock in the period where the available investment data starts.

In general we use the same depreciation schemes as KAMPS (2005a).[29] However, since the study of KAMPS (2005a) ends in 2001 we have to postpone the depreciation schemes until 2010 in a plausible way. Here we have to ensure that the depreciation rate is limited. Therefore we used a logarithmic form.

$$(6) \qquad \delta_t^j = \delta_{\min}^j \cdot \left(\frac{\delta_{\max}^j}{\delta_{\min}^j}\right)^{1+0.25\cdot\ln\left(\frac{1}{41}\cdot(t-2001+41)\right)}$$

with j = KGV, KHV, KGV and $\delta_{\min}^{KGV} = 2.5\%$, $\delta_{\max}^{KGV} = 4.0\%$, $\delta_{\min}^{KHV} = 1.5\%$, $\delta_{\max}^{KHV} = 1.5\%$, $\delta_{\min}^{KBV} = 4.25\%$, $\delta_{\max}^{KBV} = 8.5\%$ the depreciation rates for every point in time are given.

A graphical illustration of the applied depreciation rates is given in Fig. 1.

---

[25] For an overview on these methods see BERLEMANN and WESSELHÖFT (2012).

[26] See KAMPS (2005a).

[27] The used depreciation rates are constant and follow the pattern described above.

[28] KAMPS (2005a) calculated synthetic time series from 1860 to 1959.

[29] For public investment the depreciation rate is constant 2.5% till 1960 and rises till 2001 geometrically to 4.0%, for private nonresidential investment the rate is constant 4.25% till 1960 and rises to 8.5% in 2001. The rate for private residential investments is constant 1.5% till 2001. The rate of total private investment is a weighted average of the last two depreciation patterns.

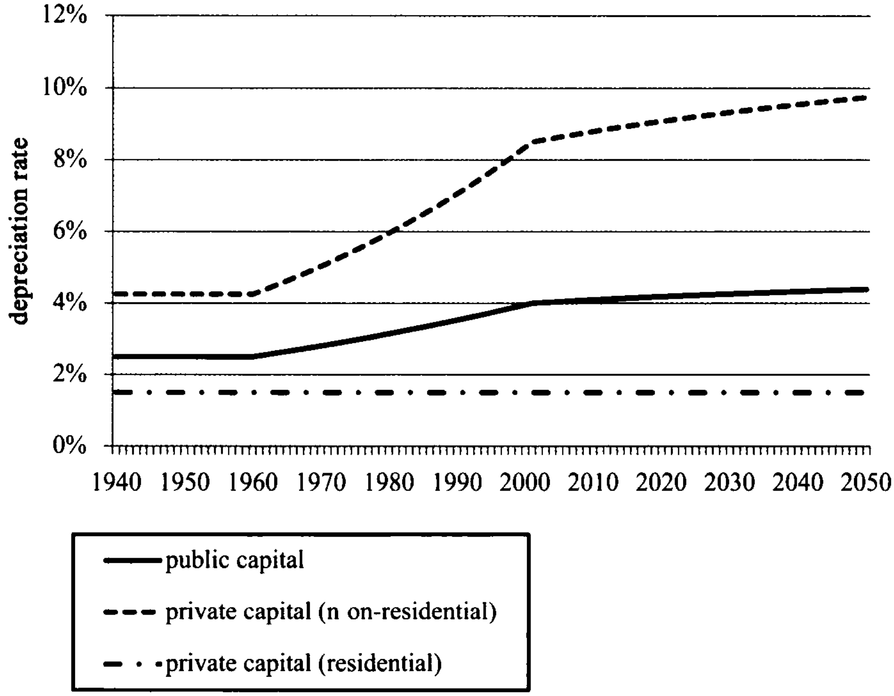

Fig. 1: Depreciation rates for different capital stocks

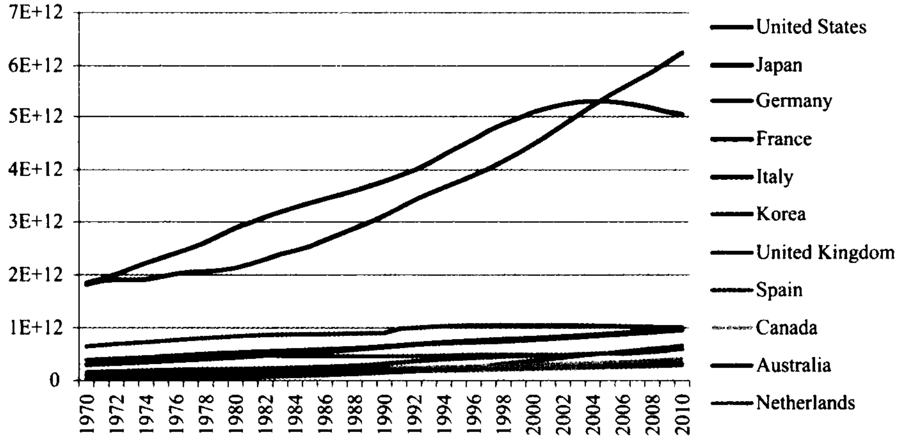

Fig. 2: Public capital stocks 1970–2010 (2008 PPP, USD)

The resulting capital stocks from 1970 to 2010 can be seen in the following figures.

Figures 2 and 3 show the evolution of the public capital stock, Figures 4 and 5 of the private capital stock. The private capital stocks consist of non-residential and residential investments. All values are expressed in USD and 2008 PPPs. Because of large differences in the amount of the stocks, the countries are splitted into two figures. The first of the two graphs includes the eleven countries with the highest capital stocks, the second with the lowest.

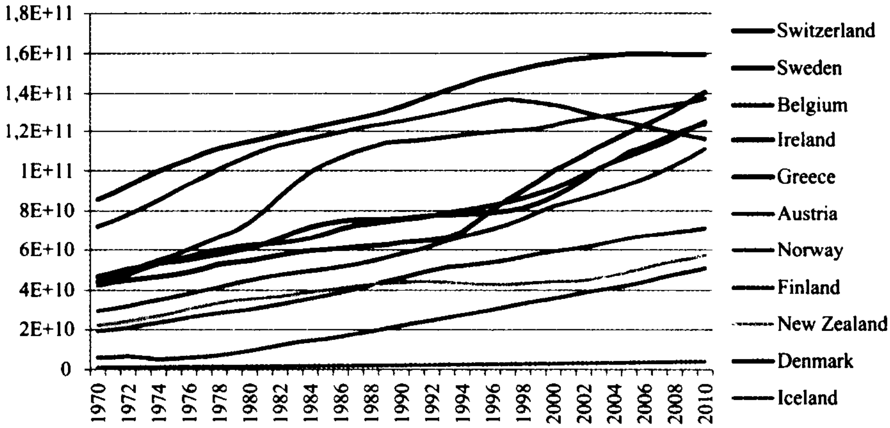

Fig. 3: Public capital stocks 1970–2010 (2008 PPP, USD)

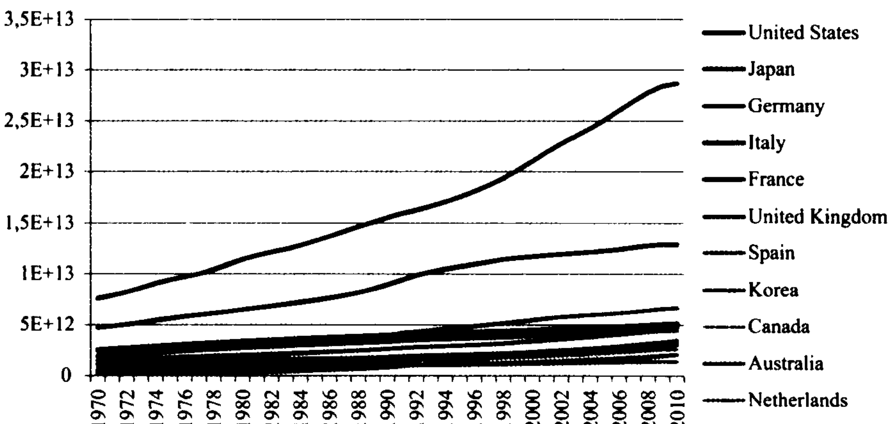

Fig. 4: Private capital stocks 1970–2010 (2008 PPP, USD)

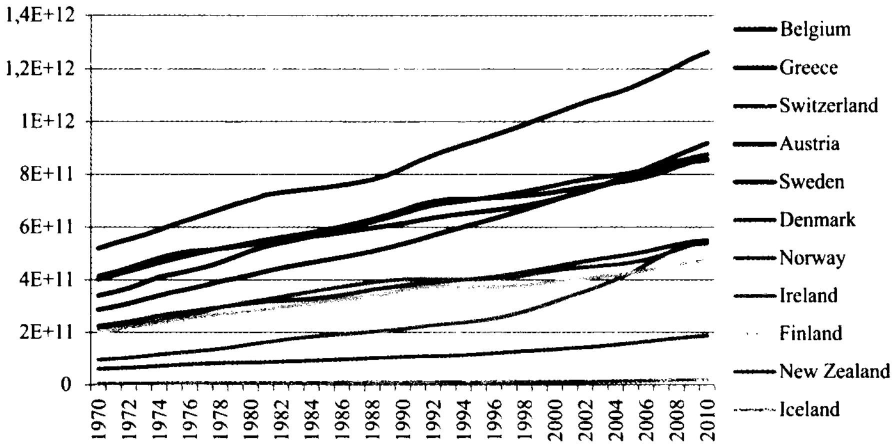

Fig. 5: Private capital stocks 1970–2010 (2008 PPP, USD)

Besides the two capital stock variables we need data on unemployment rates (N) and the real gross domestic product (GDP). The referring data was extracted from the OECD database and was available for the period of 1970 to 2010. In order to be able to interpret the impulse responses as percentage changes of the respective variable the data is expressed in logarithms and multiplied by 100.

5. *Model Selection Issues*

As discussed earlier, the time series of capital stocks and of the real GDP turn out to be non-stationary. Estimating the VAR model in levels might thus lead to spurious regression problems. However, since real GDP is related to the private and the public capital stock via a production function we should expect that the time series are cointegrated. Thus, a linear combination of the level variables should turn out be stationary.[30]

To test for cointegration relations the JOHANSEN's (2002) trace test or the Maximum Eigenvalue test are available.[31] Both tests have frequently been applied in empirical studies. For most of the countries the two tests indicate either one or two cointegration relations. However, unit root tests in general are known to have comparatively low power. In order to work with a common framework for the empirical analysis we assume the production function to be the unique cointegration relation.[32]

[30] See CHEUNG et al. (1993).

[31] See e.g. LÜTKEPOHL, SAIKKONEN and TRENKLER (2001).

[32] See e.g. HERZER and SILIVERSTOVS (2006), HERZER and NOWAK-LEHMANN D. (2006) or GHATAK et al. (1997).

When estimating the VAR model we have to decide on the appropriate lag order. We base the choice of the lag order on the Schwarz criterion.[33] The referring results are summarized in Table A-1.

Besides information on the optimal lag order, Table A-1 also reports the results of different specification tests. We conducted tests on autocorrelation, heteroscedasticity and non-normality of the residuals. The LM test for autocorrelation indicates that in most cases there is no autocorrelation. In cases where a significant degree of autocorrelation was detected the lag order was increased by an additional lag. The *p*-value of the autocorrelation test after adjustment of the lag length is reported in Table A-1.

To test on heteroscedasticity the multivariate[34] White test (1980) was applied. In most cases we found no evidence of heteroscedastic residuals. We also report the results of normality tests of the residuals.[35] While in the majority of cases the residuals turn out to be normal, this does not hold true for all countries. However, even if the residuals turn out to be non-normal this is without effect on the results of JOHANSEN's (1988, 1991) trace test on cointegration relations.[36] Moreover, the VAR parameters are known to be asymptotically efficient even in the case of non-normal residuals.[37]

In order to be able to calculate impulse response functions it is necessary to identify the empirical models. As usual in the related literature, we use Cholesky ordering for this purpose.[38] We apply the same ordering to the four endogenous variables as it is done in PEREIRA and SAGALES (1999, 2001 and 2002), MAMATZAKIS (1999), LIGTHART (2002) and KAMPS (2005b), i. e. y_t = [KGV_t, KPV_t, N_t, GDP_t].

6. Empirical Results and Interpretations

Impulse response functions are the common tool to illustrate dynamic properties of VAR models. These functions show the response of shocks for different time horizons. Since we are interested in the effect of shocks of public capital on real GDP we study the impulse response functions of one standard deviation shocks. Figures A-1 to A-4 show these impulse response functions for the 22 sample countries. The figures also show 95% confidence intervals computed with the Efron bootstrap methodology.[39] However, as BENKWITZ, LÜTKEPOHL and NEUMANN (2000) argue that bootstrapped confidence intervals in autoregressive processes should be interpreted

[33] See SCHWARZ (1978).

[34] For the multivariate variant see DOORNIK (1996).

[35] See LÜTKEPOHL (1991) for the multivariate residual test.

[36] See CHEUNG et al. (1993).

[37] See LÜTKEPOHL (1991).

[38] An alternative would be to use the approach of PESARAN and SHIN (1998) which is invariant to the ordering. However, for reasons of simplicity we stick to Cholesky Ordering, here.

[39] Implemented in JMulTi software (KRÄTZIG 2004).

with great caution, in particular in the case of small samples.[40] As a consequence, while reporting the confidence bands we refrain from interpreting them explicitly.[41]

The impulse response functions, which are documented in detail in the appendix, display a quite heterogeneous picture and thus underlines the finding reported in the survey article of Romp and de Haan (2007) that the effect of public capital differs heavily from country to country. In 9 out of the 22 sample countries, a positive shock of public capital of one standard deviation leads to an increase of at least 0.5 percentage points in real GDP (Austria, Denmark, France, Germany, Greece, Ireland, Japan, Norway and the United States). In another 9 countries the effect is ambiguous (Australia, Canada, Finland, Iceland, Korea, New Zealand, Sweden, Switzerland, and the United Kingdom). Finally, there are 4 countries in which GDP decreases by more than 0.5 percentage points in response to a one standard deviation shock of public capital (Belgium, Italy, the Netherlands and Spain).[42]

It is an interesting question which factors might contribute to explaining the differing effects of public sector investments in the sample countries. Devarajan, Swaroop and Zou (1996) argue that the effect of public sector capital investments strongly depends on the nature of these investments. In their empirical analysis they make an attempt at classifying public investments into productive and unproductive ones. They show that even principally productive investments may become unproductive whenever the level of this type of investment is already high. In this case, further public sector investments might even lead to negative growth effects since they tend to depress private capital investments as well as consumption expenditures.

While our data does not allow studying this hypothesis explicitly, this explanation seems to be quite plausible especially for the highly developed countries in our sample. In the light of this interpretation, we might interpret our findings as a judgment of the quality of public sector investments over the sample period. From this perspective, Austria, Denmark, France, Germany, Greece, Ireland, Japan, Norway and the United States performed quite well in their public investment policies while Italy, Spain, Belgium and the Netherlands did a much worse job.

Interesting insights can also be gained by comparing our results to those reported in Kamps (2005b), who has used almost the same sample countries[43] and a very similar empirical approach but an earlier sample period ending in 2001. Thus, changes in the detected growth effects of public sector investments might be attributed to changes in the performance of public investment strategies over the last decade. Following this line of argument, especially Japan, but also Austria, France, Ireland and the United States managed to improve their public investment strategies. While

---

40 See also Benkwitz, Lütkepohl and Wolters (1999).

41 For reasons see e.g. Benkwitz et al. (2000).

42 The long-run elasticity of output with respect to capital shocks can be calculated by dividing the long-run response of real GDP to a shock of public capital by the long-run response of public capital. In Table A-2 in the appendix we show the long-run elasticities for $n = 500$ periods.

43 Instead of Korea, Kamps (2005b) includes Portugal in his analysis.

KAMPS (2005b) reports positive growth effects of public sector investments for Italy and Spain, they turned out to be negative in our study, thereby indicating strongly unproductive public investment strategies in these countries throughout the last decade. However, even in Belgium, Iceland, the Netherlands, Sweden and Switzerland public sector investments seem to have been less productive than before.

7. Conclusion

Based on a newly constructed dataset of 22 OECD countries this paper studies the effects of public sector investments on GDP, thereby using a VAR methodology. We find strongly differing effects of shocks of the stock of public capital on the real gross domestic product. While in 9 of our sample countries public sector investments tend to have positive growth effects in 9 other countries growth turns out to remain broadly unaffected. In Italy, Spain, Belgium and the Netherlands investments into the public capital stock have led to negative growth effects. Thus, we detect a quite heterogeneous picture of the effects of public sector investments. Especially when the already existing levels of the public stock of capital are high (as it is the case in our sample of highly developed OECD countries), further public sector investments might turn out to be (almost) unproductive. Thus, the effect of these investments will strongly depend on the exact type of investment. Whenever resources are directed into unproductive public investments crowding out effects might lead to even negative growth effects.

References

AKAIKE, H. (1974): A New Look at the Statistical Model Identification, IEEE Transactions on Automatic Control 19 (6), 716–723.

ASCHAUER, D. A. (1989): Does Public Capital Crowd Out Private Capital, Journal of Monetary Economics 24 (2), 171–188.

BATINA, R. G. (1999): On the Long Run Effect of Public Capital on Aggregate Output: Estimation and Sensitivity Analysis, Empirical Economics 24, 711–717.

BATINA, R. G. (1998): On the Long Run Effects of Public Capital and Disaggregated Public Capital on Aggregate Output, International Tax and Public Finance 5 (3), 263–281.

BELLOC, M. and P. VERTOVA (2006): Public Investment and Economic Performance in Highly Indebted Poor Countries: An Empirical Assessment, International Review of Applied Economics 20 (2), 151–170.

BENKWITZ, A., H. LÜTKEPOHL and M. H. NEUMANN (2000): Problems Related to Confidence Intervals for Impulse Responses of Autoregressive Processes, Econometric Reviews 19 (1), 69–103.

BENKWITZ, A., H. LÜTKEPOHL and J. WOLTERS (1999): Comparison of Bootstrap Confidence Intervals for Impulse Responses of German Monetary Systems. Discussion Papers, Interdisciplinary Research Project 373: Quantification and Simulation of Economic Processes 1999 (29).

BERLEMANN, M. and J.-E. WESSELHÖFT (2012): Estimating Aggregate Capital Stocks Using the Perpetual Inventory Method: New Empirical Evidence for 103 Countries. Working Paper.

CANALETA, C. G., P. P. ARZOZ and M. R. GARATE (1998): Public Capital, Regional Productivity and Spatial Spillovers. Working Paper, Department of Economics Public University of Navarra.

CHEUNG, Y.-W. and K. S. LAI (1993): Finite-Sample Sizes of Johansen's Likelihood Ratio Tests for Cointegration, Oxford Bulletin of Economics and Statistics 55 (3), 13–328.

COHEN, J. P. and C. J. MORRISON PAUL (2004): Public Infrastructure Investment, Interstate Spatial Spillovers, and Manufacturing Costs, The Review of Economics and Statistics 86 (2), 551–560.

COMMISSION FOR AFRICA (Blair Commission) (2005): Our Common Interest. Report of the Commission for Africa.

COMMISSION ON GROWTH AND DEVELOPMENT (2008): The Growth Report: Strategies for Sustained Growth and Inclusive Development. World Bank, Washington.

CULLISON, W. E. (1993): Public Investment and Economic Growth, Federal Reserve Bank of Richmond Economic Quarterly 79 (4), 19–34.

DEMETRIADES, P. O. and T. P. MAMUNEAS (2000): Intertemporal Output and Employment Effects of Public Infrastructure Capital: Evidence from 12 OECD Economies, The Economic Journal 110, 687–712.

DEVARAJAN, S., V. SWAROOP and H.-F. ZOU (1996): The Composition of Public Expenditure and Economic Growth, Journal of Monetary Economics 37, 313–344.

DOORNIK, J. A. (1996): Testing Vector Error Autocorrelation and Heteroscedasticity. Nuffield College, Oxford, Online Access (18.07.2012 on http://www.doornik.com/research/vectest.pdf).

GHATAK, S., C. MILNER and U. UTKULU (1997): Exports, Export Composition and Growth: Cointegration and Causality Evidence for Malaysia, Applied Economics 29 (2), 213–223.

HANNAN, E. J. and B. G. QUINN (1979): The Determination of the Order of an Autoregression, Journal of the Royal Statistical Society, Series B 41, 190–195.

HERZER, D. and F. NOWAK-LEHMANN D. (2006): What does Export Diversification Do for Growth? An Econometric Analysis, Applied Economics 38 (15), 1825–1838.

HERZER, D. and B. SILIVERSTOVS (2006): Export-led Growth Hypothesis: Evidence for Chile, Applied Economics Letters 13 (5), 319–324.

JOHANSEN, S. (2002): A Small Sample Correction for the Test of Cointegrating Rank in the Vector Autoregressive Model, Econometrica 70 (5), 1929–1961.

JOHANSEN, S. (1991): Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models, Econometrica 59 (6), 1551–1580.

JOHANSEN, S. (1988): Statistical Analysis of Cointegration Vectors, Journal of Economic Dynamics and Control 12 (2–3), 231–254.

KAMPS, C. (2005a): New Estimates of Government Net Capital Stocks for 22 OECD Countries, 1960–2001. IMF Staff Papers 04/67.

KAMPS, C. (2005b): The Dynamic Effects of Public Capital: VAR Evidence for 22 OECD Countries, International Tax and Public Finance 12 (4), 533–558.

KRÄTZIG, M. (2004): The Software JMulTi. In: H. LÜTKEPOHL and M. KRÄTZIG (Eds), Applied Time Series Econometrics, Cambridge University Press, Cambridge, 289–299.

LIGTHART, J. E. (2002): Public Capital and Output Growth in Portugal: An Empirical Analysis, European Review of Economics and Finance 1 (2), 3–30.

LÜTKEPOHL, H. (1991): Introduction to Multiple Time Series Analysis. Springer, Berlin.

LÜTKEPOHL, H., P. SAIKKONEN and C. TRENKLER (2001): Maximum Eigenvalue Versus Trace Tests for the Cointegrating Rank of a VAR Process, Econometrics Journal 4, 287–310.

MAMATZAKIS, E. C. (1999): Testing for Long Run Relationship Between Infrastructure and Private Capital Productivity: A Time Series Analysis for the Greek Industry, Applied Economic Letters 6 (4), 243–246.

MITTNIK, S. and T. NEUMANN (2001): Dynamic Effects of Public Investment: Vector Autoregressive Evidence from Six Industrialized Countries, Empirical Economics 26 (2), 429–446.

MUNNELL, A. H. (1990): How Does Public Infrastructure Affect Regional Economic Performance?, New England Economic Review, 11–33.

OTTO, G. and G. VOSS (1996): Public Capital and Private Production in Australia, Southern Economic Journal 62 (3), 723–738.

PEREIRA, A. M. (2000): Is All Public Capital Created Equal?, The Review of Economics and Statistics 82 (3), 513–518.

PEREIRA, A. M. and M. D. PINHO (2006): Public Investment, Economic Performance and Budgetary Consolidation: VAR Evidence for the 12 Euro countries. College of William and Mary, Department of Economics, Working Paper 40.

PEREIRA, A. M. and O. ROCA-SAGALES (2001): Infrastructures and Private Sector Performance in Spain, Journal of Policy Modeling 23 (4), 371–384.

PEREIRA, A. M. and O. ROCA-SAGALES (1999): Public Capital Formation and Regional Development in Spain, Review of Development Economics 3 (3), 281–294.

PEREIRA, A. M. and O. ROCA-SAGALES (2002): Spillover Effects of Public Capital Formation: Evidence from the Spanish Regions, Journal of Urban Economics 53 (2), 238–256.

PESARAN, H. H. and Y. SHIN (1998): Generalized Impulse Response Analysis in Linear Multivariate Models, Economics Letters 58 (1), 17–29.

PHILLIPS, P. C. (1998): Impulse Response and Forecast Error Variance Asymptotics in Nonstationary VARs, Journal of Econometrics 83, 21–56.

ROMP, W. and J. DE HAAN (2007): Public Capital and Economic Growth: A Critical Survey, Perspektiven der Wirtschaftspolitik 8 (Special Issue), 6–52.

SCHWARZ, G. (1978): Estimating the Dimension of a Model, Annals of Statistics 6 (2), 461–464.

SIMS, C. A. (1987): Comment on "D.E. Runkle, Vector Autoregressions and Reality", Journal of Business and Economic Statistics 5 (4), 443–449.

SIMS, C. A. (1980): Macroeconomics and Reality, Econometrica 48 (1), 1–48.

SIMS, C. A. and T. ZHA (1999): Error Bands for Impulse Responses, Econometrica 67 (5), 1113–1155.

STURM, J.-E., G. H. KUPER and J. DE HAAN (1998): Modelling Government Investment and Economic Growth on a Macro Level: A Review. In: S. BRAKMAN, H. VAN EES and S. K. KUIPERS (Eds), Market Behaviour and Macroeconomic Modelling, Macmillan Press, London.

UNITED NATIONS MILLENNIUM PROJECT (2005): Investing in Development: A Practical Plan to Achieve the Millennium Development Goals: Main Report. United Nations, New York.

WHITE, H. (1980): A Heteroscedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroscedasticity, Econometrica 48 (4), 817–838.

WORLD BANK (2005): Meeting the Challenge of Africa's Development: A World Bank Group Action Plan, African Region. World Bank, Washington DC.

8. Appendix

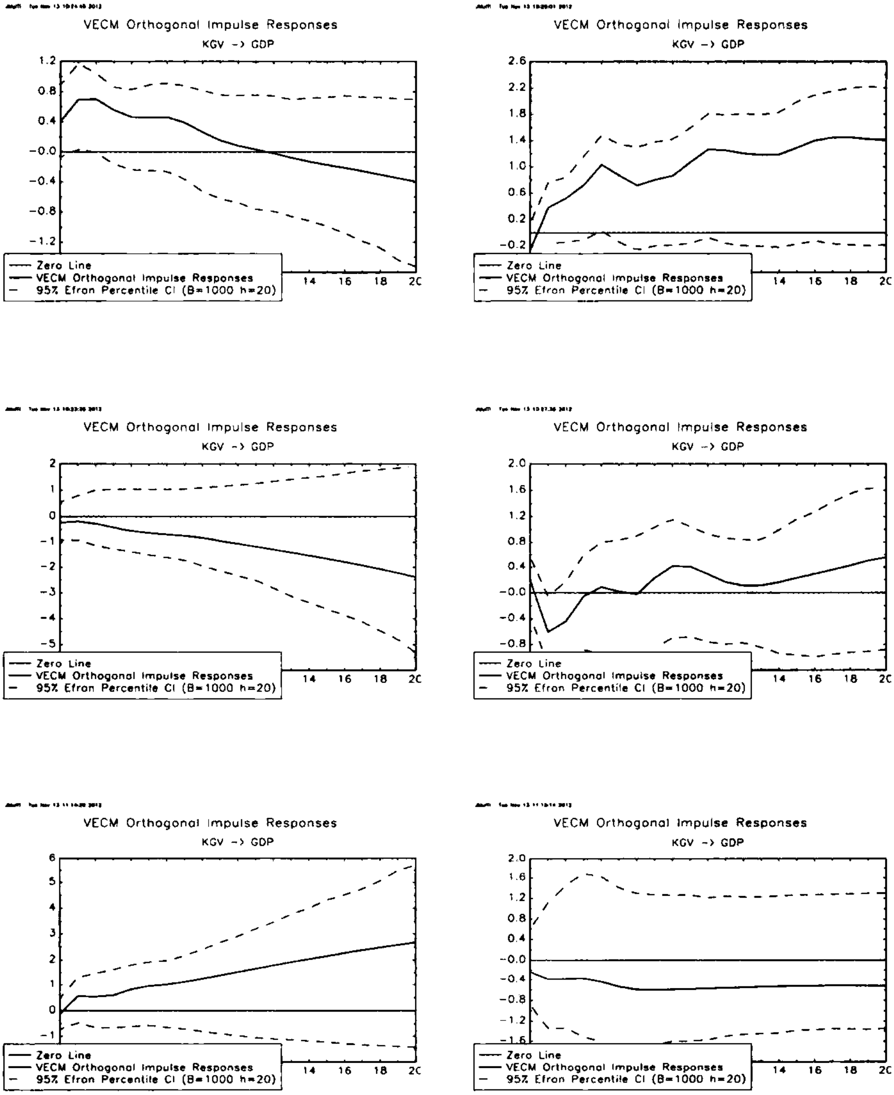

Fig. A-1: Australia, Austria, Belgium, Canada, Denmark and Finland (from left to right)

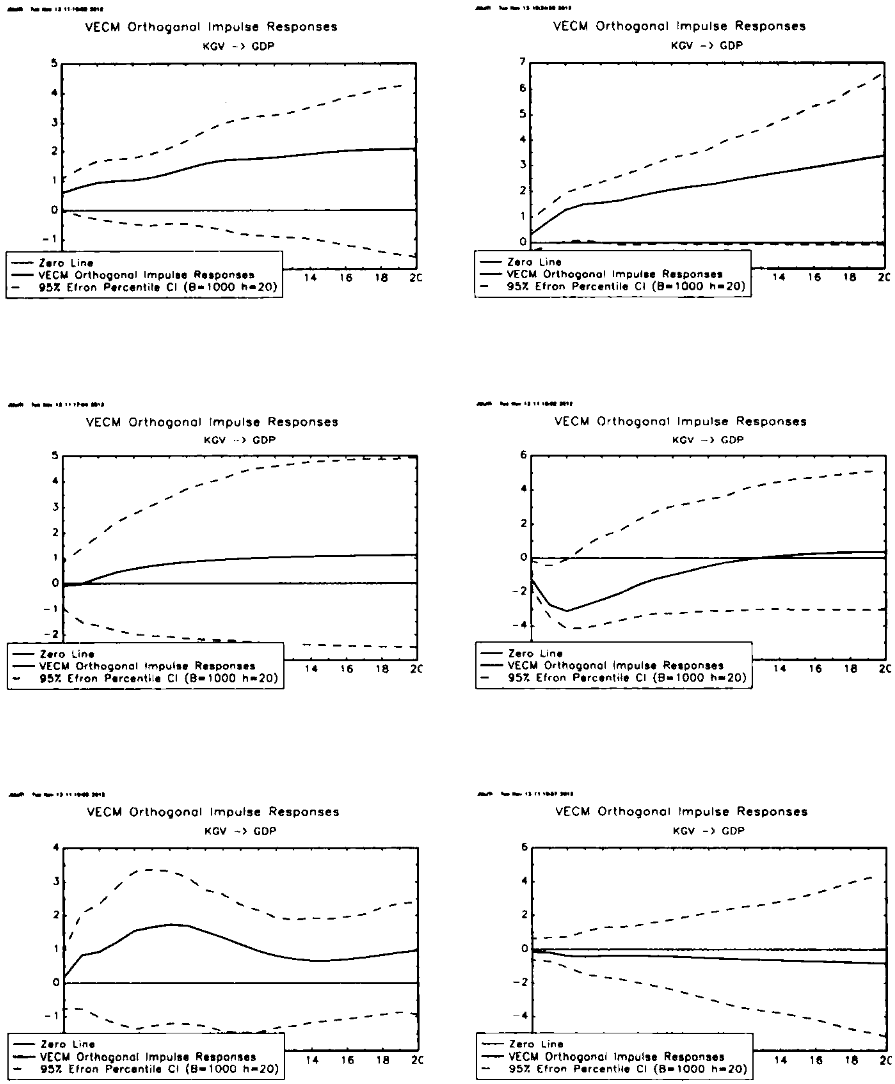

Fig. A-2: France, Germany, Greece, Iceland, Ireland and Italy (from left to right)

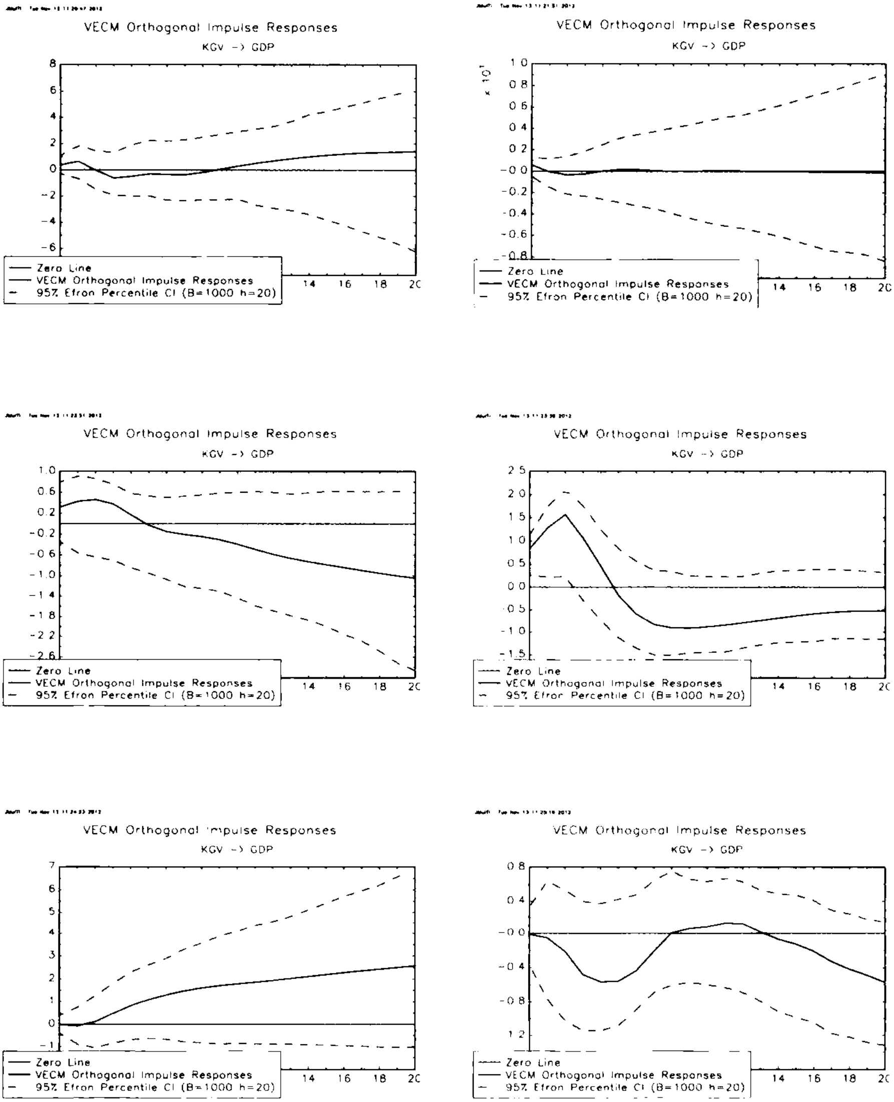

Fig. A-3: Japan, Korea, Netherlands, New Zealand, Norway and Spain (from left to right)

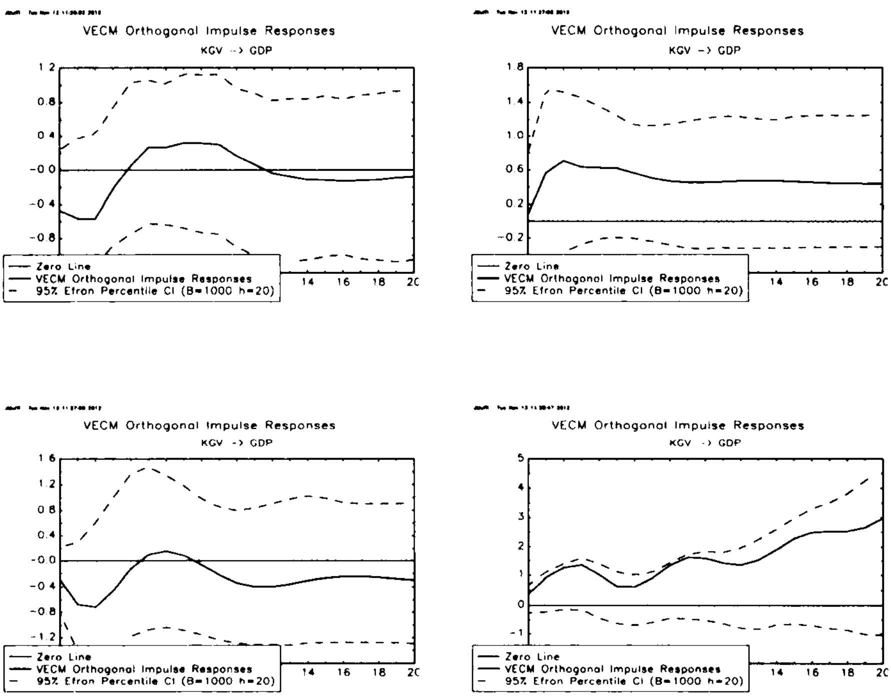

Fig. A-4: Sweden, Switzerland, United Kingdom and United States
(from left to right)

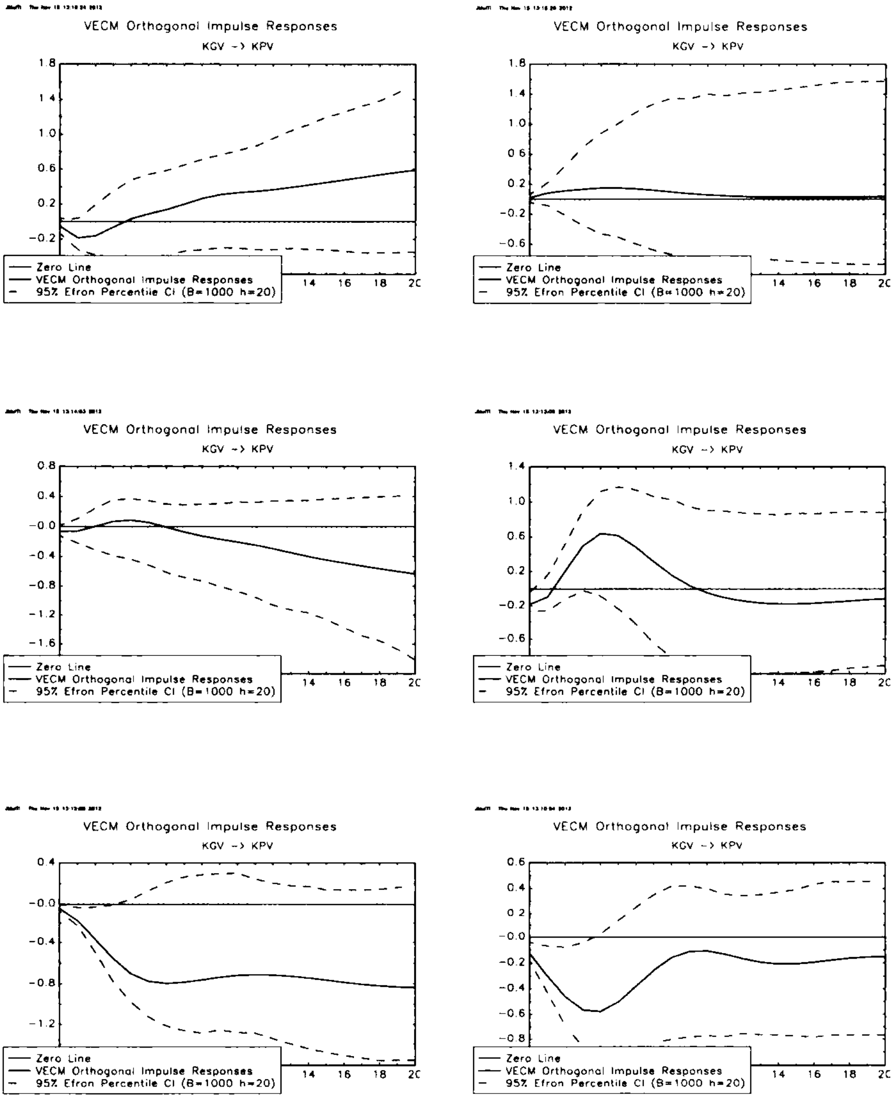

Fig. A-5: Australia, Finland, Netherlands, New Zealand, Sweden and United Kingdom (from left to right)

Table A-1: Specification of the VAR

Country	Lags[a]	Auto-correlation[b] (*p*-value)	Hetero-scedasticity[c] (*p*-value)	Normality[d] (*p*-value)
Australia	2	0.4212	0.2358	0.3502
Austria	3	0.9681	0.5389	0.0636
Belgium	2	0.584	0.0963	0.0734
Canada	3	0.1416	0.3408	0.4451
Denmark	2	0.8358	0.235	0
Finland	2	0.555	0.0051	0.2704
France	2	0.1138	0.0923	0.4766
Germany	2	0.6921	0.38	0
Greece	1	0.2945	0.0746	0.5527
Iceland	2	0.7494	0.1137	0.6972
Ireland	2	0.2515	0.0912	0.2383
Italy	2	0.5486	0.1113	0.0001
Japan	2	0.0645	0.0634	0.1009
Korea	2	0.0859	0.3914	0
Netherlands	2	0.6917	0.0127	0
New Zealand	2	0.5916	0.1941	0.0002
Norway	2	0.6805	0.0807	0.3131
Spain	3	0.0874	0.1017	0.2469
Sweden	3	0.7203	0.3895	0.5917
Switzerland	2	0.2914	0.17	0.1555
United Kingdom	1	0.4103	0.0006	0.0341
United States	3	0.0416	0.1583	0.0227

a: Determined by the Schwarz criterion (For details, see Chapter 5).

b: Null hypothesis: No autocorrelation.

c: Null hypothesis: Constant variance (Homoscedasticity).

d: Null Hypothesis: Residuals are normally distributed.

Table A-2: Long-run elasticities of real GDP with respect to KGV

Country	Long-run elasticity of real GDP with respect to KGV
Australia	−0.1419
Austria	0.451
Belgium	0.4899
Canada	0.7191
Denmark	0.1121
Finland	−0.4864
France	0.8308
Germany	0.9306
Greece	0.6236
Iceland	0.1503
Ireland	0.5103
Italy	4.9178
Japan	0.7541
Korea	−0.0537
Netherlands	−1.0581
New Zealand	−0.2165
Norway	0.9702
Spain	2.9514
Sweden	−0.0532
Switzerland	0.2787
United Kingdom	−0.0771
United States	0.1627