**Session 2**

# PUBLIC INVESTMENT

# PUBLIC CAPITAL IN THE 21ST CENTURY: AS PRODUCTIVE AS EVER?

*Jasper De Jong,[*] Marien Ferdinandusse[**] and Josip Funda[***]*

*The global financial crisis and the euro area sovereign debt crisis that followed induced a rapid deterioration in the fiscal positions of many European countries. In the ensuing fiscal adjustment process, public investments were severely reduced. How harmful is this for growth perspectives? Our main objective is to find out whether the importance of public capital for long run output growth has changed in recent years. We also aim to provide insights on differences between countries and on international spill-overs. To this end, we expand time series on public capital stocks for 20 OECD countries as constructed by Kamps (2006) and estimate country-specific recursive VARs. Results show that the effect of public capital stocks on economic growth has not increased in general, leaving little ground to conclude the current low level of public investments forms an immediate threat to potential output.*

## 1 Introduction

The global financial crisis and the euro area sovereign debt crisis that followed induced a rapid deterioration in the fiscal positions of many advanced economies. Governments reacted to this by increasing tax revenues and implementing expenditure cuts. In the process of expenditure adjustment, public investment had a large share, in particular in countries under market pressure. General government gross fixed capital formation as percent of GDP in the EU28 was in 2013 almost 25 per cent below its peak level in 2009, with the decline in for example Spain amounting to more than 60 per cent.

The cuts in public investments in the aftermath of the crisis may be caused by economic or political factors. In an environment of low growth, the number of viable projects could well be low. Moreover, financial market pressure or European fiscal rules urged countries to deliver budget balance improvements in the short run. In doing so, planned investment projects may be more easily terminated or postponed than most types of current spending.

Cuts in public investments might come at a significant cost. Public investments, or public capital, have been shown to contribute to economic growth both in the short and the long run (see, e.g., IMF, 2014; Pereira and Andraz, 2013; Romp and de Haan, 2007), although the effect varies greatly across regions, industries and types of investment (Bom and Ligthart, 2014b). Furthermore, due to international spillovers, investment cuts may harm the growth prospects in neighbouring countries.

Despite the presumable positive effect of public capital on economic potential, the growth of public capital stocks in many countries already started slowing down during the eighties. As a percentage of GDP, public capital stocks are generally either flat or falling. This means governments spend too little on investments to sustain the existing capital stock. The question now is: is this something to worry about, do governments miss out on the opportunity to benefit from

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* De Nederlandsche Bank.

** European Central Bank.

*** Hrvatska Narodna Banka.

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high marginal returns to investments? And has the recent strong decline in public investments aggravated the situation? This need not be the case. Jong-a Pin and de Haan (2008) show that the effect of a public capital shock on output has decreased over time, suggesting that marginal benefits of public capital have not increased. However, their sample ends in 2001 and hence sheds no light on developments in the beginning of the 21st century.

We contribute to the literature in a number of ways. First of all, we expand existing series on public capital stocks for 20 OECD economies, as constructed by Kamps (2004), applying a common methodology. This provides us with data for the years 1960-2013. Secondly, we estimate recursive VAR-models – starting from the period 1960-1995, then expanding the sample period by one year at the time – to obtain some idea of the potentially changing relationship between public capital and other model variables, most notable economic growth. Lastly, by comparing the impulse responses from a VAR for the euro area as a whole to the weighted impulse responses of VARs for individual euro area countries, we scrutinize the importance of spillovers between European countries.

Our results show that the effect of public capital on GDP growth differs widely between countries. The effect of public capital shocks on economic growth has not increased in general, leaving little ground to conclude the current low level of public investments forms an immediate threat to potential output. Of course, if low investment levels are sustained for a long time, this could change. Furthermore, we provide some tentative evidence of the existence of positive spillovers of public capital between European countries.

In this paper, when we use the term "public investment", this refers to general government gross fixed capital formation. However relevant, this does not include investment spending by public, but non-government organisations; expenditures on regular maintainance; or current expenditures which might actually have some characteristics of an investment, e.g., current spending on education.

## 2 Related literature

Transport infrastructure, communication services, electricity and water are used in the production process of almost every sector (Romp and de Haan, 2007). In many countries, the capital stock providing these services is largely in public hands. Public capital thus represents the wheels – if not the engine – of economic activity, in the words of the World Bank (1994).

But how exactly does public capital impact on output growth? In the short run, an increase in public investments creates positive demand effects. At the same time, public capital arguably enhances the economy's supply side. But additional public expenditures have to be financed, with potential detrimental consequences for output. This section gives a brief overview of empirical research on the relationship between public capital and output.

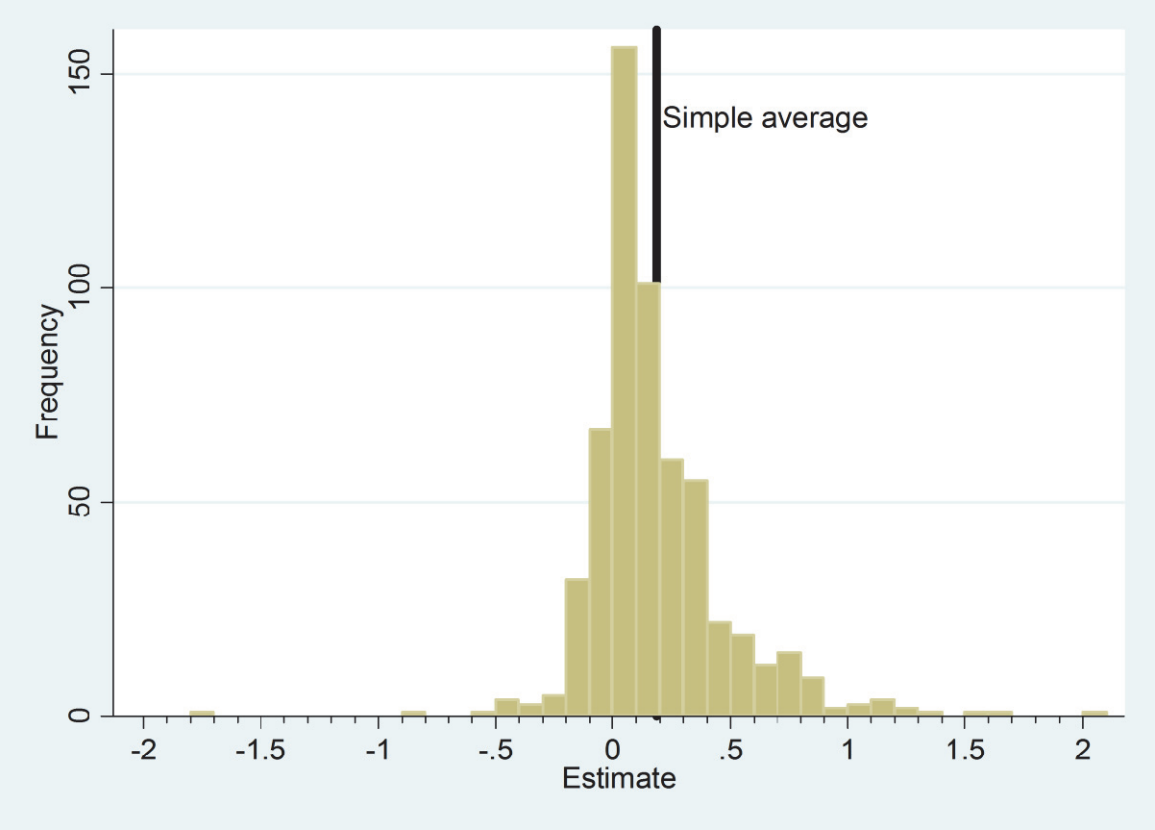
### *2.1 Partial equilibrium effects*

There is a substantial, largely empirical literature aiming to quantify the economic importance of public capital (see Pereira and Andraz (2013), EC (2014) and Romp and de Haan (2007) for extensive reviews of the empirical literature on public capital and growth).

One major branch focuses on partial effects of public capital, in particular on the contribution of public capital or investments to private sector output production. The empirical literature in this branch set off with the work of Aschauer (1989). Estimating a production function including public capital for the US, the author found strong positive effects of the public capital

**Figure 1**

**Estimated Output Elasticities of Public Capital**




Data are from Bom and Ligthart (2014b). Histogram shows published estimates of output elasticities; no correction for publication bias.

stock, and of core infrastructure in particular. The so-called production function approach, describing the technical relationship between production factors and output, was applied by many empiricists since (e.g., Kamps, 2006; Cadot *et al.*, 2006; Creel and Poilon, 2008).

Bom and Ligthart (2014b) summarize the empirical literature on production function estimates by carrying out a meta-analysis. Overall, it is difficult to draw strong conclusions on the economic importance of public capital. This is illustrated by Figure 1.[1] Figure 1 shows published estimates of public capital output elasticities, taken from 68 papers published between 1983 and 2008 (data are from Bom and Ligthart (2014b).[2] Values run from a negative –1.7 for New Zealand (Kamps, 2006) to 2.04 for Australia (Otto and Voss, 1994), with the average output elasticity of public capital after correcting for publication bias at 0.106. Estimates vary considerably over time, location, level of aggregation, measure of public capital or estimation method.

Nevertheless, some lessons can be learned. The general picture emerging is that public capital supports the potential output level. Core infrastructure (roads, railways, telecommunications, etc.) seems to be relatively more important compared to other investments in physical capital (see also Figure 2, lhs).

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[1] We greatly thank Pedro Bom (University of Vienna) for sharing the data.

[2] Caution is warranted in interpreting the data in Figures 1-3, since data are not adjusted for publication bias.

### 2.2 General equilibrium effects

The production and cost function approaches provide useful information on the macroeconomic production process and firm behaviour, but only highlight the benefits of public investment or public capital. More is always better, as more public capital will increase output and lower costs, ceteris paribus. However, a government facing the decision whether to invest more or not has to trade off these extra investments against lower consumptive expenditures, higher taxes or an increase in the debt level.

The second major branch of the literature therefore aims to provide a broader picture by taking into account feedback effects from higher public capital or investments on the rest of the economy. For example, if an increase in public investments is financed by raising tax rates, beneficial effects of extra public investments will be mitigated. Two common methods for incorporating feedback effects are estimation of VAR-models and the use of calibrated general equilibrium models.

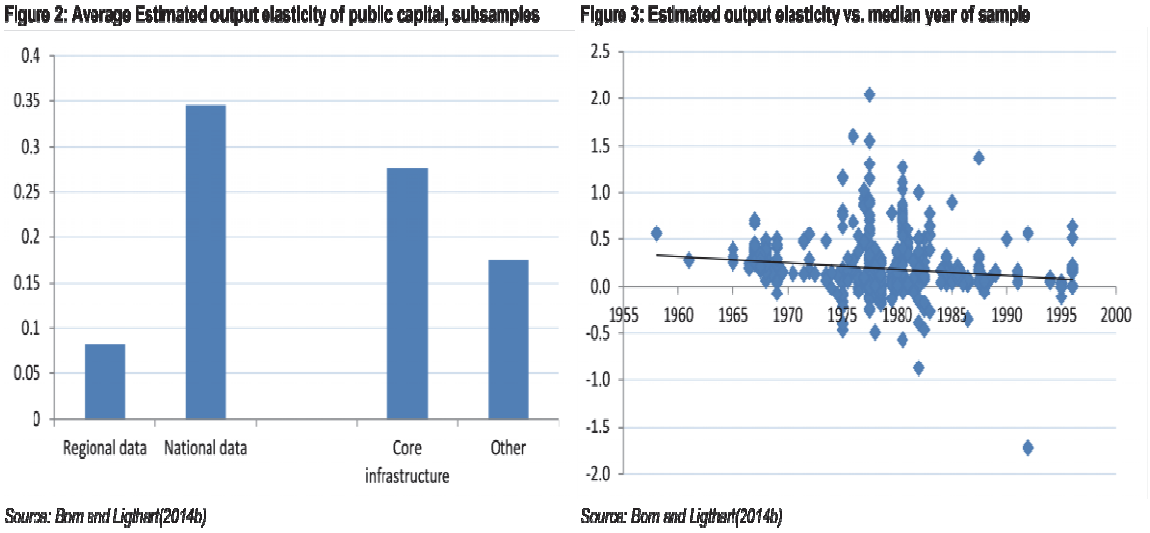
Calibrated or estimated macro-models provide the economist with a clear economic story, but at the cost of imposing restrictions on the data. A common way for incorporating public capital into a model is as a third production factor in a Cobb-Douglas production function, with constant or increasing returns to scale on private production factors (Leeper *et al.*, 2010; Bom and Ligthart, 2014a; Baxter and King, 1993). Elekdag and Muir (2014) generalise the model of Leeper *et al.* (2010), employing a multi-region DSGE model and allowing for liquidity-constrained households and accommodative monetary policy. They confirm findings by Leeper *et al.* (2010) that implementation delays in investment result in muted positive or potentially even negative responses in output and labour in the short run, but show that accommodative monetary policy can overturn the short run contractionary effects from an increase in public investments.

VAR-models, while lacking an explicit economic story, provide direct (reduced form) estimates of the dynamic relations between public capital and output growth. Moreover, they address some econometric objections to the structural approaches. A point of criticism towards the production function and cost function approaches outlined in the previous paragraph is that they impose causal relationships between the variables. However, causality might well run in multiple directions. For example, next to finding that infrastructure positively affects income growth, it could be envisaged that with income the demand for adequate infrastructure rises. VAR models do not impose causal relationships between variables a priori, and allow for testing for the existence of causal relationships in either direction. VAR models have other advantages as well. They allow for indirect links between the variables in the model. In the VAR approach, the long-run output effect of a change in public capital results from the interaction of all the variables in the model. Thirdly, VARs offer more flexibility concerning the number of long-run relationships in the model; they do not assume there is at most one such relationship (Kamps, 2004). On the downside, a clear economic framework providing guidance in interpreting the outcomes is lacking (at least in an unrestricted VAR). Furthermore, data limitations often imply the number of regressors should be kept relatively small.

Kamps (2004) estimates VARs or VECMs for 22 OECD countries. An essential ingredient to this research is the database on public capital stocks as constructed by Kamps (2006). Next to the net public capital stock, Kamps (2004) includes the net private capital stock, the number of employed persons and real GDP (in that order). Overall, an increase in public capital seems to contribute to economic growth, but less so than often found in production function estimates. This hints at the importance of taking into account feedback effects from output to public capital. Furthermore, public and private capital are found to be long-run complements in the majority of countries.

**Figure 2**

**Output Elasticities: Sub-samples and Variation Over Time**




Results found in the empirical VAR-literature remain mixed though. Jong-a Pin and de Haan (2008) extend the analysis by Kamps (2004), only partially confirming his findings. Using hours worked as a measure for labour input they find a positive effect of public capital on output in some, but by no means all countries. Sometimes the effect is even negative. Broyer and Gareis (2013) on the other hand, using data for 1995-2011, find very strong positive effects for infrastructure expenditures in the four largest euro area countries. IMF (2014), directly estimating the relationship between public investments and output growth in a panel setting, also find strong positive effects (studying 17 advanced OECD economies, 1985-2013). Effects are particularly strong during periods of low growth and for debt-financed shocks, but are not significantly different from zero if carried out during periods of high growth or for budget-neutral investment shocks.

### *2.3 Has the impact changed over time?*

An interesting question is whether the impact of public investments is constant over time. In many developed countries the public capital stock (as percentage of GDP) has been on a downward trend for a while. The question is: is this something to worry about, do governments miss out on the opportunity to benefit from high marginal returns to public capital?

This need not necessarily be the case, as Bom and Ligthart (2014b) in their meta-analysis find that estimated output elasticities of public capital are lower when more recent sample periods are used (see also Figure 2, rhs). This could support the idea that with the maturing of infrastructure networks in most developed countries, gains from additional roads, railway connections or power lines should be smaller than in the past. An alternative explanation is that early empirical studies sometimes ignored endogeneity or non-stationarity of the data, biasing estimates upwards, although Bom and Ligthart (2014b) in principle control for such issues. In the second part of their paper, Jong-a Pin and de Haan (2008) estimate a rolling-window panel-VECM. The results indicate that between 1960 and 2001, the long-run impact of a shock in public capital to output declined in a number of countries, which was correlated with a declining public capital stock.

### *2.4 Cross country spill-overs of public investment?*

The effects of public capital are generally found to be lower for regions within countries than for countries as a whole, suggesting the presence of spill-overs. Given the network characteristics of for example road and telecommunications infrastructure, positive spill-overs between regions could emerge. Bom and Ligthart (2014b) in their meta-analysis find that using regional rather than national data generally results in lower estimates of the output elasticities of public capital, hinting at the importance of spill-overs. Amongst many others, studies find evidence for spill-overs between U.S. states of public investments in infrastructure (Cohen and Paul, 2004) or infrastructure maintenance spending (Kalyvitis and Vellai, 2012); of public capital formation between Spanish regions (Pereira and Roca-Sagalés, 2003; Roca-Sagalés and Lorda, 2006) and of public transport infrastructure between Italian regions (Di Giacinto *et al.*, 2013).

However, the evidence from regional studies on the existence of spill-overs is far from uniform and the available evidence should be interpreted with caution. Some authors have pointed to the possibility of aggregation bias that results in high estimates when using aggregate data or did not find evidence for spill-overs (see Creel and Poilon (2008) for an overview). De la Fuente (2010) in a survey finds that public capital variables are almost always significant in panel data specifications for the Spanish regions, and often insignificant in similar exercises conducted with US data, which could possibly be related to the difference in maturity of infrastructure networks in both countries.

## 3 Data

Data on public and private investments, as well as real GDP series, are obtained from OECD. Total hours worked per annum are taken from the Total Economy Database.[3] We have data for 1960 and later years.

### *3.1 Construction of the data*

We use the perpetual inventory method to construct government and private capital stocks. Here we provide a brief overview of the methodology. For a full description, see Kamps (2004) and references therein.

Assuming geometric depreciation, the net public capital stock evolves as follows:

$$K_{i,t+1} = (1 - \delta_t)K_{i,t} + I_t \tag{1}$$

where $K$ measures the capital stock at the beginning of the period, $\delta_t$ is the time-varying rate of depreciation and $I$ denotes gross public investments.

From this, the public capital stock can be calculated as:

$$K_{t+1} = (1 - \delta_t)^t K_1 + \sum_{i=0}^{t-1} (1 - \delta_t)^i I_{t-i} \tag{2}$$

with $K_1$ denoting the initial capital stock. Data on investments are readily available, but one still has to determine the initial capital stock, as well as the depreciation rate to apply.

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[3] The Conference Board Total Economy Database™, January 2014, http://www.conference-board.org/data/economydatabase/

There is no official information on the magnitude of the initial capital stock for any country except the United States. Therefore, following Kamps (2004) (who in turn borrows the method from Jacob *et al.* (1997)) an artificial investment series for the period 1860-1959 is constructed. For each country, we assume that investment grew by 3.2 percent a year (the 1960-2013 average) during this period, finally reaching its observed level in 1960.

The depreciation rates used are time-varying. In fact, they increase over time. This reflects findings from a detailed analysis by the U.S. Bureau of Economic Analysis (BEA, 2001). The increase could follow from both a shift in composition of the capital stock towards assets with a higher depreciation rate, as well as a decrease in asset lives. Expanding the formula used in Kamps (2004), depreciation rates develop as follows:

$$\delta_t = \delta_{min}\left(\left(\frac{\delta_{max}}{\delta_{min}}\right)^{1/54}\right)^{t-2014+54} \tag{3}$$

with $\delta_{min}$ fixed at 2.5 per cent and $\delta_{max}$ equal to 4.8 per cent. The underlying assumption of increasing depreciation rates of the total public capital stock is mirrored in national estimates of the public capital stock.

Regarding private capital stock, we assume constant depreciation of rate 1.5 per cent for residential capital and time-varying depreciation rate going from 4.25 per cent in 1960 to 11 per cent in 2013 for non-residential capital stock. Differences in the composition of the capital stock are ignored due to lack of data.

Figure 3 presents the estimates of public capital stock for a sample of countries included in the analysis. The government capital stock data are constructed by applying a perpetual inventory method, described above.[4]

Two observations stand out. First, despite still considerable cross-country differences, capital stocks seem to have converged in size internationally. In 2013, all countries shown had estimated public capital stocks between 25 and 60 per cent GDP. Japan is a notable exception with the public capital stock of 80 per cent of GDP. There is no apparent relation between the size of the public capital and GDP per capita.

Secondly, in a number of countries public capital stocks have declined (as percent of GDP) over the last two or three decades including the most recent period of global financial crises and its aftermath. Compared to 1980, the largest fall in public capital stock was estimated for Denmark, Ireland, UK and New Zealand, in all cases above 20 per cent. US, Sweden and Netherlands all recorded a drop of more than 10 per cent.

Such developments are reflecting a lower public investment rates than in the past. General government gross fixed capital formation as a percent of GDP has declined substantially over the recent period in some countries (Figure 4). The largest reductions in public investment ratios took place in countries with high initial public investment ratios, such as Japan and Ireland as well as in countries that came under market pressure (e.g., Spain, Greece, Italy).

Furthermore, a fall in public capital stock ratios can to some extent also be the result of privatisations in the eighties and nineties, as well as a matter of valuation. Capital is valued at production costs, with its value subsequently adjusted for depreciation and price increases. Its true economic value however also depends on real income developments, but these are not accounted for. Therefore, assuming positive real GDP growth and constant production costs in percent of

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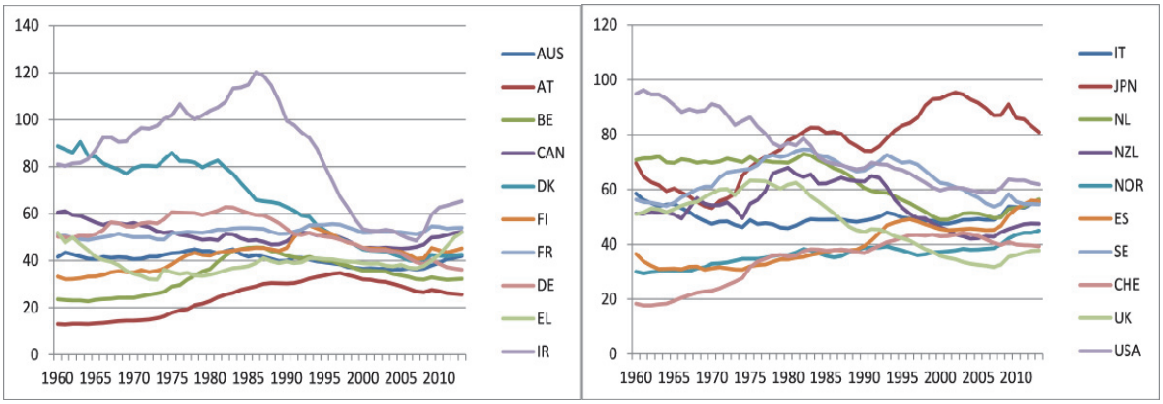
[4] As the ESA2010 data on government investment are available only from 1995 or later, for this purpose ESA95 data with a reference year 2005 were used. In this way we also avoid including the military equipment in the investment which are assumed not to be important for the production process.

**Figure 3**

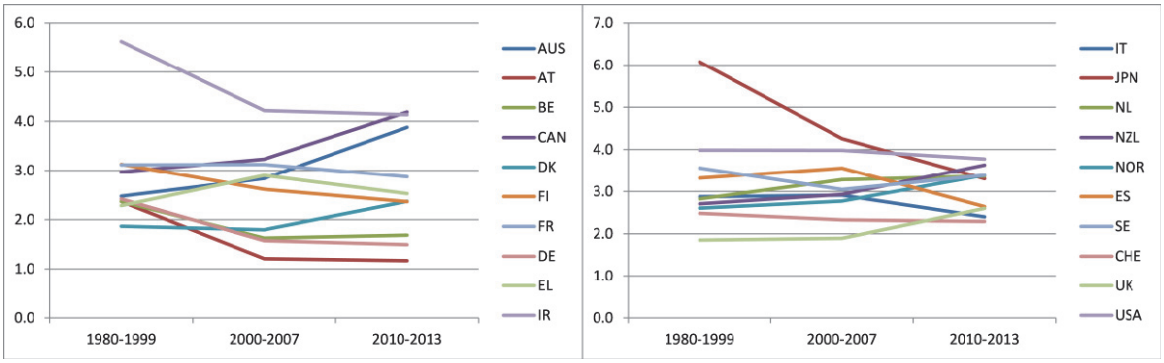
**Public Capital Stock, 1960-2013**
*(percent of GDP, volume data)*




Source: authors' calculations.

**Figure 4**

**General Government Gross Fixed Capital Formation**
*(percent of GDP)*




Source: OECD.

GDP, a road constructed in 1960 will be valued less today than a road constructed in 2000, even if maintenance spending actually prevented depreciation. In any case, it should be clear that these public capital stock measures are necessarily only proxies for the true public capital stock.

For an overview of the resulting public and private capital stocks, see Figures 9-15.

### *3.2 Statistical properties of the series:*

First, we check for the order of integration of individual series. Out of many available testing procedures, we apply two of the most commonly used tests: the ADF-test and the KPSS-test. These tests have different null hypotheses. The ADF-test has a unit root as its null, while the KPSS starts from the premise of stationary series. The relevant test-statistics and outcomes are presented in Table 1.

Series for GDP and total hours worked generally turn out to be integrated of order one and we therefore maintain this as our working assumption. The same can not be said for capital stock data. Formal tests for the order of integration of capital stocks show mixed results. In many cases, the ADF and KPSS-tests point in different directions, with capital stocks supposedly integrated of either order one or of order two. In some cases, both tests point in the direction of $I(2)$. Both results, $I(1)$ and $I(2)$-ness of capital stocks, are actually found in the empirical literature (e.g., Jong-a Pin and de Haan (2008) conclude capital stocks are $I(1)$, Everaert (2003) and Kamps (2004) find evidence for $I(2)$ capital stock series).

However, from equation 1 we know that the capital stock in a year consists of two elements, namely last years' capital stock minus depreciation and the investment series. By construction, the first part has a root very close to, but surely below one. This part of the capital stock series is therefore $I(0)$. The investment series turn out to be $I(1)$ in many/all countries. In theory this means capital stocks must be $I(1)$ as well.

So, how should we interpret the $I(2)$ findings? It is well known that unit root tests (such as ADF) have low power to distinguish between unit root and near unit root processes (Enders, 1995), *i.e.*, a false null hypothesis is relatively unlikely to be rejected. The problem is furthermore aggrevated in case of small samples. As Mahadeva and Robinson (2004) state, practically speaking it is often close to impossible to differentiate difference stationary series from a highly autoregressive one. Clearly, slowly depreciating capital stocks are by nature highly autoregressive.

However, before jumping to conclusions, we investigate another potential cause of our $I(2)$ results. A look at the data in Figure 9 suggests there may be structural breaks in the capital stock series. Perron (1989) showed that failure to account for a structural break leads to a reduction in the ability to reject a false unit root null hypothesis. Therefore, we perform Zivot-Andrews and Philips-Perron testing allowing for a break in the intercept and the deterministic trend where appropriate (results not shown).[5] Still, the evidence remains inconclusive.

Since allowing for structural breaks does not change overall results and since by deduction we concluded that capital stocks must be $I(1)$, we interpret the outcomes of the unit roots tests mainly as evidence for the low power of these tests for near unit root processes. In the empirical sections below, we assume capital stocks are $I(1)$.

## 4 Empirical approach and results

Both the production function and the cost function approach impose quite strong restrictions on the data, by assuming a causal relationships between the variables. However, causality might well run in multiple directions. For example, next to finding that infrastructure positively affects income growth, it could be envisaged that with income the demand for adequate infrastructure rises.

VAR-models form an attractive alternative to structural models. VAR-models do not impose causal relationships between variables a priori, and allow for testing for the existence of causal relationships in whatever direction. VARs furthermore allow for indirect links between the variables in the model. In a VAR-approach, the long-run output effect of a change in public capital results from the interaction of all the variables in the model. Thirdly, VARs offer more flexibility concerning the number of long-run relationships in the model; they do not assume there is at most one such relationship as is the case in the production function approach (Kamps, 2004). For these reasons, we estimate country-specific VAR-models.

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[5] In both cases, we set the trimming parameter to 0.10.

### 4.1 Econometric approach

A k-th order VAR can be written as:

$$X_t = A_1 X_{t-1} + \ldots + A_k X_{t-k} + \theta D_t + E_t \quad (4)$$

$D_t$ captures any deterministic elements. Since our sample size is limited, we aim to estimate parsimonious models and keep the number of deterministic elements as low as possible.

A cointegration model can be written as:

$$\Delta X_t = \Pi X_t + \Phi_1 \Delta X_{t-1} + \ldots + \Phi_k \Delta X_{t-k} + \theta D_t + E_t \quad (5)$$

Since we are mainly interested is on the long run effects of public capital, we estimate an unrestricted VAR in levels as a first step. As Sims *et al.* (1990) show, the OLS estimator for the autoregressive coefficients in such a model is consistent and asymptotically normally distributed, even in the case where some variables are integrated or cointegrated. Therefore, a VAR in levels can be used to investigate the properties of the data and construct a valid empirical model. Our aim is to estimate a model as parsimonious as possible while preserving proper diagnostics, *i.e.* with normally distributed, homoskedastic residuals which are not serially correlated. However, the consistency of estimates for the autoregressive coefficients does not carry over to impulse response functions (IRFs) obtained from unrestricted VARs in levels. IRFs are inconsistent at long horizons if non-stationary variables are included (Phillips, 1998).

As we are primarily interested in the IRFs, a second step is needed beyond estimating VARs in levels. To this end, we continue from the benchmark empirical model provided in the first step and investigate whether series are cointegrated. If there is cointegration, we revert to VECM estimation, further improving our model along the lines sketched above. If series are not cointegrated, we estimate a VAR in first differences. We thus end up with either a VECM, or a VAR in first differences for each country.

### 4.2 VAR models

#### 4.2.1 Selected models

Table 1 provides an overview of the selected empirical models, as well as some diagnostic checks on these models. As at least cointegration relation among variables is confirmed for all countries, we estimate VEC-models. In principle we include a trend in the cointegration relation, as well as a constant in both the cointegration relation and the VAR.

In most models, we included some deterministic elements. We often have to allow for breaks in trends or to correct for observations in specific years (see also Figures 9-15) to account for specific events. These specific events include, for example, moving some entities from the general government to the private sector in Austria from 1998 onwards, the reunification of Germany in 1990 and the economic crisis of 2009 and later years.

The number of lags is chosen with an economic use of degrees of freedom in mind. Usually we choose the model with the lowest number of lags that is not suffering from too strong autocorrelation.

The number of cointegration relations is a priori unknown (Kamps, 2004). Economic theory suggests constancy of the great ratios. Therefore, public capital to output and private capital to output could well form cointegrating relations. Furthermore, if technology behaves as a trend-stationary process, the macro-economic production function describes another cointegrating relation. With potentially up to three cointegrating relations, which is the maximum in our

**Table 1**

**Selected Models**

| Country | Sample period | Model type | # Lags | # Cointegr. Rel. | Johansen model type | Deterministic terms | Test-statistics | | Diagnostics | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Trace | Max. Eigenval | J-Bera | 1st order ac |
| AUS | 1962-2013 | VECM | 1 | 2 | 4 | - | 2 | 2 | 8.53 | 8.54 |
| AT | 1963-2013 | VECM | 2 | 2 | 4 | dummy 75-13, dummy 98-13 | 2 | 3 | 5.00 | 20.78 |
| BE | 1962-2013 | VECM | 1 | 1 | 4 | dummy 66, dummy 1972 | 1 | 1 | 10.24 | 12.33 |
| CAN | 1962-2013 | VECM | 2 | 2 | 3 | dummy 82 | 2 | 2 | 7.44 | 25.47* |
| DK | 1962-2013 | VECM | 1 | 1 | 3 | dummy 90, dummy 81-13, dummy 2009-13 | 1 | 1 | 30.55*** | 8.38 |
| FI | 1964-2013 | VECM | 3 | 1 | 3 | dummy 90-93, dummy 09, dummy 93-13 | 1 | 1 | 6.86 | 13.38 |
| FR | 1962-2013 | VECM | 1 | 2 | 4 | dummy 73, dummy 75, dummy 84-13 | 2 | 1 | 4.18 | 19.80 |
| DE | 1963-2013 | VECM | 2 | 2 | 4 | dummy 90-13, dummy 09-13 | 2 | 2 | 17.67 | 7.59 |
| EL | 1962-2013 | VECM | 1 | 2 | 4 | dummy 74-13, dummy 09-13 | 2 | 2 | 3.69 | 22.79 |
| IR | 1965-2013 | VECM | 1 | 1 | 4 | dummy 94-13, dummy 08-13 | 1 | 1 | 13.58* | 25.93* |
| IT | 1963-2013 | VECM | 2 | 1 | 4 | dummy 68, dummy 69, dummy 09 | 1 | 1 | 4.18 | 20.52 |
| JPN | 1963-2013 | VECM | 2 | 1 | 5 | dummy 91-13, dummy 09 | 1 | 1 | 12.84 | 16.12 |
| NL | 1962-2013 | VECM | 1 | 1 | 4 | dummy 09 | 1 | 0 | 4.43 | 7.61 |
| NZL | 1963-2013 | VECM | 2 | 1 | 4 | - | 2 | 0 | 5.40 | 15.81 |
| NOR | 1962-2013 | VECM | 1 | 2 | 4 | dummy 09-13 | 2 | 0 | 7.23 | 19.99 |
| ES | 1964-2013 | VECM | 3 | 2 | 3 | dummy 09 | 2 | 2 | 4.97 | 22.36 |
| SE | 1962-2013 | VECM | 1 | 2 | 4 | dummy 91-93, dummy 09 | 2 | 3 | 8.27 | 23.33 |
| CHE | 1962-2013 | VECM | 1 | 1 | 4 | dummy 75 | 1 | 0 | 13.00 | 17.50 |
| UK | 1962-2013 | VECM | 2 | 1 | 4 | dummy 73, dummy 09-13 | 1 | 1 | 12.81 | 24.55* |
| USA | 1962-2013 | VECM | 1 | 1 | 3 | - | 1 | 1 | 14.32* | 17.18 |

*Johansen model types refer to: 3 = model with intercept in cointegration relation and in VAR; 4 = intercept and trend in cointegration relation, intercept in VAR. Dummies with a single number are equal to 1 in the year mentioned, 0 otherwise. Dummies with two numbers added are 1 from the first year mentioned onwards, 0 before. Columns 'Trace' and 'Max. Eigenval.' show selected number of cointegration relations from Johansen cointegration tests, either according to the trace statistic or the maximum eigenvalue statistic. The Jarque-Bera statistic tests for normality of residuals, with as null hypothesis that residuals are multivariate normal, 8 degrees of freedom. The serial correlation LM statistic tests for first order autocorrelation, with a null of no autocorrelation. * significant at 10%, ** significant at 5%, *** significant at 1%.*

four-variable framework anyway, we need to resort to formal testing. We apply Johansens cointegration test, Table 1 shows the test results. In about half of the cases, the trace and maximum eigenvalue statistics agree on the number of contegration relations. For countries where both tests return different results, we generally follow the outcomes of the trace test as this test is more robust to nonnormality (Cheung and Lai, 1993).

The residuals of the selected models are well-behaved. Normality of residuals cannot be rejected in nearly all cases with Denmark being a notable exception. Furthermore, there is no strong evidence for first order autocorrelation or heteroskedasticity in the residuals of any model.

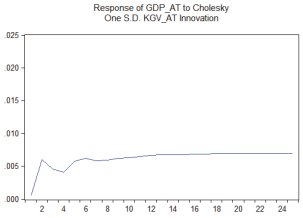
### *4.2.2 Results*

Figures 5 and 6 plot the impulse response functions for GDP to a shock in the net real public capital stock. To orthogonalize shocks, a Cholesky decomposition of the residual covariance matrix is applied. The variables are ordered as follows: net real public capital, net real private capital, total hours worked and real GDP. This particular ordering implies that we assume that public capital contemporaneously influences other variables, but is not contemporaneously influenced by the others. Government investment is largely considered to be unrelated to current changes in the business cycle as there are considerable implementation time lags related to capital projects in the public sector. Similar reasoning holds for private capital, although we assume the private sector is

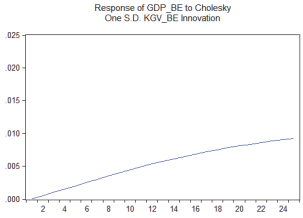
**Figure 5**

**Impulse Responses of GDP to a one s.d. Public Capital Shock, Euro Area**

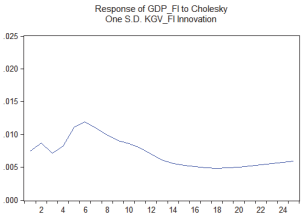
(a) Austria



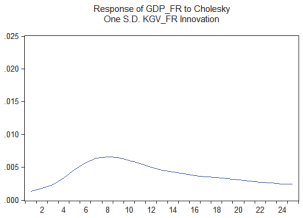

(b) Belgium



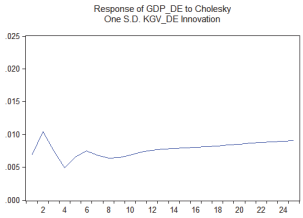

(c) Finland



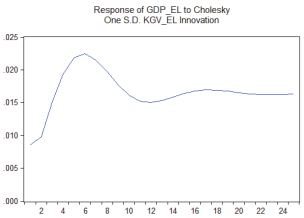

(d) France



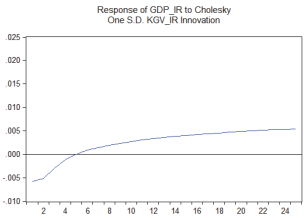

(e) Germany



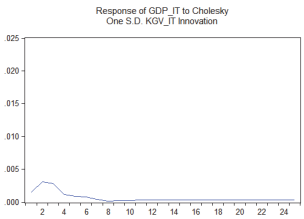

(f) Greece



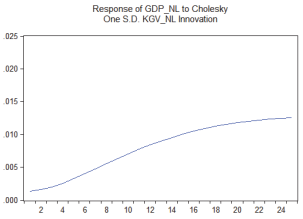

(g) Ireland




(h) Italy




(i) Netherlands




(j) Spain

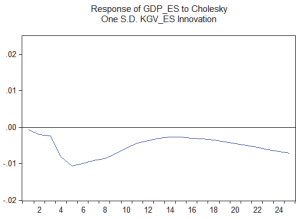
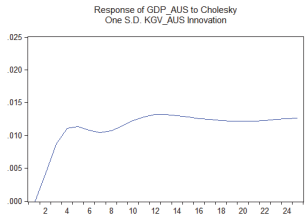


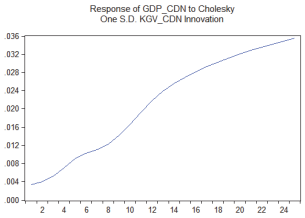
**Figure 6**

**Impulse Responses of GDP to a one s.d. Public Capital Shock, Non-Euro Area**

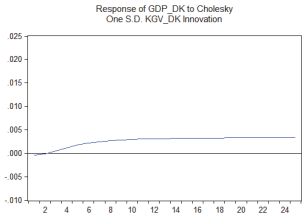
(a) Australia



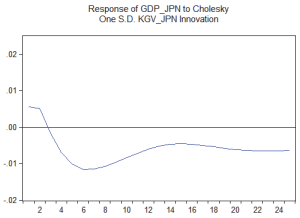

(b) Canada



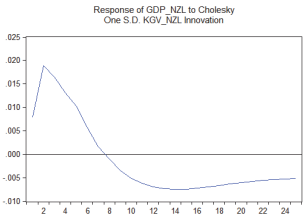

(c) Denmark



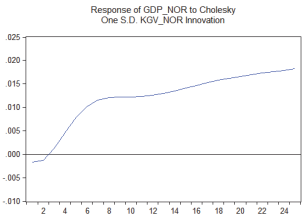

(d) Japan



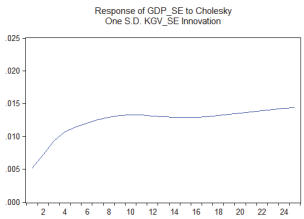

(e) New Zealand



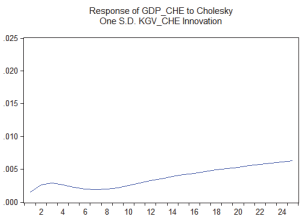

(f) Norway



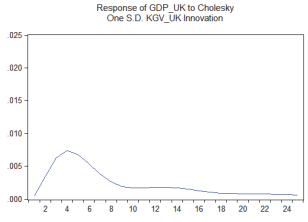

(g) Sweden



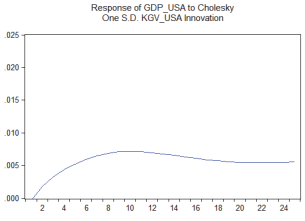

(h) Switzerland




(i) United Kingdom




(j) United States



in general able to react quicker. While labour market developments are found to be highly pro-cyclical they tend to lag output developments. Therefore, employment is ordered third, and real GDP is ordered last in our specification.[6]

Overall, similar to Kamps (2004), public capital seems to be productive for most of the countries included in the sample as the long run impact of a one standard deviation shock in public capital on GDP seems to be positive. A notable exception is Spain where, similar to Jong-a Pin and de Haan (2008), the effect is found to be negative for all periods while for Japan and New Zealand the initial positive impact is followed by negative effects. The results for Japan might be seen as expected since Japan has by far the highest level of public capital among the countries in the sample so after initial positive demand effect this additional capital has an adverse impact on output. In the case of Ireland (second largest capital stock in the sample) and Norway an initial negative effect turns positive after several periods. In general, we do find a small negative correlation between the response of GDP to the shock to public capital and the level of the public capital itself, especially in the long run.

Regarding the response of other endogenous variables included in the analysis (see Figures 13 and 14), private and public capital are found to be complements (positive response of private capital to a shock in public capital) in Austria, Belgium, Greece, Finland, France, Netherlands, Norway, New Zealand and Sweden, already in the short run. In the case of Australia, Canada and Germany complementarity holds only in the long run while in the short to medium run public capital shock has a negative effect on the private capital. As Baxter and King (1993) suggest, there are two forces determining the response of the private capital stock to a shock in public capital. First, a crowding out effect of additional government investment (that results in an increase in public capital stock) leading to a reduction in the resources available for financing private sector projects. Second, a public capital shock could increase the marginal productivity of private capital leading to an increase in private investment. One might expect the first one to dominate in the short run while in the long run the second one should dominate, albeit probably only up to a certain level of public capital stock.

The reaction of total hours worked as a measure of the labour input is in most cases negative in the long run suggesting that additional public capital wouldn't be beneficial for employment. While there are several European countries where this effect is positive even in the long run it is always very close to zero and statistically insignificant. Exceptions are Greece, and Canada and New Zealand (in the short and medium run) where the shock to public capital leads to a rather sizable increase in employment. As Kamps (2004) suggests, the reaction of labour might depend on the way the new public investment are financed (distortionary versus non-distortionary taxes). The small sample size makes it difficult to include additional variables in our models though.

The response of GDP and other variables to a public capital shock endogenously causes public capital to change over time itself. Therefore, the IRF of GDP cannot be interpreted as an estimate of the public capital multiplier. To obtain this multiplier, additional calculations are needed. The period n multiplier of public capital can be calculated as:

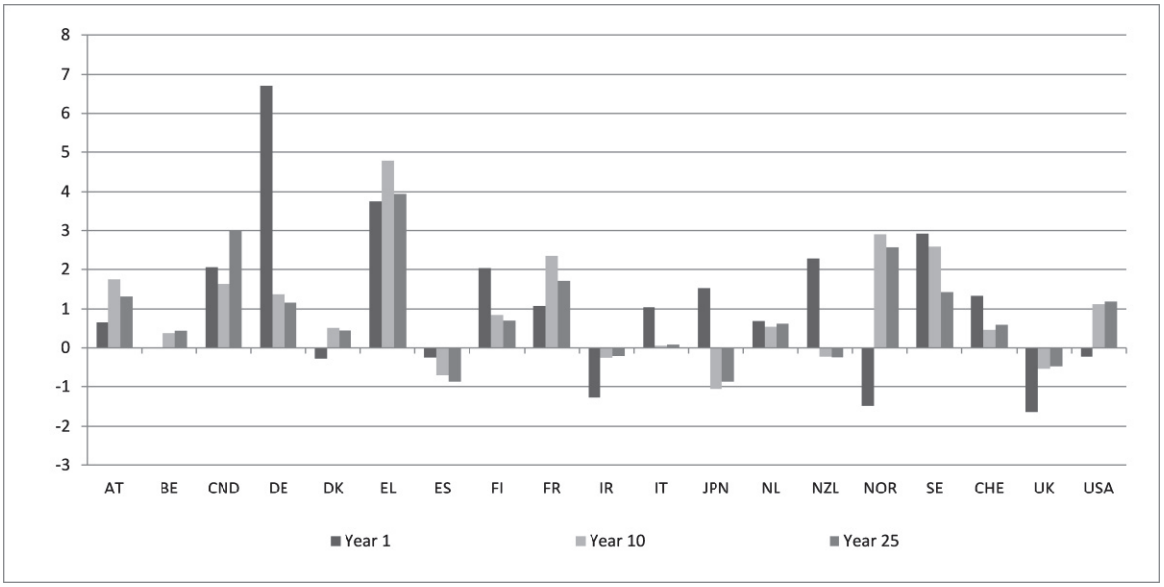
$$M_n^{KGV} = \frac{\Delta GDP}{\Delta KGV} \Big/ \frac{KGV}{GDP} \tag{6}$$

In words, a 1 percent of GDP shock in public capital results in an $M_n^{KGV}$ percent increase in GDP in period $n$.

[6] Of course, these are quite strong assumptions. We therefore performed a robustness check with different ordering of the variables but this does not affect results much. The impulse response functions for different ordering of the variables are available on request.

**Figure 7**

**General Government Capital Multipliers at Different Horizons**




Source: Authors' calculations

Figure 7 shows the estimates of the general government capital multipliers for different time horizons.[7] The highest multiplier is found for Greece where the strong reaction of GDP to a public capital shock is supported by the complementarity of private and public capital as well as a positive reaction of total hours works to this shock. Large long-run multipliers (around 3) are also found for Canada and Norway. Surprisingly, the medium and long run the public capital multiplier is found to be negative for the UK, Ireland, Japan and Spain. For all other countries the multipliers are positive and fall in the long run (after 25 periods) roughly in the range between 0.5 and 2.

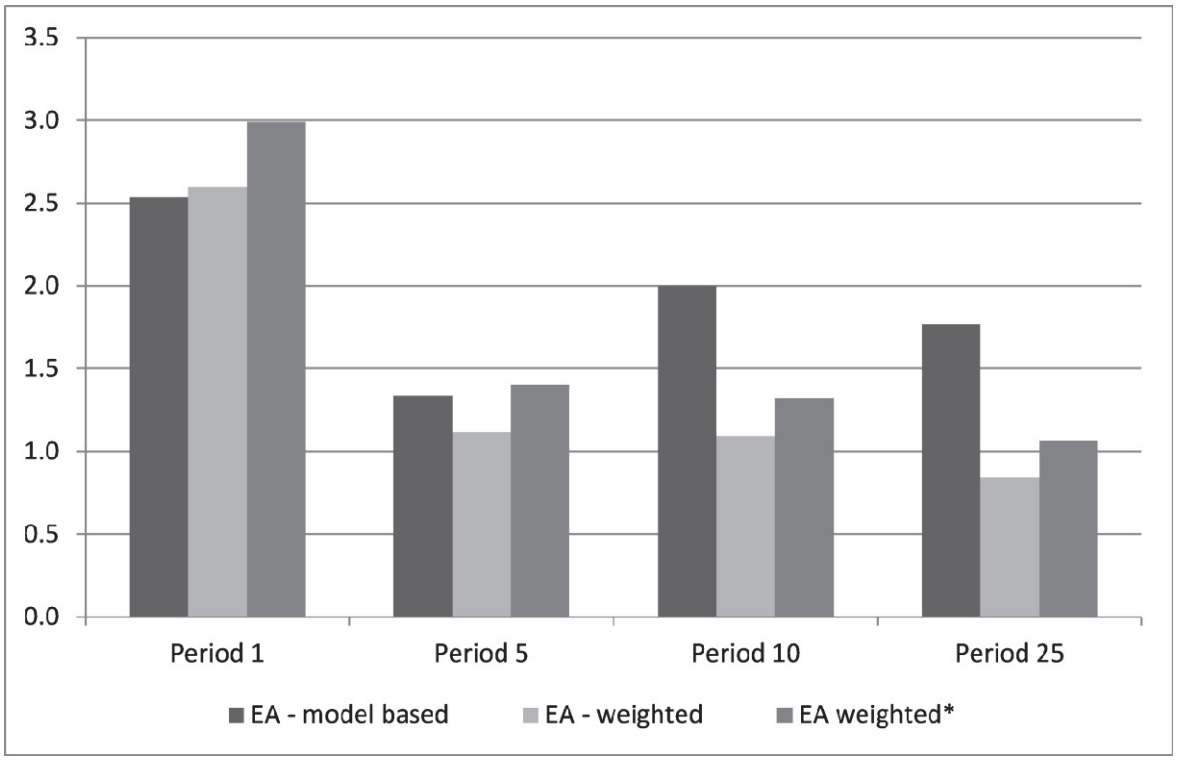
### *4.2.3 Spillovers*

This section investigates further the issue of potential spillover effects across euro area countries included in the sample. Both theoretical and empirical literature has shown that policy actions in one country may have a significant effect on economic outcomes of other countries (Auerbach and Gorodnichenko, 2012). The literature on fiscal spillovers identifies several channels for the transmission of fiscal shocks among countries. For example, the trade channel captures the extent to which increase in public spending (including investment spending) in one country has a positive output effects in other countries either through direct purchase of foreign products by the government (usually found to be small) or/and by stimulating the domestic economy which in turn increases imports from other countries (Giuliodori and Beetsma, 2004). The latter cause is found to be more important, but depends on the size of domestic multipliers and trade linkages among countries. The interest rate channel and the exchange rate channel are also potentially relevant. However, in a monetary union a fiscal stimulus in one country should not, in theory, affect the

[7] The very high impact multiplier for Germany should be interpreted with caution as it reflects a very small reaction of public capital to its on shock and already after two periods it takes the value much closer to those found for other countries.

**Figure 8**

**Fiscal Multipliers at Different Horizons Compared**




Note: Euro area* includes only countries where a positive multiplier was found in the country model Source: Authors' calculation.

short-term interest rate at the union level. Yet, if the country engaging in expansionary fiscal policy is sufficiently large, upward pressure on area-wide inflation might appear, leading to a monetary policy tightening with adverse effects on other countries in the union (Hebous and Zimmermann, 2013). Increases in the short-term interest rate may also result in upward pressure on long-term interest rates, thereby crowding out private investment. Finally, in the context of public investment, the long-term effects on output might be larger than just the country which undertakes the investment, e.g., in the case of cross country infrastructure networks. Accordingly, studies that focus on small(er) geographical areas might not be able to capture the full pay-off of public investment.

We address the issue of spillovers among countries in our sample that share a common currency (euro area)[8] in two ways.

First, we calculate a weighted multiplier for the euro area where shares in the aggregate output are used as weights (see Figure 8). These individual country multipliers ignore spillovers to other countries. We compare this weighted multiplier to a multiplier calculated from a model estimated for the euro area leve as a whole. This euro area aggregate model should in principle incorporates positive spillovers. The impact multiplier (period 1) is similar for all estimates which is in line with the literature conclusions that direct purchases of foreign products by the domestic government are usually insignificant and their effects on foreign outputs are negligible. After three

[8] Our sample includes Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Netherlands and Spain. These countries account for more than 95 per cent of the overall euro area output.

**Table 2**

**Long-run GDP Response to a Shock in Public Capital**

| | '60-'00 | '60-'01 | '60-'02 | '60-'03 | '60-'04 | '60-'05 | '60-'06 | '60-'07 | '60-'08 | '60-'09 | '60-'10 | '60-'11 | '60-'12 | '60-'13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Austria | 0.0 | 0.3 | 0.5 | 0.4 | 0.4 | 0.2 | 0.3 | 0.3 | 0.4 | 0.6 | 0.6 | 0.6 | 0.7 | 0.7 |
| Belgium | 0.0 | 0.9 | 0.4 | 1.1 | 0.5 | 0.5 | 0.4 | 0.3 | 0.5 | 1.5 | 1.3 | 1.3 | 1.3 | 1.3 |
| Finland | -0.1 | -0.3 | -0.2 | -0.3 | -0.2 | -0.1 | -0.1 | -0.3 | 0.0 | 0.0 | 0.0 | 0.4 | 0.4 | 0.6 |
| France | 3.0 | 2.8 | 0.6 | 0.3 | 0.4 | 0.4 | 0.6 | 0.5 | 0.4 | 0.3 | 0.4 | 0.3 | 0.3 | 0.3 |
| Germany | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 1.2 | 1.2 | 1.1 | 1.1 | 1.6 | 1.3 | 1.3 | 1.1 |
| Greece | 1.4 | 1.6 | 1.6 | 1.7 | 1.8 | 1.8 | 1.8 | 1.7 | 1.6 | 1.6 | 1.6 | 1.6 | 1.7 | 1.6 |
| Ireland | -1.1 | -0.5 | -0.2 | 0.1 | 0.6 | 0.7 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 1.0 | 0.8 | 0.6 |
| Italy | -0.6 | -0.5 | -0.4 | -0.3 | -0.4 | -0.4 | -0.4 | -0.4 | -0.4 | -0.4 | -0.4 | -0.2 | -0.1 | 0.0 |
| Netherlands | 5.0 | 4.6 | 4.6 | 4.3 | 4.2 | 2.5 | 2.1 | 2.3 | 2.3 | 2.3 | 1.9 | 1.5 | 1.2 | 1.2 |
| Spain | 0.5 | 1.9 | 2.2 | -0.6 | -0.9 | -1.0 | -1.2 | -1.2 | -1.1 | -1.1 | -0.8 | -0.9 | -1.1 | -1.1 |
| | | | | | | | | | | | | | | |
| Australia | 2.2 | 1.9 | 1.9 | 1.9 | 2.0 | 2.0 | 2.0 | 1.9 | 1.9 | 2.3 | 2.1 | 2.5 | 1.5 | 1.3 |
| Canada | 3.0 | 4.2 | 4.1 | 4.8 | 4.9 | 4.6 | 4.7 | 4.7 | 4.4 | 4.4 | 3.7 | 3.7 | 5.1 | 5.7 |
| Denmark | 1.0 | 1.1 | 1.1 | 1.3 | 1.3 | 1.2 | 1.2 | 0.7 | 0.6 | 0.6 | 0.7 | 0.5 | 0.4 | 0.3 |
| Japan | -0.7 | -0.7 | -0.7 | -0.6 | -0.5 | -0.6 | -0.8 | -0.8 | -0.8 | -0.8 | -0.8 | -0.6 | -0.6 | -0.6 |
| New Zealand | -0.2 | -0.4 | -0.3 | -0.2 | -0.2 | -0.2 | -0.3 | -0.3 | -0.3 | -0.3 | -0.5 | -0.5 | -0.6 | -0.5 |
| Norway | 1.5 | 1.1 | 1.2 | 2.8 | 0.5 | 2.2 | 3.5 | 3.2 | 4.0 | 4.0 | 2.7 | 1.9 | 2.0 | 2.3 |
| Sweden | 3.0 | 2.9 | 2.8 | 2.7 | 2.8 | 2.7 | 2.7 | 2.5 | 2.0 | 2.0 | 2.2 | 2.2 | 2.0 | 1.5 |
| Switzerland | 3.2 | 5.4 | 6.5 | 6.2 | 3.8 | 5.1 | 3.2 | 1.9 | 1.8 | 3.5 | 2.0 | 1.0 | 1.6 | 1.1 |
| United Kingdom | 0.6 | 0.9 | 0.8 | 0.9 | 0.8 | 0.7 | 0.5 | 0.6 | -0.3 | -0.3 | 0.2 | 0.0 | 0.0 | 0.0 |
| USA | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 | 1.4 | 1.2 | 0.8 | 0.9 | 0.8 | 0.7 | 0.6 |

*Numbers denote the long-run (period 100) response of GDP to a Cholesky one standard deviation innovation in public capital.*

years a positive differential appears which further increases in the long run. This could point to the existence of positive spillovers within the euro area. These results should however be interpreted with caution – and for more precise estimates of the size of the spillover effects more detailed modeling of trade-linkages would be necessary.

Recently, calls have emerged for Germany to increase its public spending, claiming this would have a beneficial effects also for the other countries in the euro area. Germany is the largest economy in the euro area and arguably has the fiscal space to increase spending. Therefore, we additionally re-estimate the model for Germany, but now also include GDP of one other European country at the time. This allows us to test whether a public capital shock in Germany exerts a positive effect on the output of the other country. Figure 15 gives impulse response functions. Positive effects of a shock in German public capital were found for Italy and (marginally) for Spain. Surprisingly, no significant effect was found for Germany's neighbouring countries France, Austria or Netherlands, despite significant trade linkages. These results suggest that international spill-overs from an increase in German investment spending would be rather limited.

### *4.3 Recursive VARs*

We are interested in the development of the relationship between public capital and economic growth over time. To this end, we estimate models starting from the sample 1960-2000 up to 1960-2013, each time adding one year to the estimation period. For each subsample, we impose the country-specific model for the whole period as specified in the previous section. That is, the number of cointegration relations and the number of lags is as depicted in Table 1.

**Table 3**

**Long-run Multiplier, Different Subsamples**

| | '60-'00 | '60-'01 | '60-'02 | '60-'03 | '60-'04 | '60-'05 | '60-'06 | '60-'07 | '60-'08 | '60-'09 | '60-'10 | '60-'11 | '60-'12 | '60-'13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Austria | -0.2 | 0.5 | 0.6 | 0.5 | 0.6 | 0.4 | 0.4 | 0.5 | 0.7 | 0.9 | 0.9 | 1.0 | 1.2 | 1.2 |
| Belgium | 0.0 | 0.2 | 0.1 | 0.3 | 0.2 | 0.2 | 0.2 | 0.1 | 0.2 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| Finland | -1.0 | -0.9 | -0.4 | -0.4 | -0.5 | -0.1 | -0.1 | -0.4 | 0.0 | 0.0 | 0.0 | 0.5 | 0.5 | 0.8 |
| France | 2.4 | 2.4 | 2.4 | 1.8 | 1.6 | 1.6 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.8 | 1.9 | 1.9 |
| Germany | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Greece | 3.8 | 3.5 | 3.6 | 3.6 | 3.3 | 3.1 | 3.7 | 3.6 | 3.3 | 3.3 | 3.3 | 3.3 | 3.7 | 4.0 |
| Ireland | 0.1 | 0.1 | 0.0 | 0.0 | -0.1 | -0.2 | -0.2 | -0.2 | -0.2 | -0.2 | -0.2 | -0.4 | -0.3 | -0.2 |
| Italy | -1.0 | -1.0 | -0.7 | -0.7 | -0.8 | -0.8 | -0.9 | -1.0 | -1.0 | -1.0 | -0.8 | -0.6 | -0.2 | 0.1 |
| Netherlands | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.6 | 0.6 | 0.6 |
| Spain | 0.4 | 1.0 | 1.1 | -0.6 | -0.9 | -1.0 | -1.3 | -1.4 | -1.2 | -1.2 | -0.9 | -1.1 | -1.4 | -1.4 |
| Australia | 1.2 | 1.2 | 1.2 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.2 | 1.1 | 1.0 | 0.9 | 0.9 |
| Canada | 1.6 | 1.7 | 1.9 | 2.0 | 2.2 | 2.4 | 2.9 | 3.3 | 3.2 | 3.2 | 3.1 | 3.1 | 3.3 | 3.4 |
| Denmark | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.5 | 0.4 |
| Japan | -0.8 | -1.2 | -1.0 | -0.9 | -0.8 | -0.9 | -1.9 | -2.3 | -1.5 | -1.5 | -2.0 | -0.9 | -0.8 | -0.8 |
| New Zealand | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.2 | -0.3 | -0.3 | -0.3 | -0.2 |
| Norway | 0.9 | 0.6 | 0.8 | 1.2 | 0.6 | 1.4 | 1.7 | 1.9 | 2.2 | 2.2 | 2.2 | 2.1 | 2.1 | 2.1 |
| Sweden | 1.1 | 1.1 | 1.0 | 1.0 | 1.1 | 1.1 | 1.1 | 1.1 | 1.2 | 1.2 | 1.1 | 1.1 | 1.1 | 1.1 |
| Switzerland | 1.3 | 1.3 | 1.3 | 1.3 | 1.2 | 1.1 | 1.0 | 0.7 | 0.7 | 0.9 | 0.7 | 0.6 | 0.7 | 0.6 |
| United Kingdom | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | -0.3 | -0.3 | 0.1 | 0.0 | 0.0 | 0.0 |
| USA | 1.4 | 1.4 | 1.4 | 1.4 | 1.3 | 1.4 | 1.4 | 1.4 | 1.5 | 1.3 | 1.3 | 1.2 | 1.2 | 1.2 |

*Numbers denote the long-run (period 100) public capital multiplier as defined in equation 6.*

From Table 2 a rather diffuse picture emerges. The long-run GDP response (here we simply take the value from period $t$=100) to a one standard deviation innovation in public capital increases over time in a number of, mainly euro area, countries. To take into account the fact that public capital itself also responds to a shock in public capital, Table 3 also shows the "public capital multiplier" as defined in equation 6 above. Our conclusions do not change much. Experiences differ by country, there is no general tendency for public capital to become more, or less, productive over time.

## 5 Concluding remarks

The recent cuts in public investment in many advanced economies as part of the budgetary corrections following the financial crisis have raised the question if there is public underinvestment, which through its effect on the public capital stock will harm long-term growth prospects. The public capital-to-GDP ratio has been on a long-term downward trend in many countries, for which various explanations have been offered in the literature. The first relates the evolution of the public capital stock to changing economic needs, such as less importance of physical capital in more service oriented economies and saturation effects once infrastructure networks have been built. The second puts more emphasis on political considerations during consolidation episodes, with public investment considered to be among the easier to cut public expenditures.

This paper examines whether the relationship between public capital and output has changed on the basis VAR/VECM estimates of an expanded data series of public capital stocks for 20

OECD economies for the years 1960-2013. We find that public capital seems to be productive for most of the countries in our sample, but that these results are heterogeneous across countries, as in earlier studies. We also find a small negative correlation between the effect of public capital on output and the level of public output in the long run. However, we do not find that the effect is much larger than in previous studies.

We also estimate recursive VAR-models – starting from the period 1960-2000, then expanding the sample period by one year at the time – to see if the relationship between public capital and economic growth has changed in recent years. We do not find systematic evidence that this has been the case. Our results do not suggest that there is general lack of public investment or that its marginal use has increased in recent years. Of course, the need for public investment should be considered carefully on case-by-case basis, in which other consideration, such as the expected interest rates relevant for investment decisions, can play an important role.

Finally, we compare the impulse responses from a VAR for the euro area as a whole to the weighted impulse responses of VARs for individual euro area countries and include the GDP growth of other euro area countries in the VAR for Germany as a tentative way to consider the importance of investment spill-overs in Europe. The first approach yields some evidence for the relevance of spill-overs, evidence from the latter is not conclusive.

**Figure 9**

**Log Real Net Government Capital Stocks, 1960-2013**

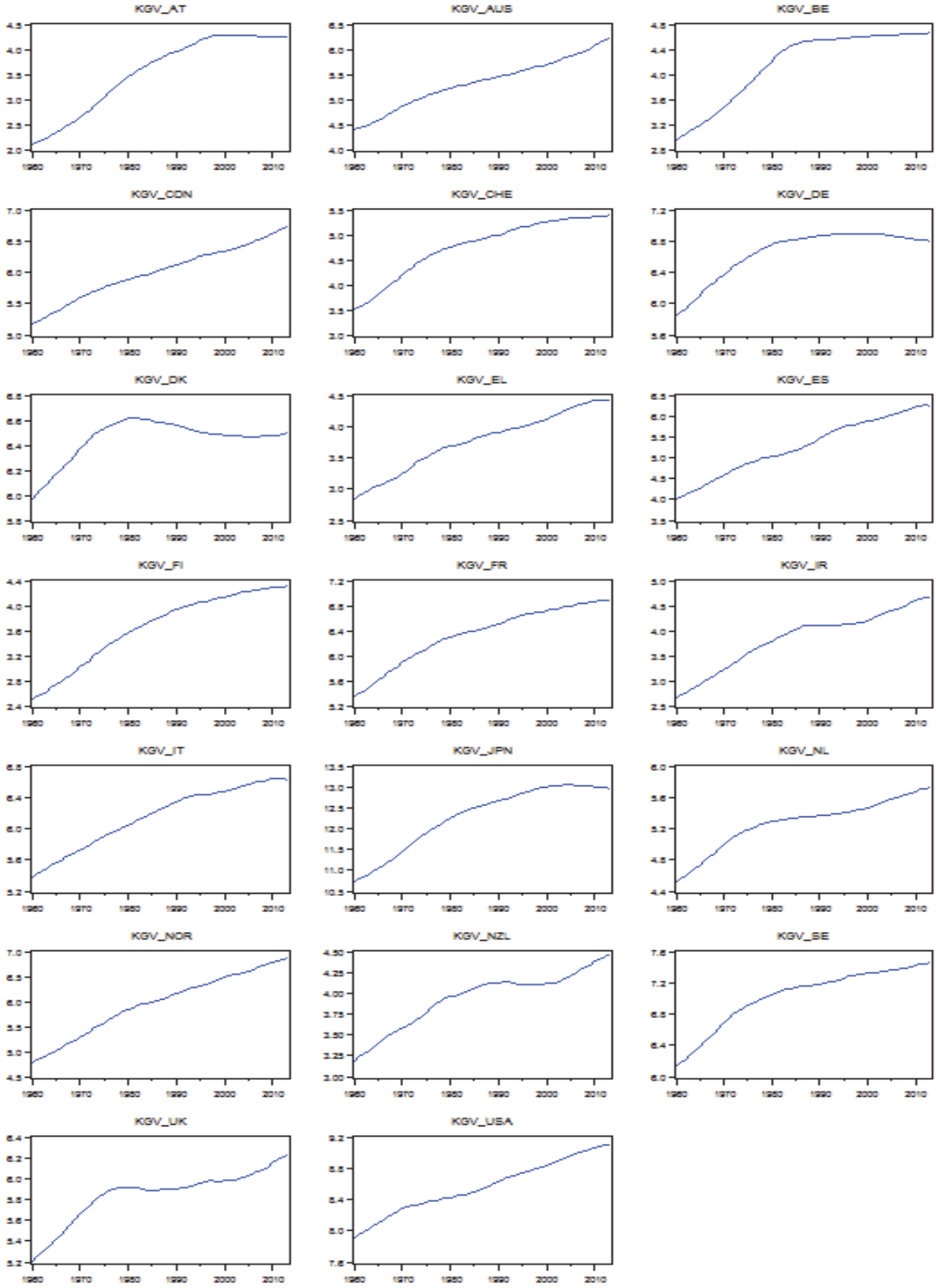


**Figure 10**

**Log Real Net Private Sector Capital Stocks, 1960-2013**

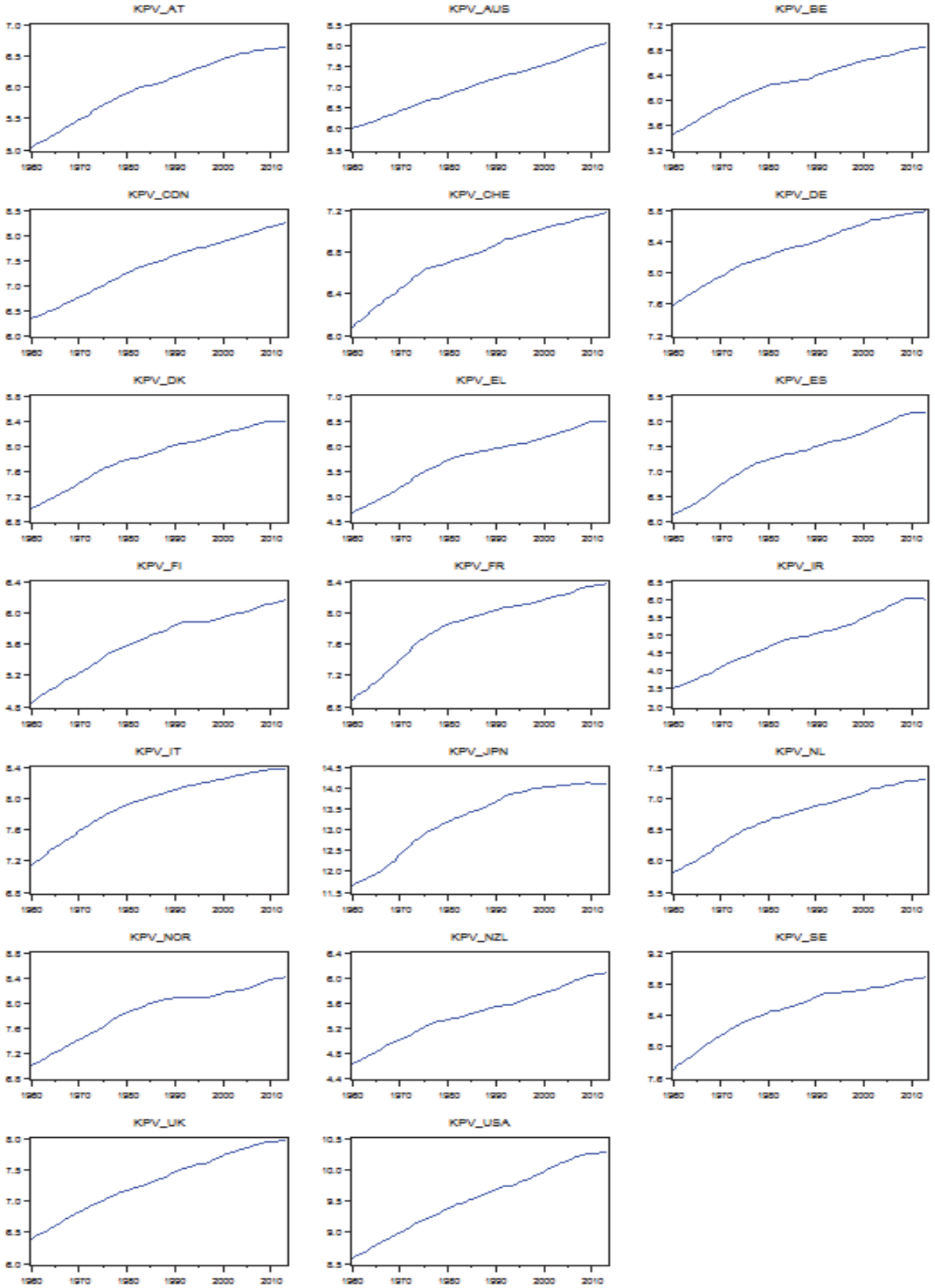


**Figure 11**

**Log Total Hours Worked, 1960-2013**

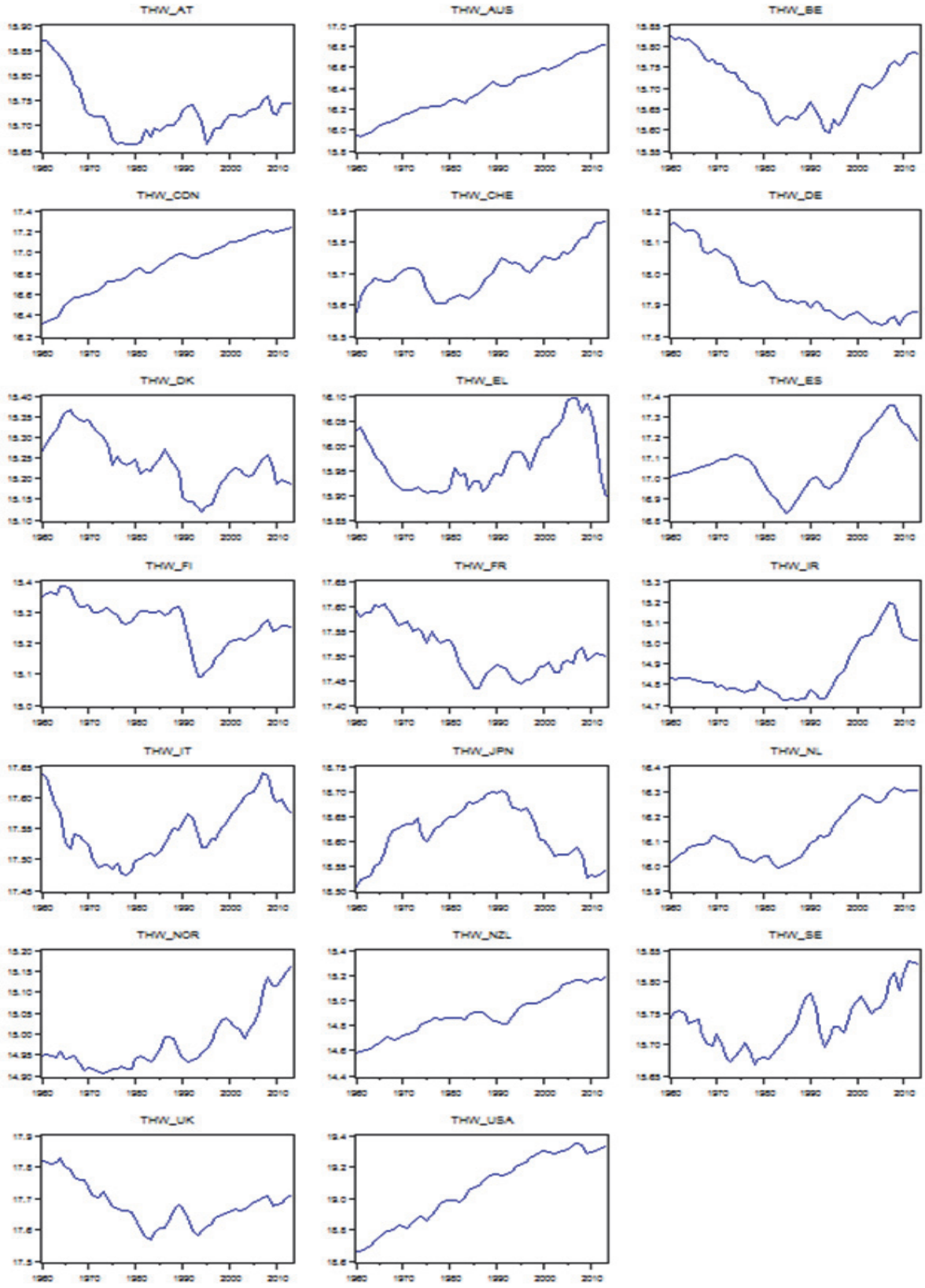


**Figure 12**

**Log Real GDP, 1960-2013**

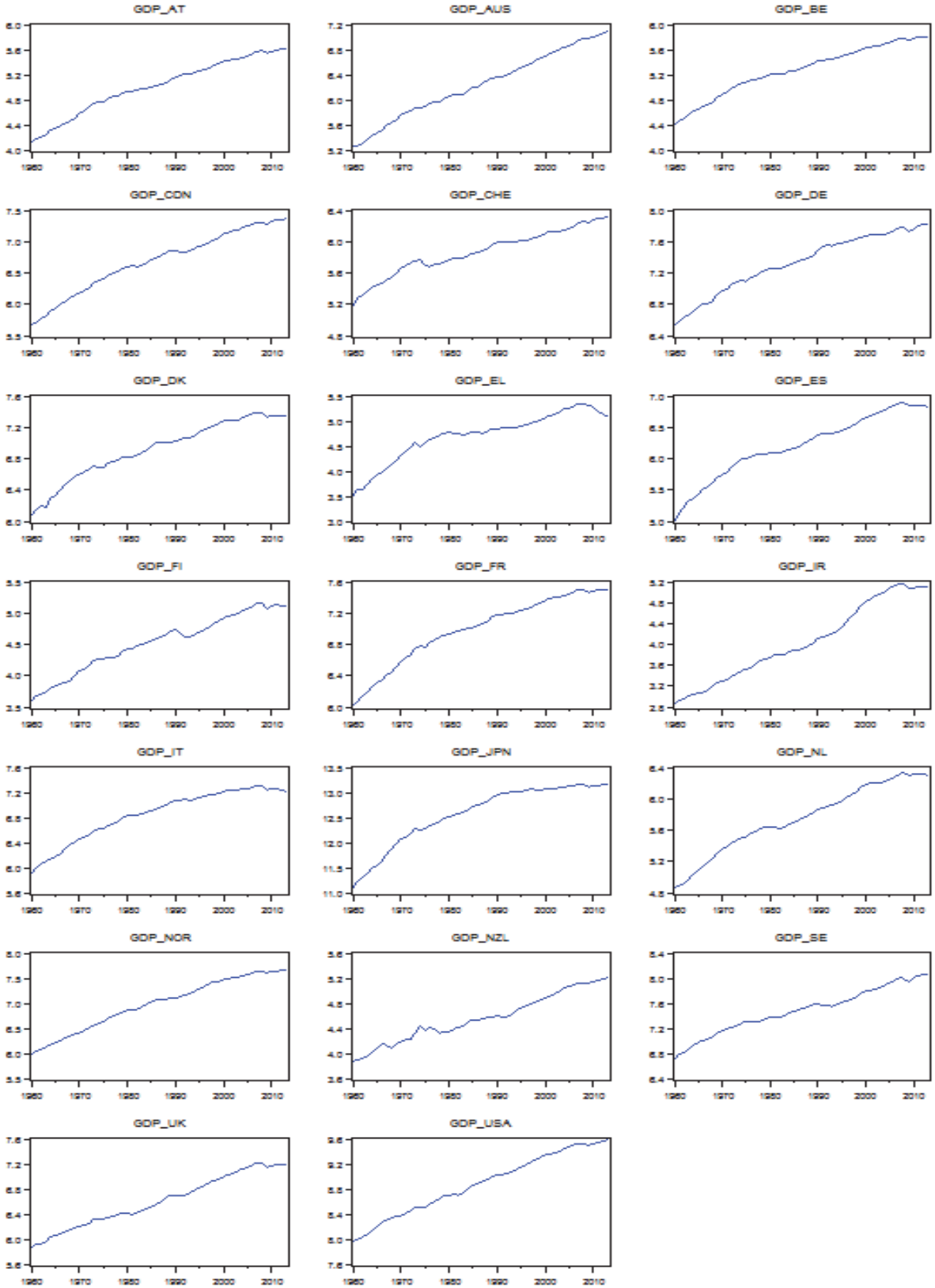
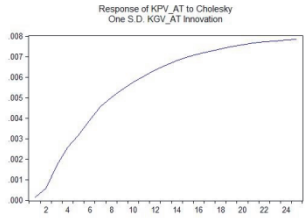


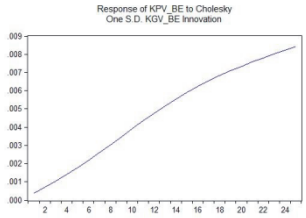
**Figure 13**

**Impulse Responses of the Net Real Private Capital Stock to a one s.d. Public Capital Shock, Euro Area**

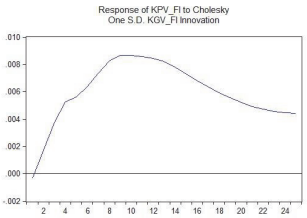
(a) Austria



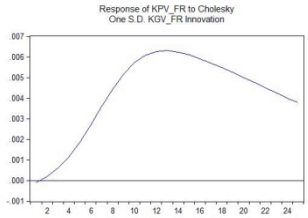

(b) Belgium



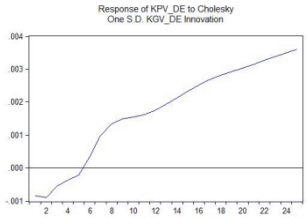

(c) Finland



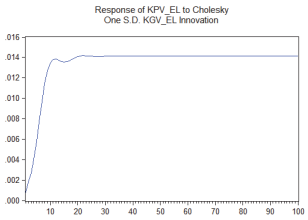

(d) France



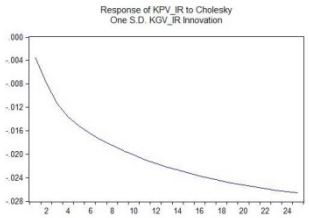

(e) Germany



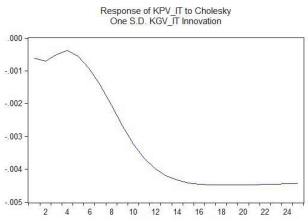

(f) Greece



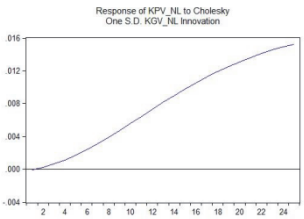

(g) Ireland




(h) Italy




(i) Netherlands




(j) Spain

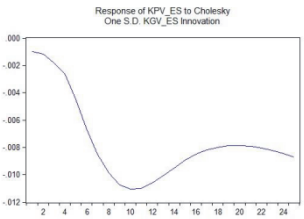
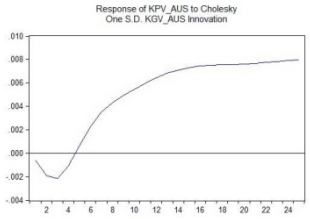


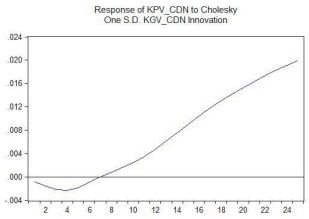
**Figure 14**

**Impulse Responses of the Net Real Private Capital Stock to a one s.d. Public Capital Shock, Non-Euro Area**

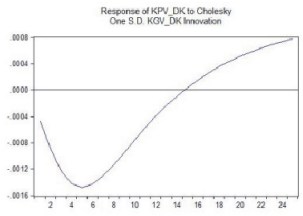
(a) Australia



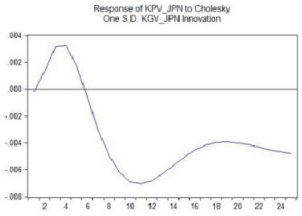

(b) Canada



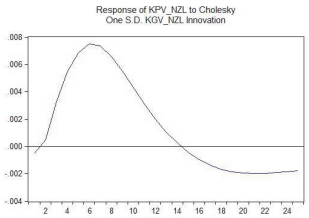

(c) Denmark



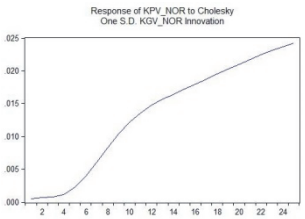

(d) Japan



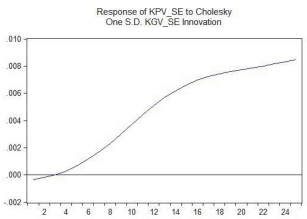

(e) New Zealand



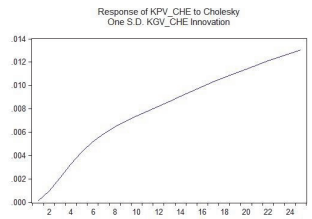

(f) Norway



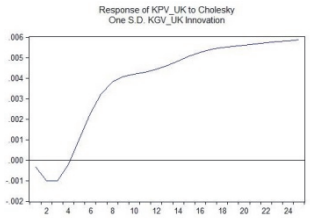

(g) Sweden




(h) Switzerland




(i) United Kingdom (j) United States



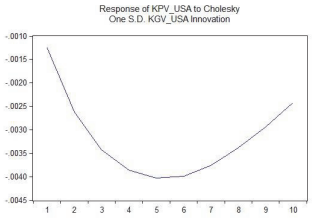
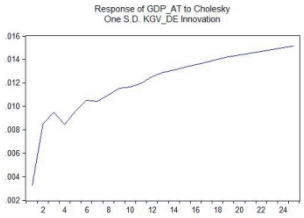



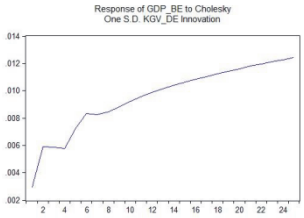
**Figure 15**

**Impulse Responses of Real GDP to a Shock to General Government Capital Stock in Germany**

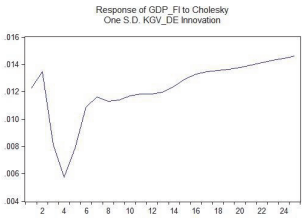
(a) Austria



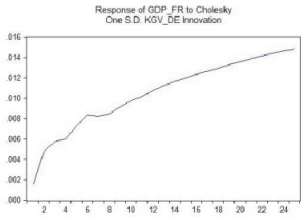

(b) Belgium



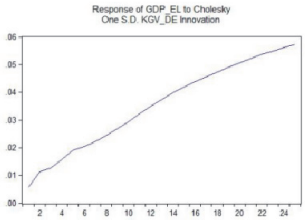

(c) Finland



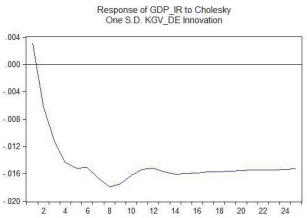

(d) France



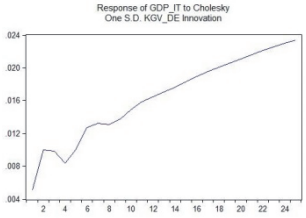

(e) Greece



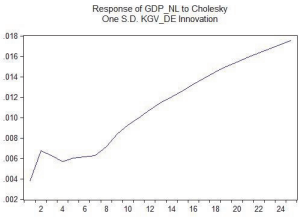

(f) Ireland



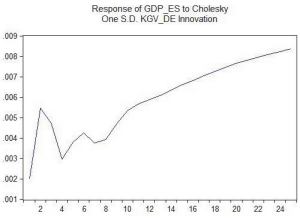

(g) Italy




(h) Netherlands




(i) Spain



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# COMMENT TO "PUBLIC CAPITAL IN THE 21TH CENTURY: AS PRODUCTIVE AS EVER?" BY JASPER DE JONG, MARIEN FERDINANDUSSE AND JOSIP FUNDA

*Luiz de Mello*[*]

## Introduction

The recovery of investment, both public and private, since the crisis has been particularly slow in most advanced economies. A growing empirical literature has therefore emerged to revisit earlier evidence on the links between output growth and investment, on the one hand, and between public and private investment, on the other. To contribute to this literature, Jasper de Jong, Marien Ferdinadusse and Josip Funda focus on public investment (measured in terms of general government gross fixed capital formation) and GDP growth in a set of 20 OECD countries during 1973-2013. They set out to identify changes in the growth-investment nexus over time in individual countries and computed impulse responses for the euro area countries. The paper's main finding is that impulse responses vary across countries but have not increased over time, despite falling government investment and, in some cases, public capital stocks.

The broader context of how business and public investment have recovered since the crisis in the OECD area provides a backdrop to the paper. Comparison with the pre-crisis period suggests that there is an investment shortfall in most OECD countries: current-price investment-to-GDP ratios remain considerably below pre-crisis levels, especially in those countries that were severely hit by the crisis (see chart below). The weakness in business investment has been due essentially to weak demand, higher user cost of capital, overall policy uncertainty, and high corporate leverage before the crisis. In turn, public investment has been held down by fiscal consolidation following the withdrawal of stimulus after the crisis, with a particularly sharp contraction at the subnational level, which accounts for close to two-thirds of public investment on average among OECD countries. Current investment is also estimated to be below long-term trends and steady-state levels (OECD, 2014).

## The empirical analysis and other considerations

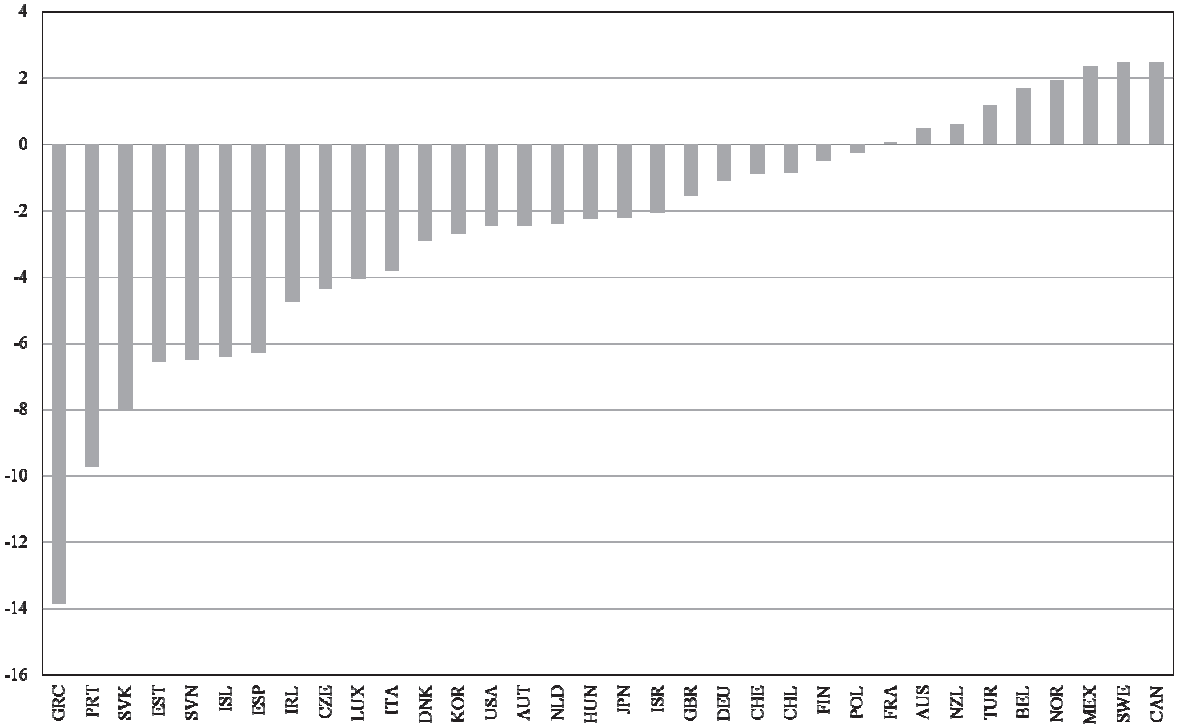
The findings reported in the paper are by and large in line with recent empirical literature, which shows mixed results but in general falling output elasticities over time. Some discussion is nevertheless warranted on the empirical analysis reported in the paper, especially on the computation of impulse response functions, which may provide directions for future work. In addition, there are more general, conceptual issues that need to be taken in to account when assessing longer-term investment trends.

A key difficulty in the empirical assessment of linkages between GDP growth and investment is the identification of exogenous shocks to investment or the capital stock, which are needed for the computation of impulse responses. Dealing with reverse causality has indeed motivated a growing empirical literature since the onset of the global crisis, including on the sign and magnitude of fiscal multipliers (see de Mello, 2014, for a review of the literature). Recent contributions to this literature include alternative identification strategies that supersede on both analytical and statistical grounds the more conventional one pursued by the authors, which is based on the ordering of the variables in an unrestricted VECM. Among these alternative options is the

[*] Deputy Director, Public Governance and Territorial Development Directorate, OECD.

**Figure 1**

**Investment Gap, 2015**
*(percent of GDP)*




Note: Investment gap is defined as total investment as a percentage of GDP in 2015 minus the 1996-2007 average.
Source: OECD Economic Outlook database.

estimation of SVARs, which allow for greater refinement in the identification of exogenous shocks on the basis of hypotheses about the temporal linkages among the variable of interest. Narrative-based strategies have also been proposed more recently, building on a chronology of policy announcements that can be used as identification devices (see, for example, Blanchard and Perotti, 2002; Auerbach and Gorodnichenko, 2012; Alesina *et al*., 2012).

Indeed, the crisis and the policy responses it brought about provide interesting narrative-based identification options that the authors could use in their analysis. Policy activism in the immediate aftermath of the crisis included the announcement of stimulus packages that in some cases delivered sharp rises in public investment, often at the subnational levels of government. These announcements and the timing of implementation of stimulus measures, which are well documented for OECD countries (see OECD, 2015, for recent policy announcements), could therefore be used to identify exogenous shocks and the computation of impulse responses. Moreover, the authors could also report the confidence intervals around the impulse responses to demonstrate the strength of the responses reported in the paper and discuss in greater detail their motivation for introducing a time trend in the cointegrating vector.

More fundamentally, and going beyond empirical considerations, the investment shortfall since the crisis brings a number of questions to the fore. One is whether or not the weakness of the recovery of investment is due essentially to a lack of attractive investment opportunities. This question is related to the nature of innovation and technological change over the last decade or so,

and the opportunities they create for business investment. In particular, the range of applicability of innovation (for example, steam engine versus electricity) determines the extent of adaptation required to technological change and the associated investment needs. Innovation and technological change also have a bearing on the extent of complementarity (or substitution) that exists between public and private investment, which, in turn, affects the growth elasticity of investment.

Another consideration is related to demographics and changes in the price of capital goods. In particular, population ageing could bring down the rate of return on investment and the investment rate altogether, although there could be offsetting effects on saving behaviour that would need to be taken on board. Moreover, the post-crisis investment shortfall could be related to changes in the price of capital goods: if prices fall, then the same amount of investment requires less spending in relation to GDP, which in turn affects the estimated elasticities (see IMF, 2014, for evidence for advanced economies, and Eichengren, 2014, for a more general discussion on investment trends).

All in all, while a better understanding of the empirical linkages between growth and investment remains important, there is much room for broadening the analysis in future work to include longer-term determinants of investment, including not least these related to innovation and changes in demographics and the price of capital goods.

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# AN EMPIRICAL ANALYSIS OF THE LINK BETWEEN PUBLIC AND PRIVATE INVESTMENT IN FOUR OECD COUNTRIES

*Jérôme Creel,*[*] *Paul Hubert*[**] *and Francesco Saraceno*[***]

*We investigate the relationship between public investment and investment decisions by firms. In theory, public investment may have contradictory effects on private investment, either crowding-out or crowding-in effects. We disentangle these effects in different agnostic linear models, in which we assess, for four OECD countries, the existence and the sign of relationship between public and private investment, including a VAR model in which private investment, GDP growth, and interest rates interact and are affected by public investment and debt among other determinants. We further look at the possibly time-varying sign of the relationship between public and private investment and its state-contingence. In a third stage, we assess the possible international spillovers of public investment. This allows producing evidence on the impact of public investment on the economy, both in the short and in the long run, taking into account different types of interaction. We find a crowding-in effect in France, a weak crowding-out effect in the US, and no robust effect in the UK and Germany.*

## 1 Introduction

The persisting weakness of the Eurozone economy is challenging European policy makers and putting pressure on the single currency. The year 2014 has seen a slow but inexorable slide of the Eurozone towards deflation that prompted a new consensus on the causes of the crisis. Mario Draghi's speech at Jackson Hole, in August 2014, marks a turning point, and puts forward a new diagnosis:

- the Eurozone crisis is a crisis of insufficient demand;
- insufficient demand can be ascribed to low consumption and, more importantly, to subdued investment;
- the impact of a prolonged recession on potential growth is large and calls for bold action;
- last, but not least, fiscal policy has a role to play in supporting growth.

While the emphasis remains on structural reforms as the primary means for fostering growth, the importance of public investment is now widely recognized, as witnessed by chapter 3 of the IMF World Economic Outlook of October 2014. In fact, investment is today seen as both a Keynesian short-term stabilization tool and as a means to restore sound levels of public (and private) capital in the long run so as to boost potential output.

In spite of this new emphasis and investment agendas for the EU, stemming from the Juncker Plan and former discussions in Germany about the requirement of boosting public investment to reduce the "investment gap" (Bach *et al.*, 2013), the management of the European

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[*] OFCE-Sciences Po and ESCP Europe.

[**] OFCE-Sciences Po.

[***] OFCE-Sciences Po and SEP-LUISS Rome.

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Corresponding author: Francesco Saraceno, e-mail: francesco.saraceno@sciencespo.fr

debt crisis may have had a negative impact on public investment. Balassone and Franco (2000) discuss the composition effect of fiscal austerity: in order to match the deficit and debt criteria before entering in the Euro area, governments decided to reduce public investment more than current expenditures. Likewise Mehrotra and Välilä (2006), while arguing that the Euro *per se* is not a determinant to the downward trend in public investment of pre-enlargement member states, show that either fiscal sustainability concerns or budgetary consolidation are significant determinants of public investment.

In this paper we shed light on the impact of public investment on growth, by investigating its impact on investment decisions by firms. In theory, public investment may have contradictory effects on private investment. On one side, it may compete with private funds for limited resources, thus crowding out private investment. This is an effect that we expect to be strong in normal times, when the economy is at (or close to) potential, but also in the short-run when financing opportunities are scarce. On the other, it may crowd-in investment. This may happen in the short run, because through Keynesian business cycle stabilization it improves the state of the economy and therefore expectations; but it can also happen in the long run, if public and private capitals are complementary in the production function, so that private investment productivity is enhanced by appropriate stocks of public capital.

In a first stage, we disentangle these effects in different agnostic linear models, in which we assess, for four OECD countries, the existence and the sign of the relationship between public and private investment. We include public and private investment in a more general model, namely a small structural VAR model in which private investment, GDP growth, and interest rates interact and are affected by public investment among other things. This allows us to gather evidence on the impact of public investment on the economy, both in the short and in the long run, taking into account debt sustainability and interaction with monetary policy. In a second stage, we look at the possibly time-varying sign of the relationship between public and private investment and its state-contingence. In a third stage, we assess the possible international spillovers of public investment. The four countries we model are France, Germany, the United Kingdom (UK) and the United States (US). They testify for the possible specific situation of Eurozone countries (France, Germany), compared with a non-Eurozone though EU country (the UK) and with a non-European country (the US).

Our analysis is subject to a number of pitfalls and biases that need to be kept in mind to assess the potential, but also the limits of the exercise. First, the relationship between public and private investment may not be constant over time, and its sign may change from period to period. This lack of stability may be explained by a number of factors, for example the business cycle, the state of public finances, and so on. To counter this limit, we estimate a time-varying correlation index, and try to isolate its determinants. Second, the relationship between public and private investment, and their determinants, may be non-linear. One could easily imagine, for example, that the positive spillovers linked to infrastructure spending have a peak beyond which their impact on private productivity is declining and may even become negative. Other problems may arise from the different time horizons of public and private investment projects that impose a consideration of leads and lags, and from the difficulty of establishing causation. In the following pages we will try to tackle these issues, but the reader should bear in mind that our proposed solutions will only partially address them.

The one limit that this paper will not deal with is the obstacle that all research dealing with public investment faces, namely that not all investment was created equal. The exact same spending, in different periods or in different countries, may have a very different macroeconomic impact. Even more problematic is the necessarily narrow definition of public investment, that includes items whose productivity may be dubious, while some forms of current expenditure (for example in education or in health care) have an impact on the potential growth rate of the economy.

Our macroeconomic data do not allow developing this subject, of paramount importance, that would require microeconomic data and case studies. In this respect, reported results may underestimate the actual impact of public investment.

The rest of the paper is organized as follows. Section 2 briefly reviews the literature about the relationships between public capital (or investment) and GDP (or economic growth). Section 3 sketches the model of complementarity between public and private investment. Section 4 presents the data. Section 5 reports statistical insights in the relationship between public and private investment. These insights are incorporated in a more general VAR model, and in an analysis of dynamic conditional correlations, including the investigation of their determinants. Section 5 also investigates the impact of public investment on private investment in a single-regression model. Section 6 concludes.

## 2 Public capital (or investment) and growth: A brief survey of the literature

The starting point of the empirical literature devoted to the relationship between fiscal policy and economic growth is Ratner (1983) who finds that US output elasticity with respect to public capital is positive but smaller than private capital (close to 6%, whereas the output elasticity with respect to private capital was 22%).[1] The literature on the effects of public capital on output and growth then accelerated after a series of contributions by Aschauer (1989a, b, c). Aschauer (1989a) finds a large elasticity of total factor productivity to public capital (around 0.4) and Aschauer (1989b) shows that public investment crowds out private investment, but that this effect is counterbalanced by the positive impact of public capital on the return to private capital. Whereas his two former empirical contributions focus on US data, Aschauer (1989c) extends his analysis to G7 countries and highlights the positive impact of public investment on labor productivity. Since then, many surveys have been dedicated to the impact of public capital and/or investment on economic growth or productivity.

The most recent survey, albeit limited mostly to infrastructure spending, is provided by Pereira and Andraz (2013). Broadly speaking, the literature on public capital and growth can be divided into four main categories: first, papers based on the production function approach, which treat public capital as an input of the aggregate production function, and estimate its effects on output, as in Ratner and Aschauer. Second, papers based on the cost function approach, that are admittedly less demanding than the previous ones regarding the restrictions (for example on the degree of substitutability among factors) that they impose. Third, papers based on cross section growth regressions à la Barro (1991), which include public capital among other explanatory variables. The fourth is the group of contributions that use VAR (or VECM) models including public capital; the advantage of this latter approach is that, by explicitly taking into account the dynamic links among variables, it allows to disentangle possible reverse causation (i.e. from output to capital/investment) and to differentiate the short run and long run relationships between public investment and GDP or public investment and private investment.

Romp and de Haan (2007) survey the literature on public capital and growth, explaining in detail each of the methodologies enumerated above, and reach a number of general conclusions. First, the majority of works surveyed, especially the most recent ones, conclude for a positive effect of public capital (or investment) on growth or on output. These effects are nevertheless considerably smaller than originally suggested by Aschauer. Such a positive but mild effect also emerges from the meta-analysis carried out by Bom and Lightart (2014) on a sample of 68 papers

[1] Drawing on a meta-analysis performed 20 years after Ratner's seminal contribution, Nijkamp and Poot (2004) broadly confirm his findings that the evidence of an impact of fiscal policy on economic growth is weak. Not surprisingly, they find nevertheless that composition matters: education and infrastructure have a stronger impact.

published between 1983 and 2008. Second, a number of papers (e.g., Batina, 1998) suggest that reverse causation, from output to capital, is also significant and positive. Finally, and quite unsurprisingly, Romp and de Haan notice that the effects of public capital on growth differ across countries, regions and sectors.[2]

While the first two methodologies naturally limit the effect of public capital to the impact on the private sector production or cost functions, both growth regressions and VAR models do not have this limitation, and can capture macroeconomic effects of public expenditure beyond those linked to the production side of the economy. The multivariate VAR approach is certainly the most relevant in this respect and for the scope of the present paper. Furthermore, as Pereira and Andraz (2013) notice, it is less subject than the production function approach to reverse causation issues.

Among the papers using a VAR approach, Pereira (2000) estimates an annual model in first differences for the US. He identifies the model assuming a Cholesky decomposition identification where innovations in public investment lead the other variables. He then finds permanent (long run) output level effects of a temporary increase in the growth rate of public investment or, which amounts to the same, a permanent increase in the level of investment. Afonso and St Aubyn (2009) estimate VARs for 17 developed countries and show that crowding-in effects go in both directions, from public to private investment and the other way round. The former effect varies across countries whereas the latter is more homogeneous across countries.

A regular feature of papers using the VAR approach is the use of yearly data. However, a few contributions have made use of quarterly data. Voss (2002) studies the impact of public investment on private investment in the US and Canada, and (weakly) concludes for crowding out effect. Otto and Voss (1996) estimate a model in hours worked, GDP, public capital and private capital for the US and Canada. They find weak evidence of a positive cointegration between private and public capital. They find a positive lagged effect on private capital (crowding in), but no significant effect on output. Mittnik and Neumann (2001) estimate a quarterly VAR model in levels with long run cointegration restrictions (their results are not significantly different when they do not impose restrictions). Their model, estimated for six OECD countries, includes private investment and current government spending, and generally finds long run, positive (but weak) effects of public investment on growth and on private investment (only for West Germany, does the long run effect seem to be significant). The UK is the only country for which the effect is not significant even in the short run. Perotti (2004) estimates a structural VAR in levels for 5 countries (Australia, Canada, West Germany, the UK, and the US). His model contains 6 variables: government current and investment spending, GDP, net taxes, interest rate and inflation. He uses institutional features to set some cross-instantaneous-elasticities at zero and estimates some others. The conclusions of Perotti are not only that investment seems to have limited effects on GDP; but also that these effects are smaller than those of current spending. A possible explanation that Perotti offers for these puzzling findings is that the level of public capital is so large in the countries considered, that public investment is not productive enough. The crowding out of private investment hence more than compensates the direct effect on aggregate demand.

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[2] We do not discuss papers dealing exclusively with developing countries. Kahn and Kumar (1997) showed that that the impact of public investment on economic growth was positive but smaller than the impact of private capital. Ghali (1998) applies a vector error-correction model to Tunisia and reports crowding-out effects and a negative long-run impact of public investment on economic growth. Haque and Kneller (2015) argue that the ineffectiveness of public investment in raising economic growth can be related to the quality of institutions. Cavallo and Daude (2011) include another determinant: the lack of openness to international trade and financial flows.

## 3 A conceptual framework

The recent reference for work on the complementarity of public and private investment is Leeper *et al.*, 2010, who present a standard DSGE model incorporating several real frictions. The most notable for our purpose is investment adjustment costs that introduce slow response of capital accumulation to policy shocks.

The firms' production function embeds the aggregate public capital stock $K^G_{t-1}$:

$$y_t = u^a_t (v_t k_{t-1})^{\alpha} l_t^{1-\alpha} \left(K^G_{t-1}\right)^{\alpha^G}$$

$\alpha^G$ is the elasticity of output with respect to public capital. Leeper *et al.* assume that the production function exhibits increasing returns with respect to public capital. $u^a_t$ is total factor productivity, $v_t$ denotes the utilization rate, $k_{t-1}$ and $l_t$ are private capital and labour respectively. The law of motion of capital is:

$$k_t = [1 - \delta(v_t)]k_{t-1} + [1 - s]i_t$$

where depreciation $\delta$ depends on the rate of capacity utilization $v_t$ and investment $i_t$ is subject to an investment shock. Public capital evolves following a standard law of motion:

$$K^G_{t-1} = (1 - \delta_G)K^G_{t-2} + A_{t-N}$$

where $A$ denotes the sum of actual spending in period $t$-$1$, for the investment decisions taken for each year since $t$-$N$. In other words, this formulation includes a time to build of public capital, whose value can be calibrated. Public capital enters the production function as a "productivity enhancer", analytically equivalent to a technology shock.[3] Public investment, and the corresponding accumulation of public capital, therefore makes expected returns of private capital and hence its level increase. This crowding-in effect may be compensated by the financing of public investment, through taxes and/ or debt, that competes with private capital for available savings and hence crowds it out.

Our purpose is to investigate these hypotheses in some detail. We will first take an agnostic approach regarding causation, and focus on correlation. Then, we will try to assess the link more in depth, developing a VAR model, and regressing private investment against public investment and standard macroeconomic variables, including some non-linearities.

## 4 Data

We carry on our empirical exercise for 4 countries, the US, France, Germany, and the United Kingdom. We build our dataset mostly from the OECD Economic Outlook. We use quarterly data from 1966Q1 to 2014Q4 (for obvious reasons, the starting date for Germany is 1991Q1). Our proxy for the cost of capital is borrowing rates, provided by Oxford Economics. A complete list of variables and their sources and names is available in Table 1, while Table 2 provides descriptive statistics for investment variables. The country with highest private (resp. public) investment growth over the sample is the US (resp. the UK). The average growth rate of private investment across the four countries is close to 3%, hence almost twice the average growth rate of public investment. The highest variance in the growth rates of public and private investment is found in the UK.

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[3] The analogy is not complete. A technology shock is permanent while a public investment shock, however persistent, is temporary because of depreciation. With standard depreciation rates (between 5% and 10%) the rate of decay of capital is nevertheless slow enough to make the difference little more than a theoretical curiosum.

**Table 1**

**Variables Description**

| Name | Description | Source | Notes |
|---|---|---|---|
| invg | Government gross fixed capital formation | OECD | y/y variation |
| invpnr | Private non-residential gross fixed capital formation | OECD | y/y variation |
| debt | Public debt | OECD | %of GDP |
| gov_bal | Public net lending | OECD | %of GDP |
| rateg | 10y gov. bond interest rates | OECD | % |
| ratep | Corporate borrowing costs | Oxford Economics | % |
| cpi | CPI | OECD | y/y variation |
| gdp | GDP | OECD | y/y variation |

**Table 2**

**Descriptive Statistics**

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| us_invpnr | 196 | 4.49 | 7.13 | -17.75 | 20.62 |
| us_invg | 196 | 1.94 | 5.95 | -13.36 | 18.88 |
| uk_invpnr | 192 | 2.83 | 7.94 | -20.55 | 23.72 |
| uk_invg | 196 | 3.49 | 20.39 | -42.72 | 79.96 |
| f_invpnr | 196 | 3.09 | 5.61 | -15.50 | 26.28 |
| f_invg | 196 | 1.55 | 5.19 | -12.36 | 15.85 |
| g_invpnr | 92 | 1.32 | 6.59 | -19.08 | 13.28 |
| g_invg | 92 | -0.44 | 7.86 | -17.55 | 28.65 |

Following national accounting standards, the OECD defines Gross fixed capital formation as "the acquisition (including purchases of new or second-hand assets) and creation of assets by producers for their own use, minus disposals of produced fixed assets. The relevant assets relate to products that are intended for use in the production of other goods and services for a period of more than a year". We made no correction to the data except for treating an abnormal peak in investment for the UK in 2005Q2 due to the reclassification of British Nuclear Fuels (BNFL).[4]

[4] For more information, see Section 3 of the background notes of the Business Investment Statistical Release at http://www.ons.gov.uk/ons/rel/bus-invest/business-investment/index.html.

**Table 3**

**Granger Causality Test**

| Country | *H0* | $\chi^2$ | Prob > $\chi^2$ |
|---|---|---|---|
| Germany | g_invpnr does not cause g_invg | 0.673 | 0.714 |
| | g_invg does not cause g_invpnr | 0.279 | 0.869 |
| France | f_invpnr does not cause f_invg | 16.42 | 0.000 |
| | f_invg does not cause f_invpnr | 6.361 | 0.042 |
| UK | UK_invpnr does not cause UK_invg | 8.522 | 0.014 |
| | UK_invg does not cause UK_invpnr | 4.404 | 0.111 |
| US | US_invpnr does not cause US_invg | 0.888 | 0.641 |
| | US_invg does not cause US_invpnr | 1.677 | 0.432 |

The output gap stands as a crucial variable, because it can be used as a proxy for the capacity utilization rate. In order to have comparable and above all sufficiently long time series, we chose to compute the output gap as an HP filtered GDP series. Existing data on the output gap, including from the OECD, do not extend sufficiently back in time.

## 5 A Multi-Dimensional Analysis of the Link between Public and Private Investment

In this section we focus on public and private gross capital formation, trying to ascertain whether for the countries we study, a pattern of correlation appears. We do not focus on causality (except in the broad temporal sense represented by Granger causality or in terms of exogenous shocks obtained from a Cholesky decomposition). Figure 1 shows the time series we use for our analysis. All variables are expressed in year-on-year percentage changes. This means that our focus is not on investment levels, but on the correlation between changes in the investment behavior of the public and of the private sector.

### *5.1 Correlation*

Our first exercise is to analyse contemporaneous correlation between public and private investment. Figure 2 reports simple correlations between private and public investment for the four countries considered, together with a linear fit and confidence intervals. The figure shows that correlation is not significantly different from zero for Germany, the UK and the US, while it is slightly positive (the slope coefficient is 0.27) and statistically significant for France.[5]

In order to add a time dimension, we made Granger causality tests for the four countries. Results are reported in Table 3. It is well known that Granger causality has very low power because it neglects the impact of expectations, and suffers by construction of an omitted variables bias. It constitutes nevertheless, especially if it yields conclusive results, a useful first glance at the temporal relationship between the variables.

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[5] Plotting the correlograms one can observe that for France and the US public investment leads private investment (in both cases the peak is at seven quarters), while it lags private investment in Germany (the peak being at eleven quarters). No relationship emerges for the UK. The figures are available upon request.

**Figure 1**

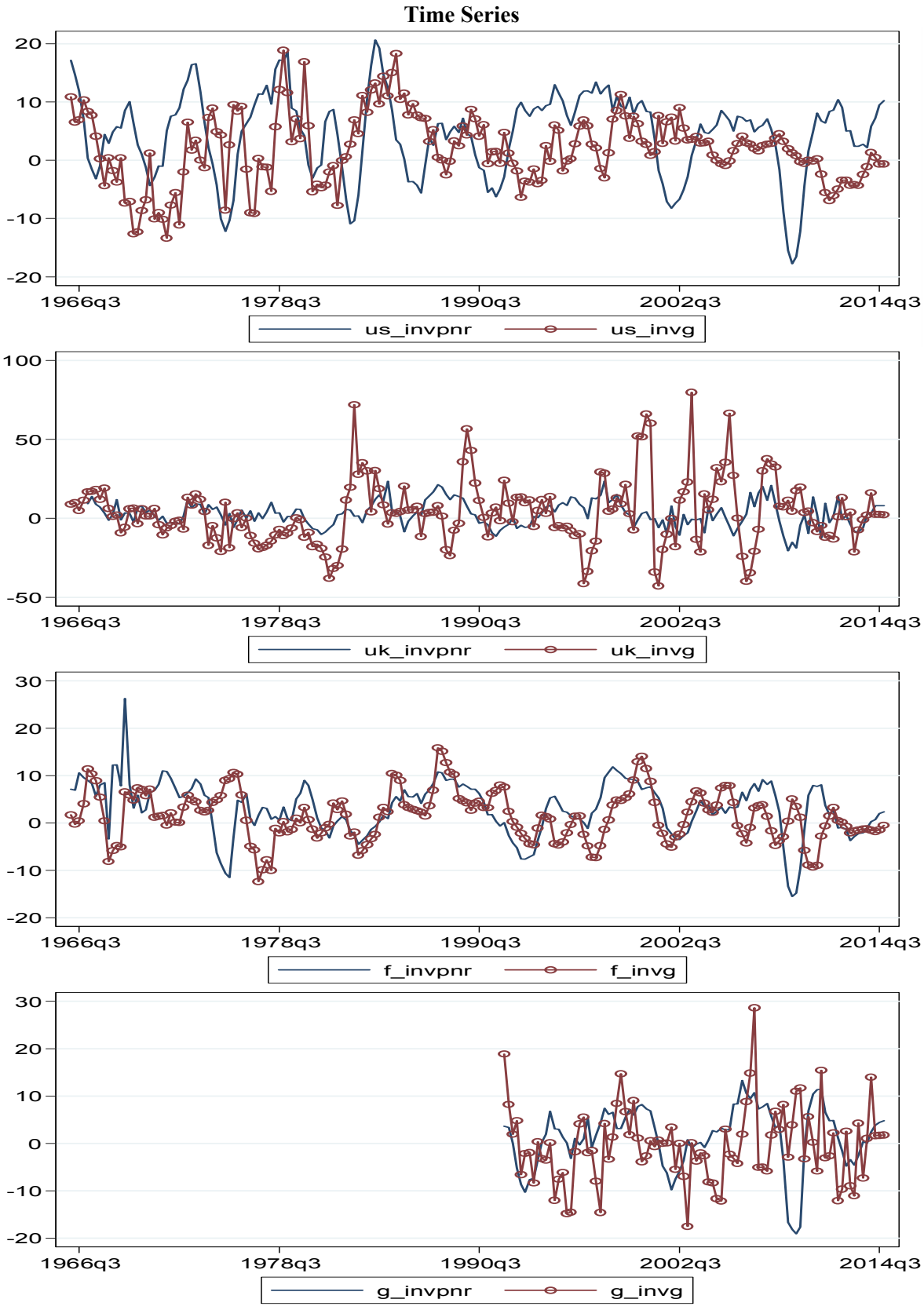
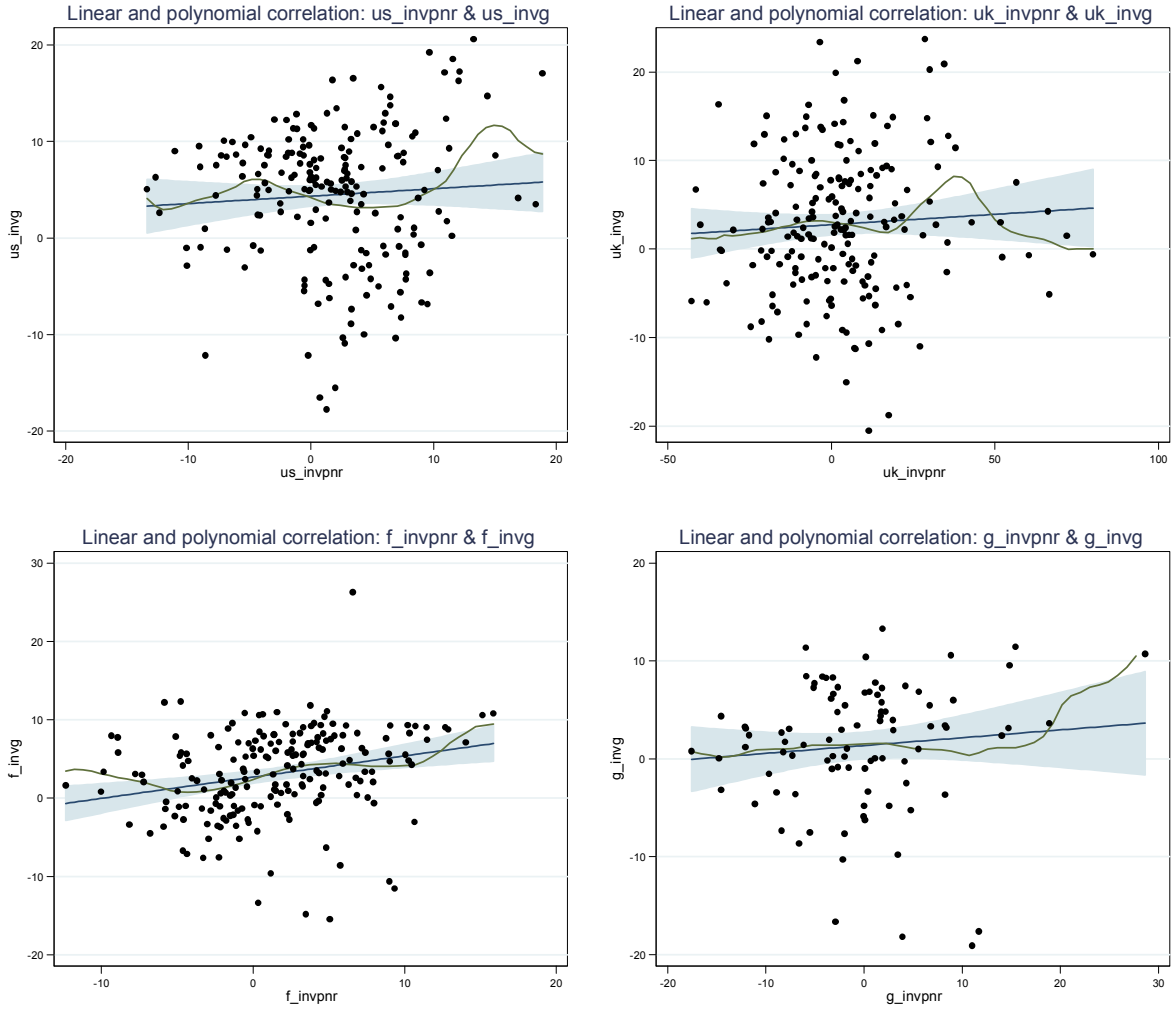

Time Series
20
10
0
-10
-20
1966q3
1978q3
1990q3
2002q3
2014q3
us_invpnr
us_invg
100
50
0
-50
uk_invpnr
uk_invg
30
f_invpnr
f_invg
g_invpnr
g_invg

**Figure 2**

**Simple Correlations**




In our case the test is not conclusive, and we do not observe strong Granger causality. This is coherent with the previous results, as for France there seems to be evidence of Granger causation in both directions, while for the other countries nothing appears (with the exception of the UK where private investment Granger causes public investment).

The overall picture that emerges from correlation and Granger-test analyses does not show a clear link between contemporaneous private and public investment in the countries considered. The exception seems to be France, where the two magnitudes seem to have a positive relationship.

### *5.2 VAR analysis*

We continue our investigation by means of a VAR analysis including a large set of macroeconomic variables which proxy the macroeconomic environment and include key macro determinants of investment: outlets (output gap), prices (CPI) and the costs of capital (sovereign interest rates and borrowing rates). While remaining to a large extent agnostic from a theoretical

point of view, the VAR model allows highlighting causal relationships, if any, and their dynamics over time. For each country, we start with a eight-variable model including the output gap, inflation, public debt, government budget balance, borrowing costs for public and private sector respectively, and both public and private investment.

$$X_t = [og\ \ cpi\ \ debt\ \ gov\_bal\ \ rateg\ \ ratep\ \ invg\ \ invpnr]$$

We estimate the model with 4 lags, and we impose a standard Cholesky decomposition to identify exogenous shocks. We take a very conservative stance by putting the two variables of interest last in the $X_t$ vector, so that these structural shocks are cleaned from the contribution of all other shocks. In other words, the IRF computed with the ordering we chose can be seen as the lowest bound of the estimation, and different orderings tend to give larger results in absolute terms (results are available upon request). All the eigenvalues lie inside the unit circle, so our VAR model satisfies the stability condition.

The results of this exploration are reported in Figure 4. For the US, the UK and Germany, the VAR delivers evidence of a negative impact of public investment on private investment. On the contrary, private investment shocks have a positive impact on public investment, except in the UK where the effect is very short-lived.

France stands out once more, as the impulse response functions are significantly positive for both investments: A shock to public investment has a positive impact on private investment, and vice-versa. This seems to point out to some positive feedback (a crowding-in effect) for France, as opposed to a crowding out effect for the three other countries.

Changing the order of public and private investment in the Cholesky decomposition does not change the impulse response to public investment (it has a positive impact on private investment for France, and a negative one for the other countries). The positive impact of private investment on public investment is not robust to a change in the ordering of the Cholesky decomposition, and as such it can be considered non robust.

The VAR estimation therefore delivers two messages: the first is that causation runs from public to private investment (the opposite link is not robust to changes in the ordering); the second is that crowding-out dominates for three countries (Germany, the UK, the US), while crowding-in dominates in France. On average for Germany, the UK and the US, the crowding-out lasts one year, whereas the crowding-in effect works one year and a half in France.

### *5.3 Dynamic conditional correlations*

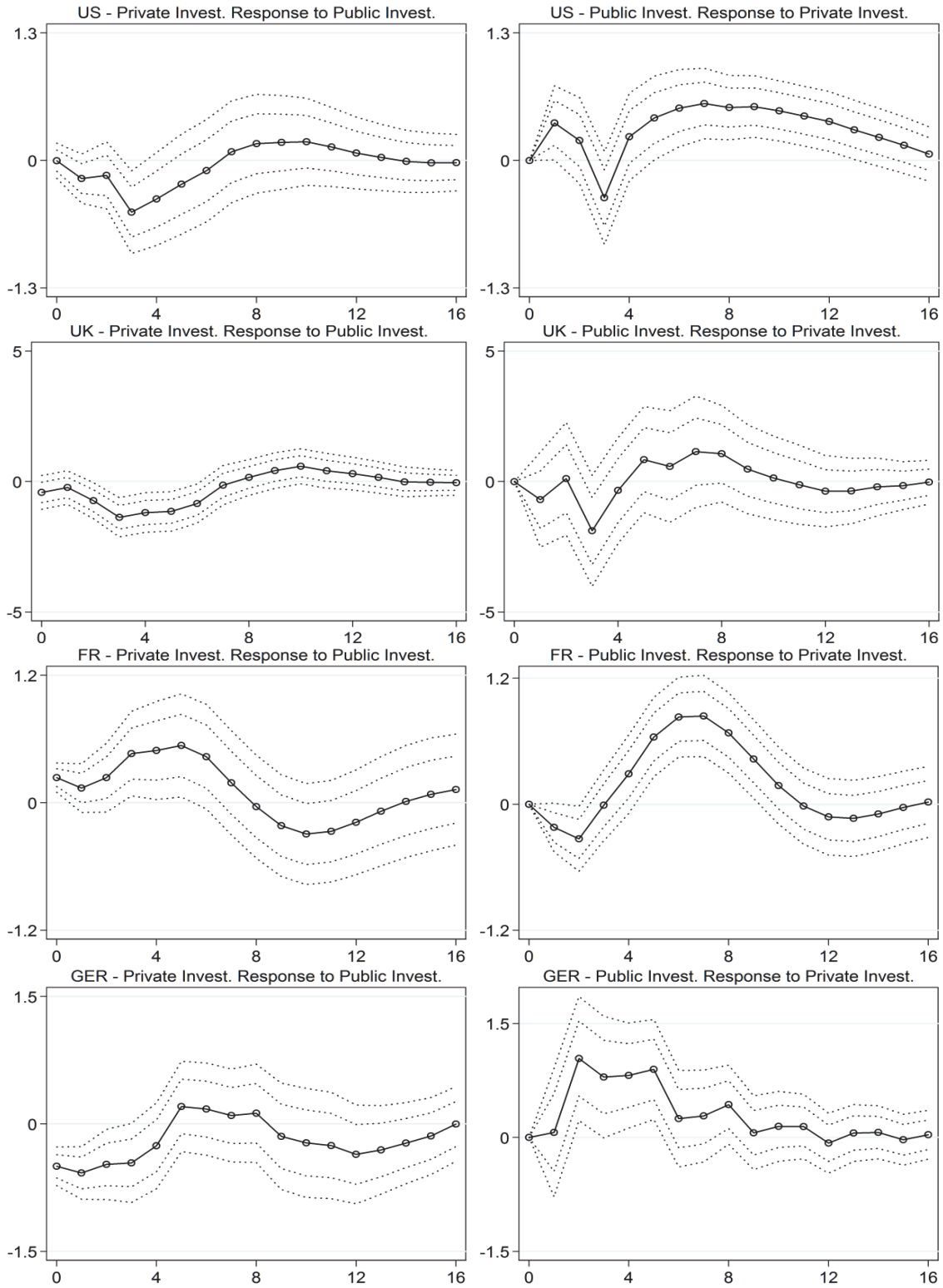
The length of the time span that we considered (almost five decades for the United States, France and the United Kingdom, more than two for Germany) may be responsible for the lack of a clear correlation between public and private investment over the period. Indeed, the existence of structural breaks could affect the results. Therefore, it is certainly worth resorting to a time-varying analysis of correlation to assess whether there have been sub-periods over which the two variables exhibit some degree of correlation. To identify the possibly time-varying relationship between public and private investment, we estimate a time-varying measure of correlations based on the dynamic conditional correlation (DCC) model of Engle (2002), in which the conditional correlation follows a GARCH(1,1) process.

The GARCH model is a specification of both the conditional mean and the conditional variance, where the variance is a function of prior unanticipated innovations $\varepsilon_t^2$ and prior conditional variances $\sigma_t^2$.

$$y_t = \beta Y + \varepsilon_t, \text{with } \varepsilon_t \sim (0, \sigma_t^2)$$

**Figure 4**

**VAR Model: Impulse Response Functions**




Note: The dotted lines represent the 68 and 90% confidence intervals.

$$\sigma_t^2 = y_0 + y_1\sigma_{t-1}^2 + y_2\varepsilon_t^2$$

A DCC-GARCH model (see Engle, 2002) can be viewed as a multivariate representation of a univariate GARCH process from which dynamic covariance is computed from conditional variance. The procedure involves 2 steps: first, estimating the conditional volatility of each individual series and, second, capturing dynamics in the covariance of the standardized residuals from the first stage procedure and using them as inputs to estimate a time-varying correlation matrix.

The vector *Y* includes a constant and a number of lags between 1 and 4 lags (depending on the country and on the convergence properties of the iterative process) of the output gap to control for capacity utilization. We also include into the *Y* vector 1 to 3 lags of total investment, to improve the fit and capture the inertia of both public and private investment.

The resulting time series, capturing the changing correlation of the two variables over time, has been filtered with an HP filter to obtain a smoother series. Figure 5 shows the dynamic correlation between private and public investment for the four countries (we include the original and the filtered series). The country that stands out in this case is the UK, where the correlation is low, unstable with very frequent sign changes. For the other countries, in particular France and the US, we observe rather long periods of relatively stable (positive or negative) correlations. In the US, the 1970s and the most recent years witness a positive correlation, whereas the 1980s show a strong negative correlation. The rising interest rates and public deficits under the Reagan administration were to some extent detrimental to private investment, despite investment incentives (Modigliani, 1988). The negative correlation remained, though at a lower level, until 2013. The timing of correlations for France is opposite to the US': correlation was negative in the late 1960s and 1970s; and it has started being positive in the 1980s when French public deficits were high and the financial system was under liberalization. It remained positive until the global financial crisis. In Germany, the correlation has been low, in comparison with the US and France, and mainly positive over the entire (though short) time span.

These patterns suggest that the relative strength of the crowding-out and crowding-in effects changes over time, and needs to be further investigated.

To conclude, our various exercises of correlation analysis suggest that for 3 countries, the UK, Germany and the US, there is no robust correlation between public and private gross capital formation. France gives a slightly more structured picture, as the two variables seem to have an overall positive relationship. France is also the only country for which there is evidence of crowding in[6], while for the UK and the US estimations point to crowding out (if anything). Dynamic correlation analysis shows that the relationship is unstable, alternating phases of positive and negative correlation. This is true for Germany, France and the US, while for the UK correlation seems erratic, as variance statistics already pointed out, confirming the weakness of the link across all the methods we used.

Nevertheless, the amount of information that can be extracted from simple correlations is limited by the existence of well-known biases. The more important one may be the existence of omitted variables, which may yield spurious correlation, or on the contrary hide actual significant relationships between variables. Other biases may be non-linearity between public and private investment, or non-linearity of the relationship with respect to the business cycle, the existence of lags, and of variability. Even dynamic correlation is not enough to eliminate these biases.

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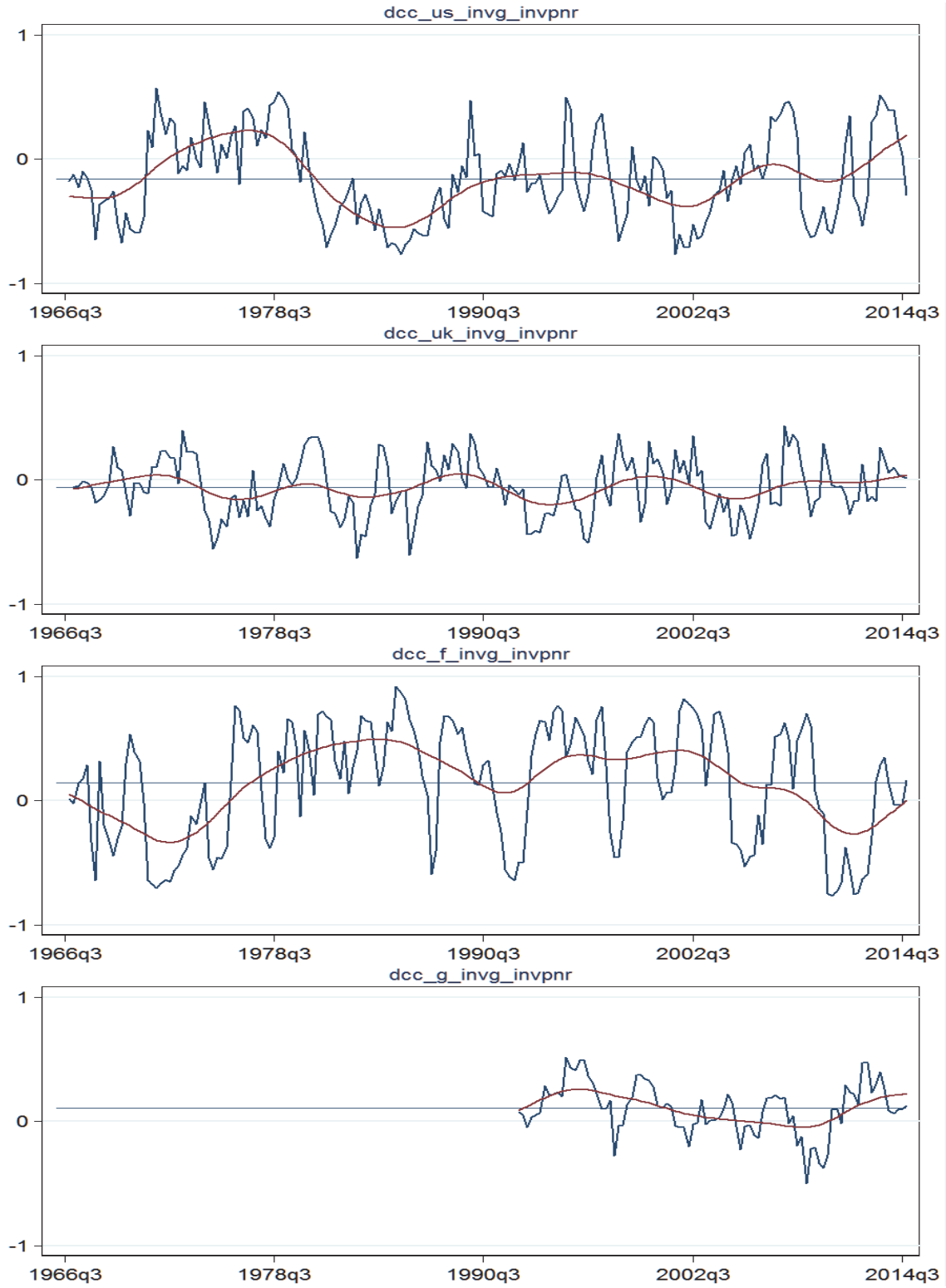
[6] DCC correlations for Germany give only a small crowding-in effect.

**Figure 5**

**Dynamic Conditional Correlations**




Note: The most volatile (blue) line is the DCC, the less volatile (red) line is the HP-trend of the DCC, and the flat line is the mean of the DCC over the sample.

### *5.4 Explaining the time-varying link*

Next, we investigate whether the macro variables used in the VAR can help explain the variation in time of the correlation between private and public investment. We regress the DCC time series (plotted in Figure 5) on the macro variables used in the VAR. To avoid multi-collinearity issues, we eliminate from the regressions public and private rates, and government balance; all these variables exhibit a strong correlation with government debt, which therefore captures all the impact of public finances on the correlation.

Overall, as Table 4 shows, there is heterogeneous evidence of an impact of macroeconomic variables on correlation across the four countries. There is also little evidence of an impact of interactions, except for France, when we try to capture nonlinearities. Coefficients of determination for the UK and Germany are very low and empirical results must be taken with caution. On the contrary, results for France may be considered as rather robust. Results are now discussed in more details.

Private investment has an impact on the correlation only in France, where a positive correlation is associated with higher levels of private investment. We interpret this impact as a requirement for a positive business climate to emerge prior to the unfolding of crowding-in effects in France.

Public investment has a negative impact on the correlation in the US, a direct indication of crowding-out effects. This effect is also present, although much less significantly, for France, except in the model of column 14 which shows that the interaction with public debt is positive. In this latter case, the sum of estimated coefficients of public investment and its interaction with debt is positive, hence a (weak) indication of crowding-in effect.

Inflation impacts the link between private and public investment, maybe through a portfolio effect: higher inflation may push reallocation from financial to real activities. This reallocation concerns private and public investment only in the US, and very weakly in France.

Public debt has differentiated effects on the correlation across sub-groups of countries. It has a negative impact in France and Germany: the correlation between public and private investment is lower if debt is higher, and public and private investments tend to crowd-out one another. On the contrary, for the US and the UK, both investment variables co-move when debt is large. Does this difference relate to fiscal rules: France and Germany, under the Stability and Growth Pact, would reduce public investment when debt grows, all else equal, whereas the US without a federal fiscal rule would not undergo a change in public investment when debt varies? The situation depicted for France and Germany would fit the main conclusion of Mehrotra and Välilä (2006). Notwithstanding the existence of fiscal rules, the difference in the reaction of the correlation between public and private investment to debt between the UK and the UK, on the one hand, and Germany and France, on the other, matches Reicher (2014)'s results. She shows that public debt has no significant impact on government gross investment in the former and a (weakly significant) positive impact in the latter (her Table 4, model 2, p.192).

Finally, the correlation between public and private investment is contingent to the business cycle. The output gap has a strongly significant negative impact on the correlation in France and is less significant in the UK. During booms the possibility of crowding out in both countries would tend to increase. At the opposite, the correlation is instead pro-cyclical for the US, though statistically less significant than in France.

**Table 4**

**Explaining DCC**

| | (1) **US** DCC | (2) **US** DCC | (3) **US** DCC | (4) **US** DCC | (5) **UK** DCC | (6) **UK** DCC | (7) **UK** DCC | (8) **UK** DCC |
|---|---|---|---|---|---|---|---|---|
| invg | -0.008*** | -0.007*** | -0.008** | -0.010 | 0 | 0 | 0 | 0 |
| | [0.00] | [0.00] | [0.00] | [0.01] | [0.00] | [0.00] | [0.00] | [0.00] |
| invpnr | 0.002 | 0.002 | 0.002 | 0.002 | 0.001 | 0.001 | 0.001 | 0.001 |
| | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |
| output gap | 0.016** | 0.016** | 0.016* | 0.016** | -0.007** | -0.008** | -0.007* | -0.007** |
| | [0.01] | [0.01] | [0.01] | [0.01] | [0.00] | [0.00] | [0.00] | [0.00] |
| cpi | 0.044*** | 0.044*** | 0.044*** | 0.045*** | 0.002 | 0.002 | 0.002 | 0.002 |
| | [0.01] | [0.01] | [0.01] | [0.01] | [0.00] | [0.00] | [0.00] | [0.00] |
| debt | 0.424*** | 0.398*** | 0.424*** | 0.438*** | 0.174*** | 0.185*** | 0.176*** | 0.175*** |
| | [0.08] | [0.08] | [0.08] | [0.09] | [0.04] | [0.04] | [0.04] | [0.04] |
| invg * invg | | 0 | | | | 0 | | |
| | | [0.00] | | | | [0.00] | | |
| invg * output gap | | | 0 | | | | 0 | |
| | | | [0.00] | | | | [0.00] | |
| invg * debt | | | | 0.006 | | | | -0.001 |
| | | | | [0.02] | | | | [0.00] |
| const | -0.523*** | -0.501*** | -0.523*** | -0.533*** | -0.177*** | -0.187*** | -0.179*** | -0.177*** |
| | [0.07] | [0.07] | [0.07] | [0.08] | [0.03] | [0.03] | [0.03] | [0.03] |
| N | 193 | 193 | 193 | 193 | 137 | 137 | 137 | 137 |
| $R^2$ | 0.35 | 0.36 | 0.35 | 0.35 | 0.12 | 0.14 | 0.12 | 0.12 |
| | (11) **FR** DCC | (12) **FR** DCC | (13) **FR** DCC | (14) **FR** DCC | (15) **GER** DCC | (16) **GER** DCC | (17) **GER** DCC | (18) **GER** DCC |
| invg | -0.004 | -0.005* | 0.006 | -0.033*** | -0.002* | -0.002 | -0.002 | -0.008 |
| | [0.00] | [0.00] | [0.00] | [0.01] | [0.00] | [0.00] | [0.00] | [0.01] |
| invpnr | 0.014*** | 0.014*** | 0.015*** | 0.016*** | 0.002 | 0.002 | 0.002 | 0.002 |
| | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] | [0.00] |
| output gap | -0.070*** | -0.071*** | -0.068*** | -0.060*** | -0.002 | -0.002 | -0.002 | -0.002 |
| | [0.01] | [0.01] | [0.01] | [0.01] | [0.01] | [0.01] | [0.01] | [0.01] |
| cpi | 0.010* | 0.010* | 0.009 | 0.007 | -0.018 | -0.018 | -0.018 | -0.017 |
| | [0.01] | [0.01] | [0.01] | [0.01] | [0.01] | [0.01] | [0.01] | [0.01] |
| debt | -0.479*** | -0.473*** | -0.470*** | -0.558*** | -0.348*** | -0.347*** | -0.350*** | -0.334*** |
| | [0.10] | [0.10] | [0.09] | [0.09] | [0.11] | [0.11] | [0.11] | [0.11] |
| invg * invg | | 0 | | | | 0 | | |
| | | [0.00] | | | | [0.00] | | |
| invg * output gap | | | 0.007*** | | | | 0 | |
| | | | [0.00] | | | | [0.00] | |
| invg * debt | | | | 0.056*** | | | | 0.008 |
| | | | | [0.01] | | | | [0.01] |
| const | 0.289*** | 0.278*** | 0.296*** | 0.367*** | 0.352*** | 0.353*** | 0.355*** | 0.341*** |
| | [0.08] | [0.08] | [0.08] | [0.08] | [0.09] | [0.09] | [0.09] | [0.09] |
| N | 137 | 137 | 137 | 137 | 90 | 90 | 90 | 90 |
| $R^2$ | 0.64 | 0.64 | 0.67 | 0.69 | 0.15 | 0.15 | 0.15 | 0.15 |
| invg coefficient when: | | | | | | | | |
| high interacted variable | - | - | 0.003 | 0.009** | - | - | - | - |
| | | | [0.00] | [0.00] | | | | |
| low interacted variable | - | - | -0.024*** | -0.015*** | - | - | - | - |
| | | | [0.01] | [0.00] | | | | |

Standard errors in brackets. * p < 0.10, ** p < 0.05, *** p < 0.01.

### 5.5 A state-contingent analysis of the link between private and public investment

We now investigate the direct instantaneous impact of public investment and six other macroeconomic variables on private investment; and include a nonlinear impact of public investment (with a squared term), and interaction terms between public investment and the output gap, public deficit and debt. The specification is close to Furceri and de Sousa (2011), without lags, including a few more interaction terms (public deficit and debt), and testing for the impact of public investment rather than government consumption' on private investment.

Table 5 shows the results. Columns (1), (5), (11), and (15) report the baseline regressions for each of the 4 countries. In this case, Germany has the higher $R^2$. The output gap has the expected sign (positive) and is significant for all the countries. Prices do not have an impact on private investment except for France and Germany for which it is strongly negative. Reading this result together with Table 4, shows that contrary to the intuition the portfolio reallocation effect mostly happens through public investment. Public debt has a negative impact for France, and no impact for the other countries.

Coming to public investment, it has generally no impact on private investment, except for France, where there is evidence of crowding-in effect. Nonlinearities play no role at all.

Overall, these results confirm the ones we found above: The only country for which there is evidence of crowding-in effect is France. France therefore seems to fit the Leeper *et al.* (2010) theoretical framework discussed in Section 3. No significant or robust result appears for the UK and Germany. For the US there is moderate evidence of crowding out.

Our results are partially at odds with Furceri and Sousa (2011), who run estimations on 145 countries, including the four we focus on. They test crowding-in versus crowding-out effects *via* the effect of government *consumption* on either private consumption or investment. They show that in Germany, the UK and the US, higher government consumption produces a significant decrease in private investment, whereas no significant effect can be found in France. For the US these results can be read in comparison with Blackley (2014), who finds that US government purchases have a significant negative impact on private investment (crowding-out). He also shows that composition matters: public investment positively impinges on private investment (crowding-in), whereas public consumption and military purchases reduce private investment (crowding-out). Our analysis shows that the sign and intensity of the relationship depends to some extent on other variables (in particular public finances).

### 5.6 Spillovers

Our final exercise is to test for the existence of possible spillovers from foreign public investment on domestic private investment. The most direct effect would be *via* increased growth and imports that in turn boost growth and investment in partner countries. For countries with very strict ties as for example the Eurozone countries, an interest channel could also play: with integrated financial markets, public investment may drive up interest rates across the border, with a negative effect on the partner country private investment level (for more details, the reader is referred to Auerbach and Gorodnichenko, 2012).

We regress private investment on the same variables as those appearing in Table 5, adding for each regression public investment in the three other countries among the exogenous variables. Table 6 displays some spillover effects. As rough as they are, the results are broadly in line with what could be expected. In France and in Germany, private investment is positively affected by public investment in the largest economy, the US. The German economy, traditionally reliant on

**Table 5**

**Explaining Private Investment**

| | (1) **US** invpnr | (2) **US** invpnr | (3) **US** invpnr | (4) **US** invpnr | (5) **UK** invpnr | (6) **UK** invpnr | (7) **UK** invpnr | (8) **UK** invpnr |
|---|---|---|---|---|---|---|---|---|
| invg | 0.065 | 0.012 | 0.18 | 0.356 | -0.015 | 0.003 | -0.011 | -0.145 |
| | [0.07] | [0.08] | [0.13] | [0.24] | [0.03] | [0.04] | [0.06] | [0.19] |
| output gap | 2.121*** | 2.087*** | 2.011*** | 2.069*** | 1.149** | 1.184** | 1.137** | 1.185** |
| | [0.23] | [0.23] | [0.25] | [0.23] | [0.45] | [0.45] | [0.47] | [0.45] |
| cpi | 0.118 | 0.118 | 0.1 | 0.015 | -0.479 | -0.469 | -0.479 | -0.445 |
| | [0.19] | [0.19] | [0.20] | [0.21] | [0.29] | [0.29] | [0.29] | [0.30] |
| debt | -4.591 | -3.19 | -4.184 | -6.203* | -8.662 | -9.504* | -8.569 | -8.930* |
| | [2.89] | [2.99] | [2.92] | [3.16] | [5.36] | [5.46] | [5.49] | [5.39] |
| invg * invg | | 0.015* | | | | -0.001 | | |
| | | [0.01] | | | | [0.00] | | |
| invg * output gap | | | 0.038 | | | | 0.002 | |
| | | | [0.04] | | | | [0.02] | |
| invg * debt | | | | -0.699 | | | | 0.294 |
| | | | | [0.56] | | | | [0.41] |
| const | 12.523*** | 11.186*** | 12.068*** | 13.693*** | 11.793*** | 12.596*** | 11.709*** | 11.951*** |
| | [2.39] | [2.50] | [2.43] | [2.56] | [3.70] | [3.82] | [3.84] | [3.71] |
| N | 196 | 196 | 196 | 196 | 137 | 137 | 137 | 137 |
| $R^2$ | 0.31 | 0.32 | 0.32 | 0.32 | 0.07 | 0.08 | 0.07 | 0.07 |
| | (11) **FR** invpnr | (12) **FR** invpnr | (13) **FR** invpnr | (14) **FR** invpnr | (15) **GER** invpnr | (16) **GER** invpnr | (17) **GER** invpnr | (18) **GER** invpnr |
| invg | 0.310*** | 0.251*** | 0.153 | 0.610*** | -0.035 | -0.048 | 0.006 | 0.427 |
| | [0.08] | [0.09] | [0.13] | [0.22] | [0.05] | [0.05] | [0.06] | [0.31] |
| output gap | 2.351*** | 2.274*** | 2.273*** | 2.208*** | 3.014*** | 3.006*** | 2.916*** | 3.031*** |
| | [0.31] | [0.32] | [0.31] | [0.33] | [0.23] | [0.23] | [0.24] | [0.23] |
| cpi | -0.660*** | -0.639*** | -0.631*** | -0.620*** | -1.343*** | -1.358*** | -1.488*** | -1.561*** |
| | [0.16] | [0.16] | [0.16] | [0.16] | [0.45] | [0.45] | [0.46] | [0.47] |
| debt | -13.219*** | -12.762*** | -13.113*** | -12.185*** | -0.599 | -0.698 | -1.094 | -1.803 |
| | [2.81] | [2.83] | [2.80] | [2.89] | [4.47] | [4.47] | [4.45] | [4.50] |
| invg * invg | | 0.012 | | | | 0.003 | | |
| | | [0.01] | | | | [0.00] | | |
| invg * output gap | | | -0.100 | | | | 0.038 | |
| | | | [0.06] | | | | [0.03] | |
| invg * debt | | | | -0.597 | | | | -0.72 |
| | | | | [0.42] | | | | [0.47] |
| const | 15.039*** | 14.345*** | 14.658*** | 13.986*** | 8.134** | 8.009** | 8.501** | 9.354** |
| | [2.23] | [2.30] | [2.23] | [2.34] | [3.51] | [3.52] | [3.50] | [3.58] |
| N | 137 | 137 | 137 | 137 | 92 | 92 | 92 | 92 |
| $R^2$ | 0.42 | 0.43 | 0.43 | 0.43 | 0.68 | 0.68 | 0.69 | 0.69 |

Standard errors in brackets. * p < 0.10, ** p < 0.05, *** p < 0.01.

exports, also benefits from larger levels of public investment in France. The contrary does not hold, and a public investment push in Germany seems to have a negative impact on French private investment. Somewhat surprisingly, private investment in the traditional partner of the US, the UK, is unaffected by what happens in the other countries.

It is noteworthy that the introduction of spillover effects in the regression of French private investment does not modify the crowding-in effect, which is still statistically significant at the 5% threshold. On the contrary, CPI and debt are no longer significant.

**Table 6**

**Spillovers**

| | (1) **US** invpnr | (2) **UK** invpnr | (3) **FR** invpnr | (4) **GER** invpnr |
|---|---|---|---|---|
| us_invg | -0.170 | 0.383 | 0.782*** | 0.292** |
| | [0.22] | [0.33] | [0.12] | [0.13] |
| uk_invg | -0.037 | -0.016 | -0.007 | -0.003 |
| | [0.03] | [0.05] | [0.02] | [0.02] |
| f_invg | 0.135 | -0.126 | 0.254** | 0.287*** |
| | [0.16] | [0.24] | [0.10] | [0.10] |
| g_invg | -0.112 | -0.155 | -0.117** | -0.091* |
| | [0.09] | [0.13] | [0.06] | [0.05] |
| output gap | 0.551 | 1.416** | 3.239*** | 2.983*** |
| | [0.51] | [0.55] | [0.34] | [0.21] |
| cpi | 2.714*** | -1.028 | -0.776 | -0.373 |
| | [0.76] | [1.03] | [0.65] | [0.51] |
| debt | 0.44 | -3.106 | -6.455* | 8.880* |
| | [6.13] | [6.35] | [3.45] | [5.07] |
| const | -0.317 | 8.672* | 10.880*** | -0.304 |
| | [6.24] | [5.06] | [3.17] | [4.19] |
| N | 92 | 92 | 92 | 92 |
| $R^2$ | 0.269 | 0.107 | 0.603 | 0.732 |

Standard errors in brackets. * p < 0.10, ** p < 0.05, *** p < 0.01.

## 6 Conclusion

This paper contributes to the literature on the impact of public investment in the economy, by focusing on the direct link between private and public investment. Our contribution is original in that we perform a number of exercises trying to assess the robustness of the link, and to determine whether crowding in or crowding out dominates. As the correlation analyses show, raw data do not allow to determine a clear relationship.

Our analysis gives a few results. First, thanks to the VAR estimation we determine that causation, if any, runs from public to private investment. When trying to assess the sign of this causation, then, we conclude that for France there is reasonable evidence of textbook-like effects: increases of public investment generally trigger increases of private investment, unless the economy is overheating and/or public finances are in dire conditions. For the United States instead, the link is in general weaker, and tends to point to prevailing crowding out effects, except for very low levels of public debt. The same can be said for Germany, where nevertheless the relationship is even weaker than for the US. The UK stands out as the country for which the results are more inconclusive. In fact, this was somehow to be expected, as the descriptive statistics of Table 1 show much larger variability than for the other countries. Moreover, the sequence of institutional changes certainly blurred the impact of public investment in the UK: the Code for Fiscal Stability was adopted in 1998 and paved the way for an impetus of public investment, but it was finally abandoned on the onset of the global financial crisis. Thus, noise is likely to have hidden the possible relationship between both public and private investment. Our policy recommendation is therefore only directed towards France for which a stimulus plan centered on public investment would have a chance of lifting private investment from its current low levels.

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# ASSESSING POLICY OPTIONS FOR THE EU COHESION POLICY 2014-2020

*Andries Brandsma,[*] Francesco Di Comite,[*] Olga Diukanova,[*] d'Artis Kancs,[*]*
*Jesus López Rodríguez, [*] Damiaan Persyn[*] and Lesley Potters[*]*

*In this paper, we estimate the impact on GDP of Cohesion Policy 2014-2020 for 267 EU regions running a set of simulations with RHOMOLO, a spatial CGE model tailored for economic analysis at the subnational level. We do so by treating the different parts of Cohesion Policy as exogenous and independent shocks, which are first considered separately and then combined to estimate an overall effect. Our simulation suggests that European regions display significant heterogeneity in their deviations from the baseline due to Cohesion Policy, both in absolute terms and relative to the amounts received.*

## 1 Introduction

In this paper we present the expected impact of the Cohesion Policy 2014-2020 on EU regions based on simulations using RHOMOLO, a spatial Computable General Equilibrium (CGE) model designed to provide ex-ante policy impact assessment at the regional level (see Brandsma *et al*, 2015). The different budget lines of Cohesion Policy are implemented as exogenous shocks. First separately and then combined into an overall effect. The paper has been organised as follows. First, Section 2 gives a short description of what Cohesion Policy is, to get an idea of its importance and magnitude. Section 3 provides a technical description of RHOMOLO, touching upon its' structure, characteristics and dynamics. Section 4 describes in detail the design of the four main scenarios that have been simulated (Human Capital, R&D, Non-R&D and Infrastructure investments) and Section 5 presents the outcomes of these simulations with respect to the non-policy baseline. Finally, Section 6 concludes.

## 2 Background information on Cohesion Policy

The EU Cohesion Policy, also known as Regional Policy, is one of the oldest and most important policy instruments of the European Union, absorbing roughly one third of the entire EU budget and involving every region of each Member State. It is designed as an investment policy which is expected to kick-start growth, employment, competitiveness and development on a sustainable basis.

The commitment to develop a common regional policy for development dates back to the Treaty of Rome, which instituted the European Economic Community in 1957, but its actual operationalization evolved substantially over time, following institutional changes and the EU enlargement. Currently, the Cohesion Policy is structured as the combination of three instruments (European Regional Development Fund, European Social Fund and Cohesion Fund) aimed at achieving three main objectives following the strategic guidelines inspired by the Europe 2020 growth strategy: convergence, competitiveness and territorial cooperation.

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[*] European Commission, DG Joint Research Centre, IPTS Institute, Seville (Spain).

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Each instrument is designed to address a different set of objectives and target different stakeholders:

- The Cohesion Fund is aimed at Member States with a Gross National Income (GNI) per capita of less than 90 per cent of the EU average and supports actions in the framework of the convergence objective. The main activities concerned include trans-European transport networks and environmental sustainability, notably in the fields of energy or transport (e.g., supporting energy efficiency, the use of renewables, public transport, intermodality and so on);
- The ESF (European Social Fund) is meant to support Member States in their labour market policies in the framework of the convergence and competitiveness objectives. The areas covered by the ESF include policies aimed at fostering lifelong learning schemes, reducing search and matching costs in the labour market, promoting social integration, combating discrimination and strengthening human capital by reforming education systems;
- The ERDF (European Regional Development Fund) aims to support Regions in order to strengthen economic and social cohesion and correct imbalances. It deals with the three objectives of Cohesion Policy (convergence, competitiveness and territorial cooperation) by directly financing private investments policies; physical infrastructures (linked to R&D, telecommunications, environment, energy or transport); financial instruments to support regional and local development and cooperation; technical assistance measures.

Cohesion Policy Funds are provided taking into account the principles of additionality, concentration, programming and partnership. Additionality requires that contributions from the Structural Funds must not replace public or equivalent structural expenditure by a Member State in the regions concerned by this principle. Concentration refers to local concentration (the majority of the funds will be located in the poorer regions), concentration in objectives (growth and jobs) and concentration in time (must be spent three years after allocation). Programming means that the funds are used for multi-annual national programmes aligned on EU objectives and priorities. Finally, partnership aims at development through a collective process involving authorities at European, regional and local level, social partners and organisations from civil society.[1]

To give an idea of the potential impact of Cohesion Policy, the combination of the Structural Funds (ESF and ERDF) and the Cohesion Fund amounted to roughly €347 billion or 0.3 per cent of the EU27 GDP in the last programming period 2007-2013, although this can go up to 4 to 5 per cent of GDP due to the principle of concentration in certain targeted countries and regions.

### *2.1 Cohesion Policy 2014-2020: Overall envelope*

The European Commission has adopted a draft package of the Cohesion Policy for 20142020. The new proposals are focused on the "Europe 2020" objectives mainly targeting growth and jobs. For an ex-ante assessment of its impact, the planned regional investments are introduced into RHOMOLO. Section 4 will explain in detail the design of the simulations and Section 4.4 presents the results. See Table 1 for basic descriptive data on expenditures per type of region and expenditure category.

The total amount of Cohesion Policy is divided over 86 categories of expenditure (see Annex 2) that have been merged into five main budget lines for being able to toggle the adequate parameters in the model. The policies under these headers are quite diverse and, as a consequence, the assumptions as to which exogenous parameters of the model are affected and how, are necessarily quite strong.

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[1] See http://ec.europa.eu/regional_policy/index_en.cfm for more detailed information about Regional Policy.

**Table 1**

**Details on Cohesion Policy Expenditures**
**The Four French Regions that Are Not in RHOMOLO Are Not Taken into Account**
*(millions of euros)*

| Region Type[2] | # | GDP 2007 | RTDI | Aid to Private Sector | Infra-structure | Human Capital | Technical Assistance | Total | % |
|---|---|---|---|---|---|---|---|---|---|
| **Less Developed Regions** | 65 | 1,147,683 | 25,250 | 27,127 | 129,128 | 38,408 | 12,162 | 232,075 | 68% |
| **Transition Regions** | 51 | 1,407,194 | 5,772 | 6,218 | 14,339 | 10,201 | 1,585 | 38,115 | 11% |
| **More Developed Regions** | 151 | 9,120,647 | 10,916 | 9,101 | 24,167 | 24,196 | 2,954 | 71,335 | 21% |
| **Total** | 267[3] | 11,675,524 | 41,938 | 42,447 | 167,634 | 72,805 | 16,701 | 341,525 | 100% |
| **percent of total CP** | | | 12% | 12% | 49% | 21% | 5% | 100% | |

Funds designated to *Human Capital* aim at bringing improvements to the labour markets by investing in training and education of employees. As can be seen, the vast majority (68 per cent) of the funds is destined to the Less Developed Regions. The joint human capital expenditures are assumed to translate into an improvement of labour productivity in the model. The full setup of the simulation is discussed in Section 4.1.

Funding for *Research, Technical Development and Innovation* (RTDI) is aimed at supporting firms of in the process from basic research to actual implementation of innovations. The RTDI related expenditures are assumed to affect the research and development capacity of the economy, which is translated into changes in the total factor productivity (TFP) parameter of the model. Section 4.2 discusses these simulations in detail.

The category *Aid to Private Sectors* aims at supporting non-R&D activities, which play an important role in the economic development of countries and regions by positively affecting their TFP growth. These non-R&D innovation activities consist e.g. of technology and know-how acquisitions, such as machinery and other equipment patents, trademarks, designs, etc. In Europe, about 40-60 per cent of the industrial value-added and 50 per cent of all industrial employees are engaged in the non-R&D intensive sector (Som, 2012). Moreover, more than half of all innovating firms in the EU are non-R&D performers (Arundel *et al.*, 2008). Therefore, considering the high shares of funding devoted to the non-R&D activities and the importance of these activities in the promotion of innovation and TFP growth in Europe, it is important to evaluate the ex-ante short and long term effects of the planned regional non-R&D investments across EU regions. More details are provided in Section 4.3.

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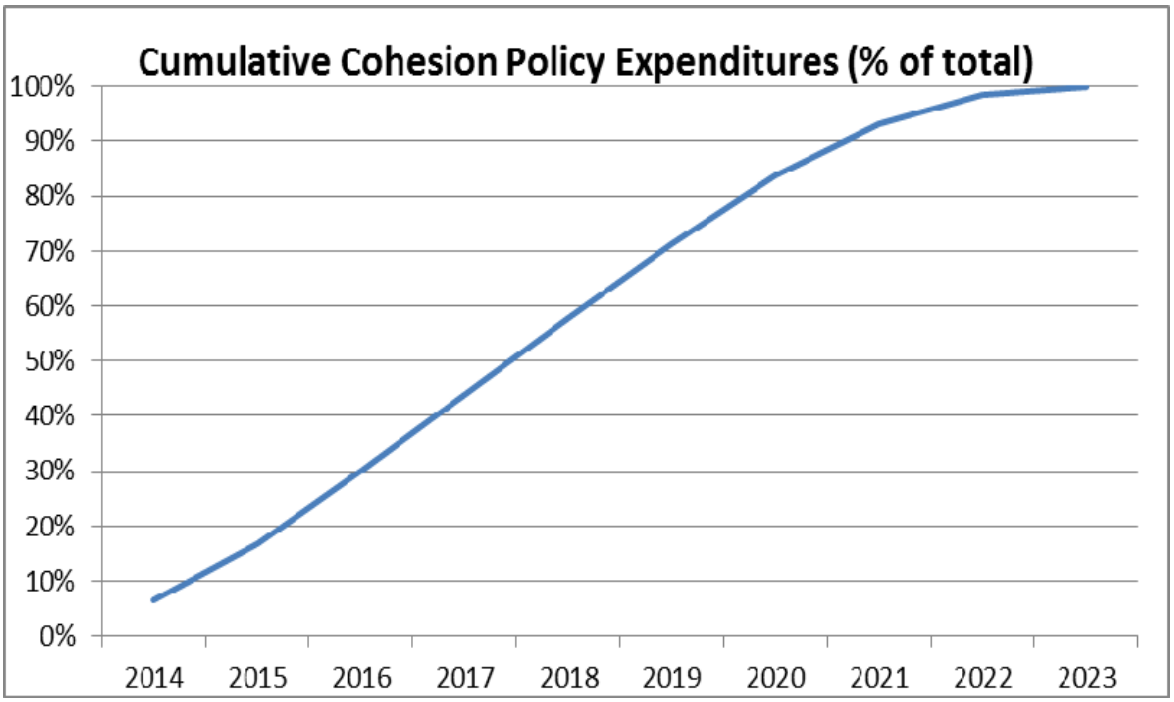
[2] Less Developed Regions are defined as having a GDP per capita that is less than 75 per cent of the EU27 average. The GDP per capita of the Transition Regions is between 75 and 90 per cent of the EU27 average and for the More Developed Regions this is above 90 per cent.

[3] The EU27 has a total of 271 NUTS2 regions, but 4 French regions were left out because of their very particular characteristics: Guadalupe, Martinique, Guyana and Réunion. Croatia recently joined the EU, but has not yet been introduced into the model.

**Figure 1**

**Time Profile of Cohesion Policy Expenditures**




Cohesion Policy funds aimed at *Infrastructure* mainly support regions in improving connectivity within the region and between other regions, focussing on railways, motorways and airports, as well as environmental and social infrastructure. These policies in general will decrease transport costs, as well as the general cost of firms for doing business with other regions such as communication costs, be it for selling final goods or sourcing intermediates. These investments will be modelled as decreasing the transport costs. The setup is discussed more in detail in Section 4.4.[4]

### *2.2 Cohesion Policy 2014-2020: Time profile*

Based on experience from passed Framework Programmes, the *expenditure* period for the funds is from 2014 to 2023, taking into account the N+3 rule.[5] The time profile is shown in Figure 1.

## 3 Technical description

The RHOMOLO model is calibrated to the regionalised Social Accounting Matrices (SAMs) of the EU member states that were extracted from the World Input-Output Database (WIOD). SAMs for the NUTS2 regions were constructed using the data of regional production by sector,

[4] Notice that, given its size in the overall budget and the difficulty to model it in a consistent way, the category Technical Assistance has not been modelled. It mostly concerns technical support given to regions or other local authorities in streamlining bureaucratic procedures and public programming and auditing.

[5] If the funding in question has not been spent by 2020, the Commission can 'decommit' future budget allocations.

bilateral trade flows among the NUTS2 regions and trade with the rest of the world (ROW), as described by Potters *et al.* (2013). The version of the model used for this paper includes 6 NACE[6] Rev. 1.1 industries: Agriculture (AB), Manufacturing (CDE), Construction (F), Transport (GHI), Financial Services (JK) and Non-market Services (LMNOP). An illustration of the SAMs used for RHOMOLO is shown in Annex 1.

EU regions are modelled as small open economies that accept EU and non-EU prices as given, which is consistent with the regional scope of the model. In this perspective, EU external relations involve only one non-EU trading partner that is represented by the ROW aggregate.

Interregional trade flows are estimated based on prior information derived from the Dutch PBL dataset (see Thissen *et al.*, 2013). Data on bilateral transport costs per sector are provided externally by the TRANSTOOLS model,[7] a model covering freight and passenger movements around Europe. The costs of different shipments are calculated in terms of share of the value shipped, based on the time needed to reach the destination using alternative modes of transport. Transport costs thus differ by type of good and depend on the distance between the regions and the variety and characteristics of modes of transport connecting them, which also means that they can be asymmetric. The representation of trade and transport flows among the NUTS2 regions gives the model a spatial dimension, indicating that EU regions differ not only in their stocks of production factors but also in geographic location.

Mobility of capital and labour is assumed to occur within regions, but international or intra-regional migration of production factors is not considered in the core model version.

Because of the models' large dimensionality (268 of NUTS2 regions, 6 sectors, 10+ years modelling horizon), a rather simple approach to introduce dynamics has been applied that rests on the assumptions of exogenous growth, which is in line with Solow's model (Solow, 1956). The main advantage is that this type of dynamics does not require a time index in the core equations. All agents of the model have myopic expectations and cannot anticipate future changes in relative prices or make choice between consumption and savings depending on the interest rate. Using a perpetual inventory method (OECD, 2001), the sum of interest rate and depreciation rate are employed to estimate the regions' capital stocks from the value of their operating surplus, as available in the SAMs. The interest rate is set at the level of 5 per cent and the capital depreciation rate at 6 per cent per annum. In order to keep the model baseline "clean" of trade spillovers that change relative prices and induce sectorial changes, we apply a uniform 2 per cent annual growth rate to all regions.

The model solves for the sequence of equilibrium states when all time periods are connected with the equation of capital accumulation: each year in each region a portion of capital stock depreciates and gets augmented by the previous year investments, so that capital stock and investments grow at the same rate with the rest of economy. Values of inventory changes and investments in each region are adjusted in order to achieve consistency among the observed investments, the estimated capital stock and the required replenishment of the capital stock. Therefore, there are no changes in regions' economic structures over the steady-state baseline period. All prices remain constant; only the quantities grow at the same constant rate. As such, we get clearer insights by comparing the after-shock results with the baseline values.

The core model equations are specified in a calibrated share format proposed by Rutherford (1999), programmed in GAMS as a mixed complementarity problem (Mathiesen, 1985) and solved using a PATH solver.

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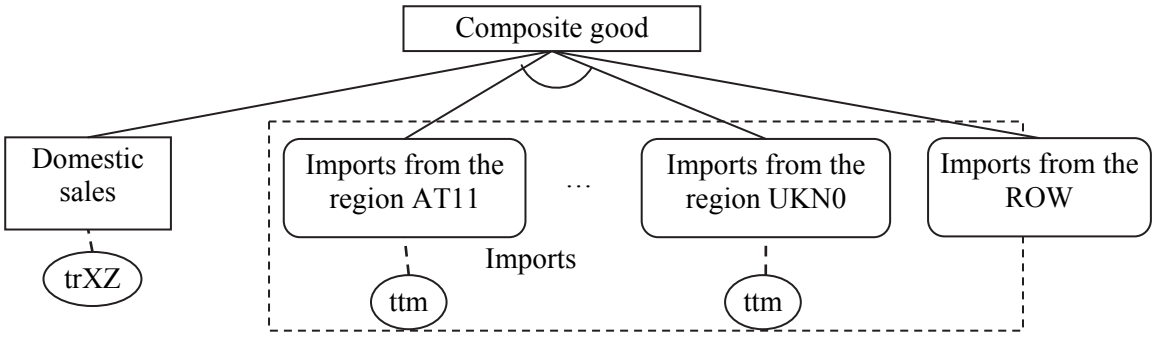
[6] See http://epp.eurostat.ec.europa.eu/statistics_explained/index.php/Glossary:NACE

[7] See Burgess *et al.* (2008) or visit http://energy.jrc.ec.europa.eu/TRANS-TOOLS/TT_model.html

**Figure 2**

**Composite of Domestically-produced and Imported Varieties of the Same Good**




### *3.1 Market equilibrium*

#### *3.1.1 Composite of domestic and imported varieties*

Domestically produced and imported varieties are combined to form a composite good. Trade and transport margins are applied to imports from other NUTS2 regions (*ttm*) and to domestic sales (*trXZ*). Following this specification, the structure of this good is depicted in Figure 2.

Composite goods are consumed by industries, households, government and the investment sector.

#### *3.1.2 Industries' nested cost function*

The lower level of the sector's production function features a combination of labour and capital services, which are then combined with intermediate inputs. Coefficients of factor productivity improvements are assigned to labour (*fpl*) and capital (*fpk*).

With this specification, producers can maintain the same levels of output using less production factors. The same structure of nested production functions is adopted for all sectors (see Figure 3).

#### *3.1.3 Household and Public utility*

The top level of nested household utility function combines the consumption of final goods and savings (see Figure 4). Zero substitutability between consumption and savings is assumed. On the second level of nesting, final goods were combined with the Cobb-Douglas function.

The structure of public utility is identical to that of households and is described in Figure 4.

#### *3.1.4 Investment sector*

The investment sector combines in fixed proportions the final goods, transfers and inventory changes (see Figure 5). Transfers between investment sector, the EU and ROW are expressed on a net basis. The tax rate on output of regional investment good is defined as a lump-sum transfer to the government.

**Figure 3**

**Sector's Nested Production Function**

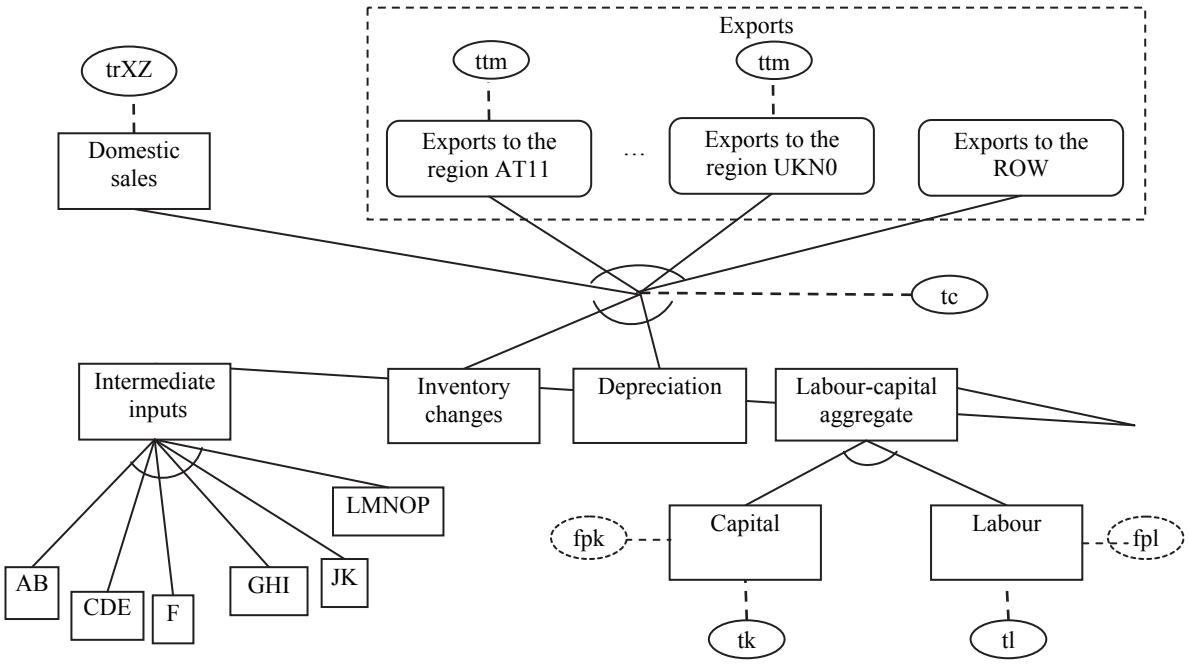
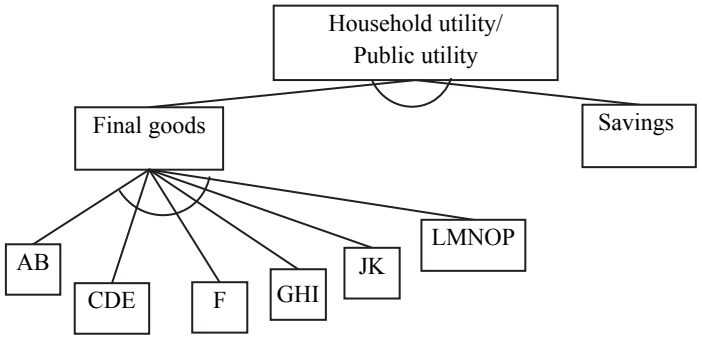



**Figure 4**

**Structure of Regional Household Expenditures and Public Expenditures**




*3.1.5 Inventory changes*

Inventory changes combine final goods and transfers (see Figure 6**).** This entity pays taxes on output, which is defined as lump-sum transfer to the government. Transfers between regional inventory changes, the EU and ROW are expressed on a net basis.

**Figure 5**

**Structure of Regional Investment Demand**

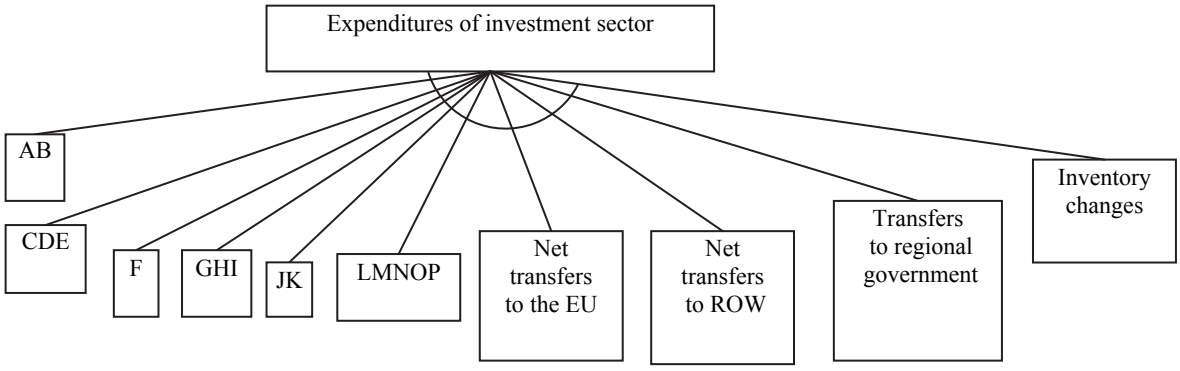
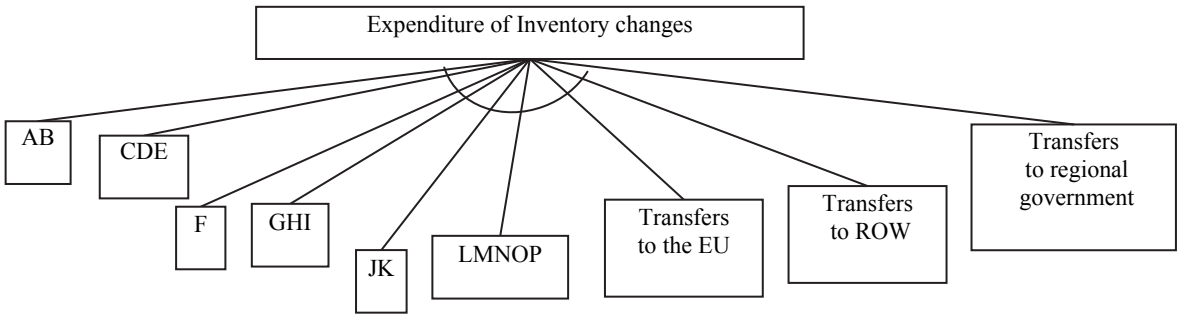



**Figure 6**

**Structure of Regional Demand of Inventory Changes**




### *3.2 Market clearing conditions*

In order to specify the market clearance conditions, we derived the supply and demand functions of the primary factors, intermediate inputs or final goods by differentiating the profit or cost function by the price of that good (Hotelling's and Shephard's lemmas).

#### *3.2.1 ROW closure*

Following a common approach, the ROW closure was specified as equality between the sum of regional exports to the ROW, the sum of regional imports to the ROW plus the balancing constraint. We fix the exchange rate and use the producer price index as *model numéraire*.

### *3.3 Budget balance*

#### *3.3.1 Households*

According to the information provided in the regional SAMs, households supply labour and capital services, pay taxes from their endowment of labour and capital, receive net transfers from the public sector and also net transfers from abroad. In the current model version, taxes on labour

and capital endowment are modelled as lump-sum transfers from the households to the regional government. Disposable income of regional households is fully spent on their consumption of final goods and savings.

### *3.3.2 Public sector*

According to the SAMs, income of regional government consists of taxes on sectors' output, sectors' consumption of labour, capital services, taxes on regional investment good and inventory changes, net transfers abroad and net transfers from regional households. Disposable income of regional governments is fully spent on their consumption of final goods and savings.

## 4 Scenario construction

### *4.1 Human capital related policies*

The budget line Human Capital of the Cohesion Policy program combines a wide variety of measures. Some measures aim at fostering re-integration of long-run unemployed on the labour market, while others pertain to improving life-long learning or on the job training. To simulate the effects of cohesion expenditure on human capital in RHOMOLO, this wide variety of measures has to be translated into an exogenous change to the model by assuming that these expenditures lead to an increasing regional labour productivity (the *fpl* parameter), at the cost of a temporary decrease in the local labour supply.

Next, a choice is required as to how efficient the policy is to improve regional labour productivity. For this, we assumed that the relative human capital stock increase in a region induced by Cohesion Policy equals the relative size of the cohesion expenditure with respect to the local expenditure on education, taken from EU KLEMS (Timmer *et al.*, 2007). Next, we turned to the general literature, where it is found broadly that increasing the stock of human capital by 1 per cent leads to an increase of 0.3 per cent in output per worker (Sianesi and Van Reenen, 2003).

In the initial years of the policy implementation, labour supply simultaneously is assumed to decrease and remains subdued during the programming period. After the programming period, labour supply recovers to its original level.

Future work will focus on the stark assumptions made for these simulations. Firstly, the homogeneity of the labour productivity increase between countries for a given percentage increase relative to local education expenditure will be relaxed, as it seems likely that not all countries and regions would benefit equally from an increase in the human capital stock. Secondly, policies will be separated out which may be expected to operate not through increasing labour productivity, but rather e.g. through improving labour market efficiency.

### *4.2 R&D investments*[8]

In the 2014-2023 period, €42 billion have been allocated to lines of expenditure[9] related to the support to RTDI. This is 12 per cent of the grand total of Cohesion Policy funds; 60 per cent of this goes to the less developed regions, a lower percentage than the 70 per cent across all budget lines.

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[8] Notice that, in the next versions of RHOMOLO, the regional R&D sector modelled in this paper will be replaced with a national R&D sector with positive externalities at the regional level.

[9] These lines are 01-09, 11-15 and 74, see Annex 2.

The current version of RHOMOLO uses the TFP to channel the support to RTDI. There is considerable empirical evidence of the effect of R&D on TFP, very well elaborated in Hall *et al.* (2009). The Cohesion Policy investment is first expressed as an increase in R&D intensity compared to the baseline and subsequently a TFP equation is used to model the increase in TFP resulting from R&D. This is the most standard formulation derived in Hall *et al.* (2009) which is reproduced here in a distributed lag format, reflecting that it takes time for an investment in R&D to be turned into innovation and consequently a productivity improvement. The TFP equation is as follows:

$$TFP_{reg} = \gamma * TFP(-1) + (1-\gamma) * \left(b_0 + b_1 * \frac{RTDI_{reg,sec}}{GDP_{reg}} + b_2 * \frac{RTDI_{reg,sec}}{GDP_{reg}} * TFPgap_{reg,reg*} + b_3 * TFPelsewhere\right) + \varepsilon \quad (1)$$

where $TFP_{reg}$ represents the level of regional TFP at a given point of time that subsequently has an impact on the total output. The term $\frac{RTDI_{reg,sec}}{GDP_{reg}}$ is the R&D intensity for each sector in each region. The second explanatory variable is the combined interaction between the average R&D and the gap in TFP with the leading region.

The third term between brackets represents the possible spillovers from TFP increases in other regions and sectors ($TFPelsewhere$). These spillovers are the key reason why the social return on R&D exceeds the private return and thereby would justify public investment and support to R&D in the private sector. This is a topic of empirical research taken up by Belderbos and Mohnen (2013), who propose a patent citation-based indicator to measure the presence of intra- and inter-sectoral knowledge spillovers, nationally as well as cross-border. This could possibly at a future stage be transformed into a spatial structure for the spillovers between regions but for the moment b3 is set to zero.

Kancs and Siliverstovs (2015) conclude that R&D rates of return in developed economies are strongly positive and may be as high as 75 per cent, although they are more likely to be in the 20 to 30 per cent range. This estimate is introduced in the model by setting a rate of return. This is close to the estimate used in QUEST III (McMorrow and Röger, 2009).

The empirical evidence on the spillover effect and catching-up is not as strong, but it is likely that the farther away from the technology frontier the greater the potential for catching up, conditional on the ratio of R&D to GDP. This is introduced in the model by a multiplicative term expressing that the higher the R&D intensity the greater the part of the TFP gap that is closed every year. An increase in RTDI expenditure compared to the baseline will set in motion this process, which is assumed to operate with the same distributed time lag and coefficient as the R&D effect on its own. This would approximate a doubling of the rate of return on RTDI for regions which are at $TFP = 1$ compared to the technology frontier ($TFP = 2$).[10] The estimates behind this specification are confirmed by the econometric research of Kancs and Siliverstovs (2015).

### *4.3 Non-R&D subsidies*

Innovation can take place through activities which do not require R&D such as the purchase of advanced machinery, patents and licenses, training related to the introduction of new products or processes, etc. These forms of acquiring knowledge and technology are referred to as non-R&D

[10] Luxembourg, Brussels and Greater London are excluded from the frontier, because they are financial centres with a very high TFP in the data.

(NR&D) innovation activities. From the policy point of view it is important to analyse the impact of NR&D subsidies since the European Commission devotes an important portion of their budgets to finance them. In the Cohesion Policy 2014–2020, around €41 billion are devoted to NR&D activities. The current version of RHOMOLO analyses its impact considering that the main channel of influence of these activities is through their impact on TFP. We employed the our previous estimations of TFP elasticity with respect to the NR&D investments $(\gamma_3 + \gamma_1 \overline{Ird})$[11]. Mathematically, the following expressions have been used to estimate the shifts on TFP due to Non-R&D funds:

$$gTFP_{reg,t} = (\gamma_3 + \gamma_1 \overline{Ird}) \left( \frac{NR\&D_{t-1,reg}}{GDPbau_{t-1,reg}} \right) \quad (2)$$

$$TFP_{reg,t} = gTFPbau_{reg,t} + gTFP_{reg,t\ 3}) \quad (3)$$

where $gTFP_{reg,t}$ is the annual regional growth rate in TFP in region $reg$ in year $t$ due to NR&D innovation expenditures; $\gamma_3 + \gamma_1 Ird$ is the elasticity of TFP improvements wrt. NR&D investments, $NR\&D_{t-1reg}$ is the amount of NR&D innovation expenditures assigned in the year $t-1$; $GDPbau_{t-1,reg}$ is the forecasted GDP region $reg$ in the year $t-1$; $gTFPbau_{reg,t}$ is the baseline annual regional TFP growth in the region $reg$ during the year $t$; $TFP_{reg,t}$is the growth rate induced by the NR&D investments.

DG REGIO provided us not only with the values of allocated funds but also with the planned annual absorption of non-R&D investments for each region during the compliance period of 2014–2023. It should be mentioned, that regional NR&D investments were not distributed homogenously within the period of 2014–2023, but allowed for quite high spikes from one year to the next. Given that the model baseline was projected assuming a steady-state 2 per cent annual growth rate, region's values of TFP growth can double or triple from one year to another.

### *4.4 Infrastructure investments*

In a first step, an aggregate measure of the total Cohesion Policy expenditure on transport infrastructure is derived for each region. For this purpose, all policy instruments directly affecting transport infrastructure are aggregated in one category, INF. We use the aggregation scheme provided by DG REGIO.[12]

In a second step, we attempt to impute the spatial dimension of the transport infrastructure funds based on region-specific expenditures as calculated in the first step by estimating how region-specific expenditure translates into region-pair-specific expenditure. The spatial dimension is important, because transport infrastructure improvement affects not only the region, where the money is spent, but also all other regions with which it trades. We follow the literature and use the following formula to impute a spatial matrix of bilateral transport investments, $ECP^{INF}_{reg,regg}$:

$$ECP^{INF}_{reg,regg} = \phi_{reg,regg} \left( \frac{ECP^{INF}_{reg} + ECP^{INF}_{regg}}{2R} \right) \quad (4)$$

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[11] This expression takes values in the range [0.15-0.18].

[12] Note that no weights are applied at this stage of aggregation, although, according to the theoretical literature (European Commission, 2011), the aggregation of different policy measures should account for differences in their expected impact. This will be introduced in future simulations.

where $ECP^{INF}_{reg}$ and $ECP^{INF}_{regg}$ are ECP transport infrastructure expenditures in regions $reg$ and $regg$, respectively and $\phi_{reg,regg} \equiv \tau^{1-\sigma}_{reg,regg}$ is the freeness of trade, which ranges from zero, when trade is perfectly un-free (bilateral trade costs are prohibitive between $reg$ and $regg$), to unity, when trade is perfectly free and bilateral trade costs are zero (Baldwin *et al.*, 2005). $\tau^{1-\sigma}_{reg,regg}$ denotes bilateral trade costs between pairs of regions as measured by TRANSTOOLS.

The bilateral measure of transport infrastructure investments (4) accounts for both the intensity of the Cohesion Policy expenditure in the regions and for the proximity of the regions. The second term on the RHS in equation (4) calculates the average transport investment for every pair of regions. The first term on the right-hand side introduces a spatial structure (economic geography) in the bilateral measure of transport infrastructure investment by weighting the proximity (integration) of regions. The farther away the trading regions are (trade is more costly), the less weight will be attributed to the transport infrastructure improvements between the two regions. The weighting implies that the further away are the two regions, the lower impact will have a fixed amount of expenditure (1 km of road can be improved much better than 10 km of road with the same amount of funds).

In a third step, we transform $ECP^{INF}_{reg,regg}$, which is a bilateral measure of expenditures, into changes in bilateral trade costs between regions, which are measured as a share of trade value. This is done by pre-multiplying the bilateral measure of transport infrastructure investments ($ECP^{INF}_{reg,regg}$) by an elasticity that measures the effectiveness of transport infrastructure investments. This elasticity of trade costs with respect to the quality of infrastructure is retrieved from studies on TEN-T infrastructure (European Commission, 2009), since no comparable elasticities are available for Cohesion Policy investments in transport infrastructure. As a result, we obtain a transport infrastructure scenario that can be readily implemented in the model.

## 5 Simulation results

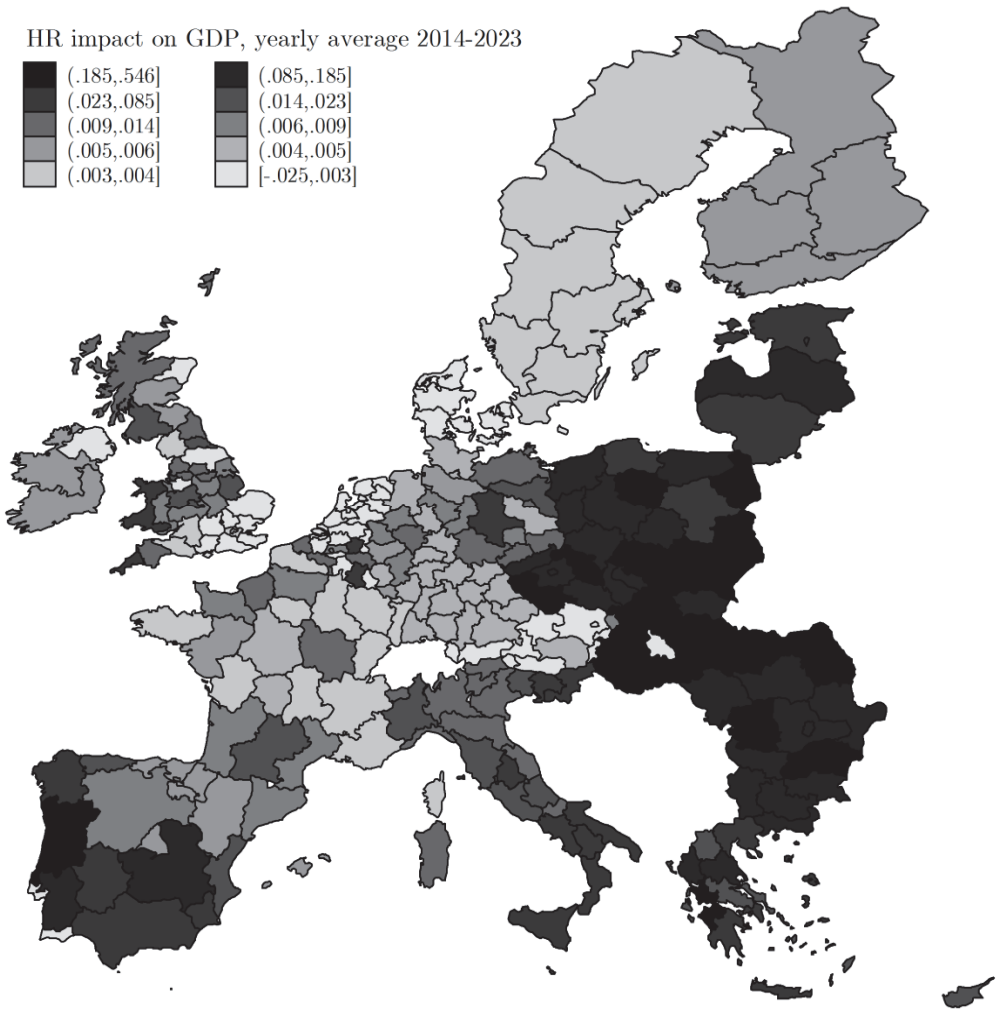
Given the high number of interactions and spillovers in RHOMOLO, regional shocks due to Cohesion Policy propagate quickly beyond regional borders. In fact, EU regions are highly interconnected through a dense network of trade in goods and services, flows of physical capital and technology that make the model and the interpretation of its results rather complex. Therefore, in order to fully capture the effects of each expenditure item and the role played by interconnections, we show the simulated impact of each measure in isolation and then their combination. Following the order proposed in the scenario construction (Section 4), we present first human-capital related policies, then R&D investments, followed by non-R&D subsidies and infrastructure investments. Finally, we show the overall impact of Cohesion Policy is obtained by combining the simulations and show the extent of spatial interrelations.

### *5.1 Interventions in the field of human capital*

Cohesion Policy expenditures on human capital encompasses a wide variety of measures. It is projected to account for about 20 per cent of total Cohesion Policy expenditures for the 2014-2020 period. To simulate the effects on human capital in RHOMOLO, the Human Capital expenditures are assumed to lead to an increase in labour productivity, however at the cost of a temporal decrease in the regional labour supply. Formally, an expenditure on human capital of

**Map 1**

**Impact of Interventions in the Field of Human Resources on NUTS 2 Regions GDP, 2014-2023**
*(yearly average)*




1 per cent relative to local education expenditures is assumed to increase local labour productivity by 0.3 per cent.[13]

Increase in regional labour productivity implies an increase in regional GDP but also an increase in labour demand and wages, which, in the long run, will attract new migrants. The following map displays the impact expected by 2030 of investment in human resources under Cohesion Policy 2014-2020.

As Map 1 suggests, the overall effect of investment in human resources is clearly positive, especially in most of the Central and Eastern European Member States. This reflects the distribution of Cohesion Policy support which is much higher for less developed regions compared to the transition and more developed regions.

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[13] This elasticity is taken from the literature (Sianesi and Van Reenen 2003).

However, the difference in regional impact also stems from other factors. First, investment in human resources is likely to produce a larger impact on GDP in regions where the level of local expenditure on education is low. These are indeed places where Cohesion Policy support will significantly change the level of public support provided to human resources. Second, RHOMOLO includes six industrial sectors which are more or less intensive in labour. Regions where the industrial fabric incorporates a larger proportion of labour intensive industries (such as for instance manufacturing) are likely to benefit more from an increase in labour productivity.

Finally, investment in human resources also generates spatial spillovers. As for infrastructure investments, the increase of GDP in the regions receiving support also benefits other regions because of the interregional trade links.

### *5.2 Interventions in the field of R&D*

R&D is another key sector of intervention for Cohesion Policy and accounts for approximately 12 per cent of the total Cohesion Policy budget (or €42 billion) that is to be allocated to lines of expenditure associated with support to research, technological development and innovation (RTDI) during the 2014-2020 programing period. More than 60 per cent of this should be allocated to the less developed regions.

As discussed in Section 4.2, in RHOMOLO, support to RTDI is assumed to increase TFP. An increase in R&D affects GDP in several ways. First, GDP increases due to the fact that, as mentioned above, R&D leads to an increase in factor productivity. This also implies a reduction in the prices of intermediate inputs and hence of production costs which also contributes to increase GDP. Finally, the price of consumption goods also decreases which encourages demand and hence the level of economic activity. As for other fields of intervention, other regions benefit from a rise in GDP due to increased demand from the regions receiving RTDI support.

The model also accounts for spatial spillovers specific to R&D. Formally, it is assumed that the farther away a region from the technology frontier, the greater the potential for absorption and imitation of technological progress produced elsewhere. This not only implies that lagging regions are catching up on more advanced ones in terms of technology but also that an increase in R&D produces a bigger impact on factor productivity in regions where the level of technology is originally low.

The results of the simulation show positive effects in all regions, with very few exceptions due to the intensification of competition from catching-up regions (see Map 2). Czech, Hungarian, Polish and Portuguese regions benefit the most, with impacts on regional GDP of 1-2 per cent above the baseline in 2020. The impact on GDP in the less developed regions on average is somewhat higher than 1.2 per cent in 2020, after which it levels off to 0.2 per cent of the baseline in 2030. A renewed/continued increase in RTDI would be needed to keep the regional economies on a higher growth path.

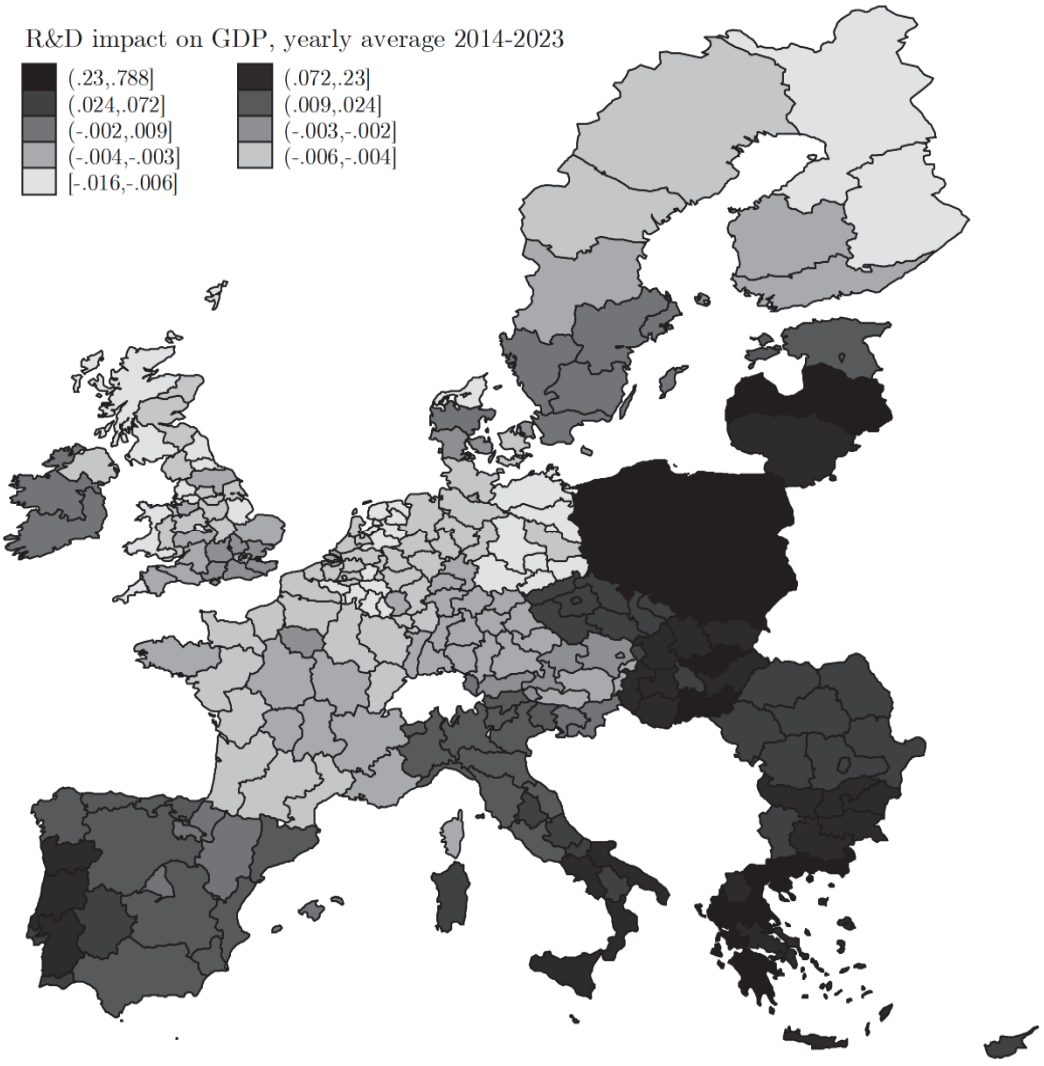
In general, the impact is higher in less developed regions than in transition regions. This is explained by the fact that less developed regions receive more support from Cohesion Policy than the two other groups and that R&D investment has a higher impact on TFP in lagging regions in terms of technology.

### *5.3 Interventions in the field of non-R&D subsidies*

As explained in Section 4.3 and described at length in Diukanova and Lopez-Rodriguez (2014), non-R&D subsidies are another key component of the overall Cohesion Policy. Map 3

**Map 2**

**Impact of Interventions in the Field of R&D on NUTS 2 Regions GDP, 2014-2023**
*(yearly average)*



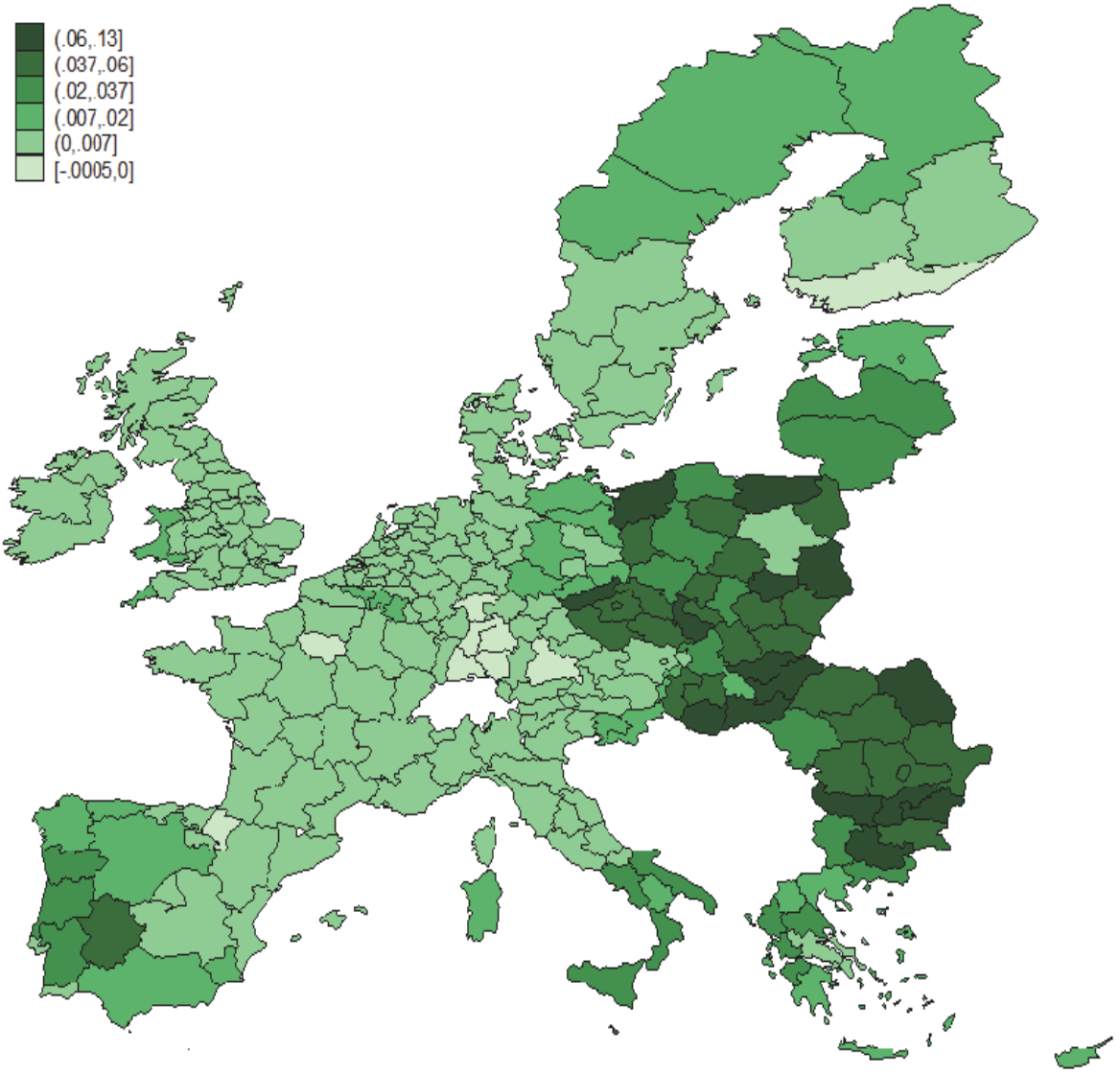

shows the impact of non-R&D subsidies on GDP across the NUTS2 regions in EU27. The impact on non-R&D subsidies is positive in all regions although their magnitude varies considerably between different types of regions. The most benefited regions are those located in the Eastern parts of Europe and the Southern European periphery (Greece, south of Italy Spain and Portugal). Central European regions only mildly benefit. The results of the simulations are highly correlated with the amount of non-R&D funds received.

### *5.4 Interventions in the field of infrastructure*

Finally, investment in infrastructure represents an important part of Cohesion Policy funding. For the 2014-2020 period, it is projected that investments in infrastructure will be around €168 billion, about half of all funds available.

**Map 3**

**Impact of Interventions in the Field of Non-R&D on NUTS 2 Regions GDP, 2014-2023**
*(yearly average)*

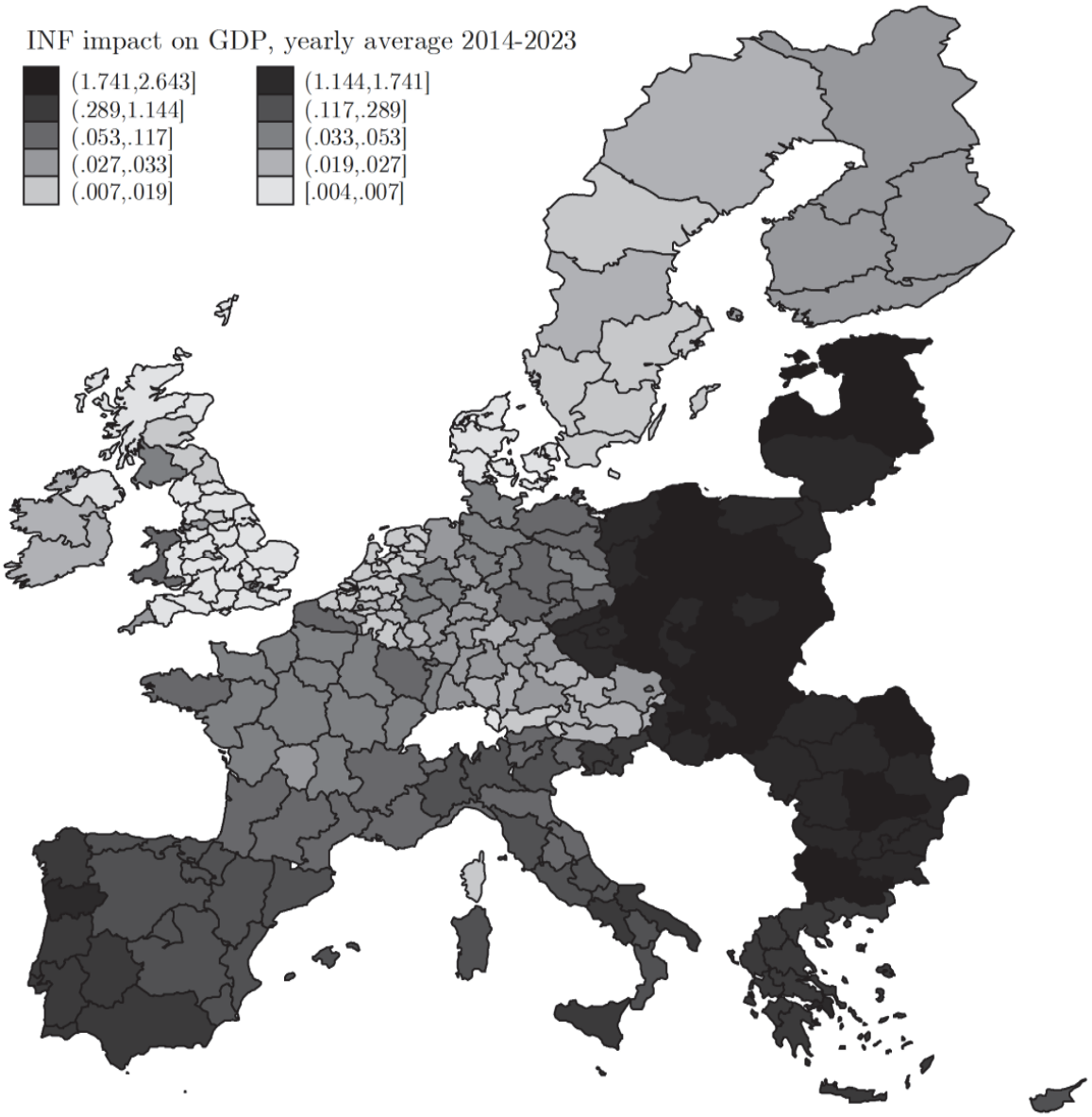



However, there are large differences between regions concerning Cohesion Policy expenditure on infrastructure. Indeed, larger amounts are allocated to less developed regions. In addition, the share of infrastructure in the allocation is also higher than in more developed regions. Accordingly, Cohesion Policy expenditures on infrastructure are considerably higher in less developed regions compared to transition and more developed regions.

In order to simulate the impact of Cohesion Policy investment in the field of infrastructure, the corresponding expenditure (in euros) needs to be 'translated' into changes in some of the model's parameters. Infrastructure investments are assumed to reduce transport costs between regions and the parameters representing transport costs are adjusted accordingly. Bilateral transport costs can be used to calculate an indicator of each region's accessibility. There are significant

**Map 4**

**Impact of Interventions in the Field of Infrastructure on NUTS 2 Regions GDP, 2014-2023**
*(yearly average)*

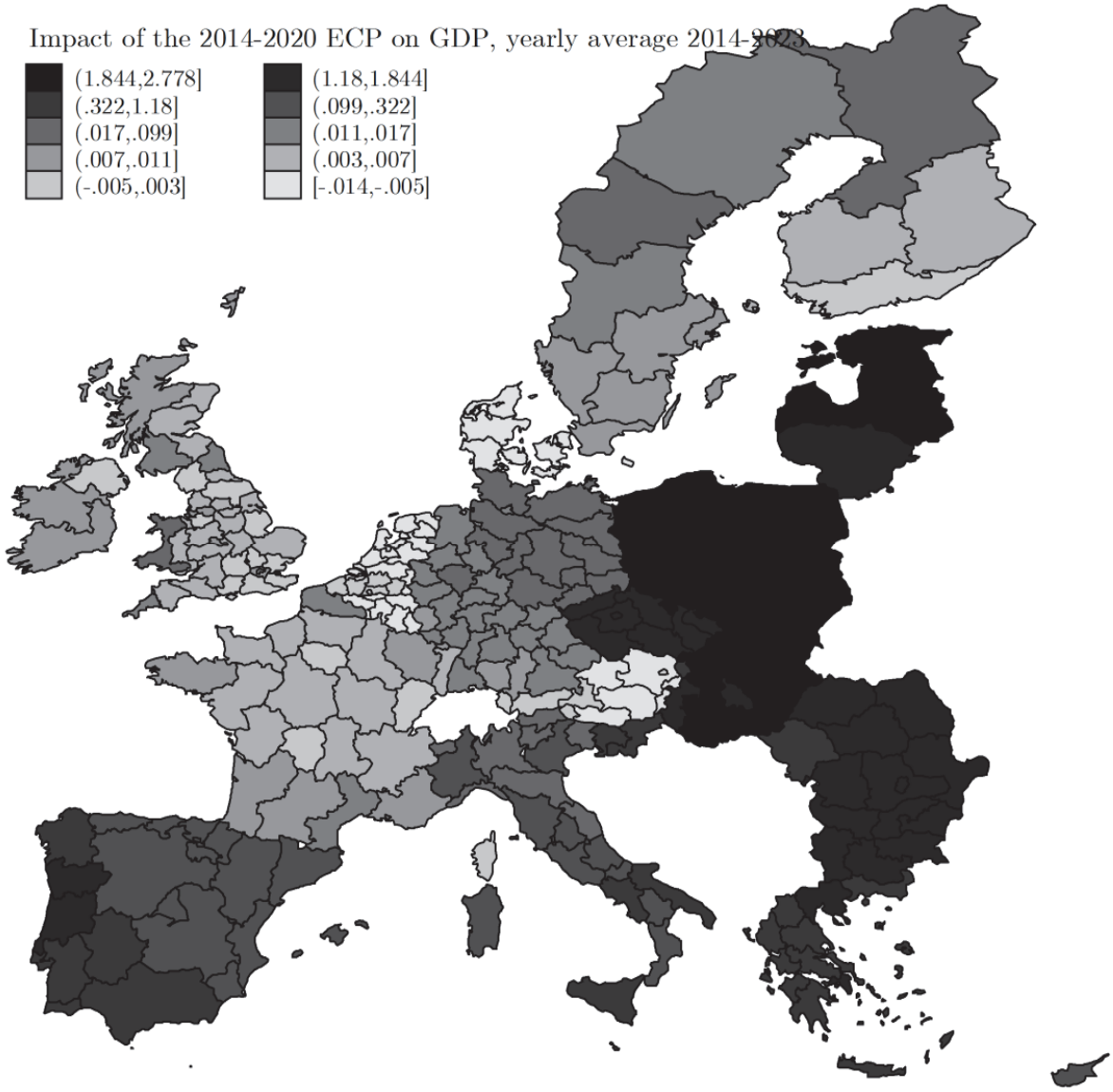



differences in transport cost reductions between regions and the largest improvements in accessibility take place in the less developed regions which reflects the expenditure pattern of Cohesion Policy.

Improvement in transport infrastructure means that regions have a better access to the EU markets which increases their exports and hence boosts the level of economic activity. Enhanced accessibility also implies a reduction in the price of imported intermediate goods and of consumption which contributes to reduce firms' production costs and increase real income of households. All these effects lead to an increase in regional GDP as shown in Map 4.

**Map 5**

**Impact of the 2014-2020 Cohesion Policy Programmes on NUTS 2 Regions GDP, 2014-2023**
*(yearly average)*




The largest returns of investment for improving accessibility are found in the less developed regions of the EU, due to the fact that it is in these regions where transport infrastructure is lacking and where improvement in accessibility investment makes thus the biggest difference.

The impact of investment in the field of infrastructure does not only materialise in the regions where the investment takes place. A region benefiting from enhanced accessibility increases its imports of goods from the other regions which in turn also experience an increase in their exports and hence their GDP. The impact of local intervention therefore has a tendency to progressively disseminate in space through the numerous trade links existing between the EU regions.

### *5.5 Simulating Cohesion Policy 2014-2020*

We now turn to the simulation of the full Cohesion Policy package for the period 2014-2020. As mentioned above, RHOMOLO has been calibrated so as to follow the results of QUEST at the national level for each year and each Member State. This amounts to use RHOMOLO to disaggregate the results obtained with QUEST at the NUTS2 level. Map 5 shows the average annual impact for the implementation period (2014-2023). This can be considered as the short run as it corresponds to the period during which both demand side and supply side effects of the interventions are supposed to play.

The impact is particularly large for regions located in Eastern and Central Europe. It is the highest in the Polish regions of Śląskie, Podkarpackie, Małopolskie and Lubelskie as well as in Východné Slovensko (Slovakia) where, compared to the baseline scenario with no policy interventions, Cohesion Policy is expected to increase GDP by more than 3 per cent per year on average between 2014 and 2023. A number of regions in Southern Europe also benefit from a large positive impact of Cohesion Policy on their GDP. For instance, between 2014 and 2023 GDP is expected to increase on average by 1.7 per cent per year in Norte (Portugal) and by 1.5 per cent per year in Kentriki Makedonia (Greece).

This mainly reflects the fact that these regions are the main beneficiaries of Cohesion Policy. As resources allocated to these regions are generally high, one can expect to also observe a higher impact in terms of GDP. Such regions are also generally lagging behind in terms of infrastructure and hence are in a situation where investment in this field is likely to produce a particularly large impact. In addition, Cohesion Policy support in the fields of human resources adds much more to the total amounts dedicated to education in these regions than in regions of more developed Member States. Finally, they are in general relatively more specialised in labour intensive industries, which implies that they particularly benefit from investment in human capital and the increase in labour productivity that follows.

Even if regions located in more developed Member States benefit less from Cohesion Policy interventions, the impact of the policy still remains significant in a number of more developed regions. For instance, GDP is expected to increase on average by 0.11 per cent per year in Lazio (Italy) or by 0.12 per cent per year in West Wales and The Valleys (UK) during the implementation period. The impact is obviously smaller in these regions where the allocation of cohesion funds is more modest and which are already largely endowed in infrastructure and human capital and technology. However, these regions still benefit from their own Cohesion Policy programmes but also from those implemented in other regions, in particular the less developed regions.

## 6 Conclusions

This paper presented RHOMOLO, the European Commission's spatial CGE model used for ex-ante impact policy assessment of the EUs 267 NUTS2 regions at the 6 NACE Rev. 1.1 industry level, through a simulation of the planned Cohesion Policy for the years 2014-2020. The Cohesion Policy expenditures were grouped into four main categories, covering Research, Technical Development and Innovation (RTDI). Infrastructure, Human Capital and Aid to Private Sector. These expenditures are assumed to affect a set of parameters including factor productivity and transport costs that determine the model outcome.

A spatial CGE model such as RHOMOLO is essential for capturing the effects of Cohesion Policy but has its limitations. The Cohesion Policy expenditures were grouped into four main categories, covering "Research, Technical Development and Innovation", investment in Infrastructure, investment in human capital and "Aid to private sector". These expenditures are

assumed to affect a set of parameters including factor productivity and transport costs, which determine the model outcome.

The main dynamics in RHOMOLO are the long-term effects of capital accumulation that continue even after the funding has ended. As inter-temporal optimisation and forward-looking expectations are not currently included, inter-temporal dynamics of the simulations are not always reliable. Therefore, RHOMOLO has been calibrated to the European Commission's QUEST III model to obtain consistent results for each year and each Member State. What can also be done is to filter the input of the simulations through a module which incorporates more sophisticated dynamics than what we use currently in the model.

**ANNEX 1**
**THE REGIONAL SOCIAL ACCOUNTING MATRIX**

<table>
<tr><th></th><th>Commodities</th><th>Industries</th><th>Value Added Inputs</th><th colspan="2">Final Demand Sectors</th></tr>
<tr><td>Commodities</td><td></td><td>Intermediate Demand</td><td rowspan="2"></td><td>Final Demand</td><td>Exports</td></tr>
<tr><td>Industries</td><td>Output</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Value Added Inputs</td><td></td><td rowspan="2">Value Added and Taxes</td><td colspan="3" rowspan="2"></td></tr>
<tr><td>Taxes less Subsidies on Products</td></tr>
<tr><td rowspan="2">Final Demand Sectors</td><td></td><td rowspan="2"></td><td>Sources of Value Added</td><td></td><td>Incoming Transfers</td></tr>
<tr><td>Imports</td><td colspan="2">Outgoing Transfers</td><td></td></tr>
<tr><td></td><td colspan="5">Trade & Transport Margins</td></tr>
</table>

## ANNEX 2
## CATEGORIES OF COHESION POLICY EXPENDITURES

| **Categories of Expenditure 2007-'13** | |
|---|---|
| **Research and technological development (R&TD), innovation and entrepreneurship** | |
| 1 | R&TD activities in research centres |
| 2 | R&TD infrastructure (including physical plant, instrumentation and high-speed computer networks linking research centres) and centres of competence in a specific technology |
| 3 | Technology transfer and improvement of cooperation networks between small and medium-sized businesses (SMEs), between these and other businesses and universities, post-secondary education establishments of all kinds, regional authorities, research centres and scientific and technological poles (scientific /technological parks, technopoles, etc.) |
| 4 | Assistance to R&TD, particularly in SMEs (including access to R&TD services in research centres) |
| 5 | Advanced support services for firms and groups of firms |
| 6 | Assistance to SMEs for the promotion of environmentally-friendly products and production processes (introduction of effective environment managing system, adoption and use of pollution prevention technologies, integration of clean technologies into firm production) |
| 7 | Investment in firms directly linked to research and innovation (innovative technologies, establishment of new firms by universities, existing R&TD centres and firms, etc.) |
| 8 | Other investment in firms |
| 9 | Other measures to stimulate research and innovation and entrepreneurship in SMEs |
| **Information society** | |
| 10 | Telephone infrastructures (including broadband networks) |
| 11 | Information and communication technologies (access, security, interoperability, risk-prevention, research, innovation, e-content, etc.) |
| 12 | Information and communication technologies (TEN-ICT) |
| 13 | Services and applications for the citizen (e-health, e-government, e-learning, e-inclusion, etc.) |
| 14 | Services and applications for SMEs (e-commerce, education and training, networking, etc.) |
| 15 | Other measures for improving access to and efficient use of ICT by SMEs |
| **Transport** | |
| 16 | Railways |
| 17 | Railways (TEN-T) |
| 20 | Motorways |
| 21 | Motorways (TEN-T) |
| 26 | Multimodal transport |
| 27 | Multimodal transport (TEN-T) |
| 28 | Intelligent transport systems |
| 29 | Airports |
| 30 | Ports |
| 32 | Inland waterways (TEN-T) |

| | |
|---|---|
| **Energy** | |
| 34 | Electricity (TEN-E) |
| 36 | Natural gas (TEN-E) |
| 38 | Petroleum products (TEN-E) |
| 39 | Renewable energy: wind |
| 40 | Renewable energy: solar |
| 41 | Renewable energy: biomass |
| 42 | Renewable energy: hydroelectric, geothermal and other |
| 43 | Energy efficiency, co-generation, energy management |
| **Environmental protection and risk prevention** | |
| 52 | Promotion of clean urban transport |
| **Increasing the adaptability of workers and firms, enterprises and entrepreneurs** | |
| 62 | Develop life-long learning systems and strategies in firms Training and services for employees to step up adaptability to change Promoting entrepreneurship and innovation |
| 63 | Design and dissemination of innovative and more productive ways of organising work |
| 64 | Development of specific services for employment, training and support in connection with restructuring of sectors and firms and development of systems for anticipating economic changes and future requirements in terms of jobs and skills |
| **Improving access to employment and sustainability** | |
| 65 | Modernisation and strengthening of labour market institutions |
| 66 | Implementing active and preventive measures on the labour market |
| 67 | Measures encouraging active ageing and prolonging working lives |
| 68 | Support for self-employment and business start-up |
| 69 | Measures to improve access to employment and increase sustainable participation and progress of women in employment to reduce gender-based segregation in the labour market and to reconcile work and private life, such as facilitating access to childcare and care for dependent persons |
| 70 | Specific action to increase participation of migrants in employment and thereby strengthen their social Integration Improving the social inclusion of less-favoured persons |
| 71 | Pathways to integration and re-entry into employment for disadvantaged people; combating discrimination in accessing and progressing in the labour market and promoting acceptance of diversity at the workplace |
| **Improving human capital** | |
| 72 | Design, introduction |
| 73 | Measures to increase participation in education and training throughout the life-cycle, including through action to achieve a reduction in early school leaving, gender-based segregation of subjects and increased access to and quality of initial vocational and tertiary education and training |
| 74 | Developing human potential in the field of research and innovation, in particular through post-graduate studies and training of researchers and networking activities between universities, research centres and businesses’ |

| **Non-Lisbon** | |
|---|---|
| 10 | Telephone infrastructures (including broadband networks) |
| 44 | Management of household and industrial waste |
| 45 | Management and distribution of water (drink water) |
| 46 | Water treatment (waste water) |
| 50 | Rehabilitation of industrial sites and contaminated ¡and |
| 53 | Risk prevention (...) |
| 61 | Integrated projects for urban and rural regeneration |
| 75 | Education infrastructure |
| 77 | Childcare infrastructure |
| 18 | Mobile rail assets |
| 19 | Mobile rail assets (TEN-T) |
| 22 | National roads |
| 23 | Regional/local roads |
| 24 | Cycle tracks |
| 25 | Urban transport |
| 31 | Inland waterways (regional and local) |
| 33 | Electricity |
| 35 | Natural gas |
| 37 | Petroleum products |
| 44 | Management of household and industrial waste |
| 45 | Management and distribution of water (drinking water) |
| 46 | Water treatment (waste water) |
| 47 | Air quality |
| 48 | Integrated prevention and pollution control |
| 49 | Mitigation and adaption to climate change |
| 50 | Rehabilitation of industrial sites and contaminated land |
| 51 | Promotion of biodiversity and nature protection (including Natura 2000) |
| 53 | Risk prevention. |
| 54 | Other measures to preserve the environment and prevent risks |
| 55 | Promotion of natural assets |
| 56 | Protection and development of natural heritage |
| 57 | Other assistance to improve tourist services |
| 58 | Protection and preservation of the cultural heritage |
| 59 | Development of cultural infrastructure |
| 60 | Other assistance to improve cultural services |
| 61 | Integrated projects for urban and rural regeneration |
| 75 | Education infrastructure |
| 76 | Health infrastructure |
| 77 | Child care infrastructure |
| 78 | Housing infrastructure |
| 79 | Other social• infrastructure |
| 80 | Promoting the partnerships, pacts and initiatives through the networking of relevant stakeholders |
| 81 | Mechanisms for improving good policy and programme design, monitoring and evaluation |
| 82 | Compensation of any additional costs due to accessibility deficit and territorial fragmentation |
| 83 | Specific action addressed to compensate additional costs due to size market factors |
| 84 | Support to compensate additional costs due to climate conditions and relief difficulties |
| 85 | Preparation, implementation, monitoring and inspection |
| 86 | Evaluation and studies; information and communication |

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# COMMENT TO "ASSESSING POLICY OPTIONS FOR THE EU COHESION POLICY 2014-2020" BY ANDRIES BRANDSMA, FRANCESCO DI COMITE, OLGA DIUKANOVA, D'ARTIS KANCS, JESUS LÓPEZ RODRÍGUEZ, DAMIAAN PERSYN AND LESLEY POTTERS

*Teresa Ter-Minassian*[*]

I appreciate the opportunity to comment on this interesting paper on assessing policy options for the EU Cohesion policy 2014-2020. This policy is an important part of the EU's institutional architecture, accounting for about one third of the EU's budget. It has acquired increased importance in recent years, as many EU countries have been forced by the crisis to cut back public investments. The policy has evolved over time, reflecting the expansion of EU membership, and its changing development needs, in particular gaps in infrastructure and human capital.

Not surprisingly, there has been a spate of cross-country, cross-region, and national studies that have attempted to assess the effectiveness of the policy.[1] The evidence from the studies is mixed, but on balance it suggests that the policy has been more effective in promoting convergence in national growth rates within the EU than in reducing within-countries regional disparities.

Recent spatial economics literature highlights the advantages of agglomeration and the consequent policy challenges in promoting economic convergence of relatively isolated and backwards regions with faster-growing metropolitan areas. A number of studies have emphasized the obstacles to convergence posed by weaknesses in institutions (e.g., corruption, legal uncertainties, and poor administrative capacities).

The reformulated Cohesion Policy for 2014-20 aims to address some of these issues. Specifically, it aims to combine the regional convergence objective with those of the Europe 2020 strategy, namely: innovation; increased competitiveness; employment growth; environmental sustainability; and social inclusion. This new approach is reflected in an increased focus on: investments in R&D; SMEs; the environment; access to high speed internet; and labor market programs.

The main instruments of the Cohesion Policy for 2014-2020 are: five structural funds (ESIFs), with common streamlined rules; and partnerships with national governments, with levels of support and co-financing varying depending on the level of the country's development. A key feature is an increased focus on strengthening governance, including at the sub-national levels of government. National strategies supported by the Cohesion Policy must be broadly consistent with structural reform priorities identified in the European Semester.

The paper by the EC's Regional Economic Modelling Team represents a useful attempt to evaluate ex-ante the expected impact of the Cohesion Policy for 2014-20. It presents the methodology and results of a simulation of the growth impact of the budgeted expenditures under 4 main lines of the policy (Human capital, R&D, Aid to Private Sector, and Infrastructure) on 267 EU regions. The simulation uses a spatial CGE model (RHOMOLO), supplemented by other analytical tools as needed (SAMs, and the TRANSTOOL model to analyze the impact of the policy on transport costs). The paper does not attempt to model the effects of Cohesion spending on capacity-building.

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[*] Formerly IMF.

[1] See Shankar and Shaw, 2009 for a comprehensive literature review.

The paper's key assumptions can be briefly summarized as follows:

- Cohesion expenditures on human capital (21 per cent of the total) are assumed to reduce labor supply and increase workers' productivity in a ratio of 0.3 to 1;
- The expenditures on R&D (12 per cent of total) are modeled as increasing (with a distributed lag) total factor productivity (TFP). The impact is assumed to be greater the farther away is the region from the technology frontier;
- Subsidies to non-RD&D private innovation activities (12 per cent of total) are also assumed to boost TFP with an elasticity of 0.15-0.18;
- The impact of infrastructure investments (49 per cent of total) on bilateral trade costs is modeled with a three-step procedure.

The different policy interventions are simulated first separately and then jointly. The distribution of the effects of the different components of the policy varies across regions, partly reflecting differences in initial conditions (skills and infrastructure gaps). The combined impact of the policy is estimated to boost the average EU GDP by 0.4 per cent, that of the newer members (EU13) by 2.6 per cent, and that of the EU15 by 0.2 per cent. Much of the difference in the effects reflects differences in the allocation of the funding. However, differences in initial gaps and in production structures also play a role.

In my view, the paper provides a valuable and carefully constructed analysis of a very relevant policy question, using state- of-the-art analytical tools. As for any analysis based on a CGE model, its results depend heavily on the assumptions underlying its specification and main parameters. The relevant literature shows significant variance in the available empirical estimates of the parameters.

For this reason, it would be desirable to test the robustness of these assumptions through a range of sensitivity analyses, in particular regarding the elasticities of labor and total factor productivity to positive spending shocks. It may also be desirable to analyze to what extent differences in labor productivity among the six sectors included in the model affect the estimated impact of industry-specific interventions.

I think that a significant limitation of the analysis is the fact that the quality of institutions does not influence in the model the effectiveness of the Cohesion Policy funds. This limitation largely explains why the impact of the funds is found to mostly mirror their projected geographic distribution. Yet, as found by some of the studies mentioned above, capacity constraints can affect the rate of absorption of the funds, and leakages due to inefficiencies and corruption can and do impact adversely their growth and employment stimulation potential.

A formal incorporation of this important dimension in the model may be prevented by a lack of comparable regional indices of the quality of institutions in the EU. However, it may be possible to supplement the model-based analysis with more detailed qualitative case studies of a few regions projected to be especially successful (or unsuccessful) in utilizing the Cohesion Policy funds (as measured by the projected ratio of impact to funds allocation). Such case studies should attempt to identify potential institutional obstacles to the effectiveness of the funds, and suggest possible remedial actions.