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

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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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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}:

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

α^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 δ 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*	χ^2	Prob > χ^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

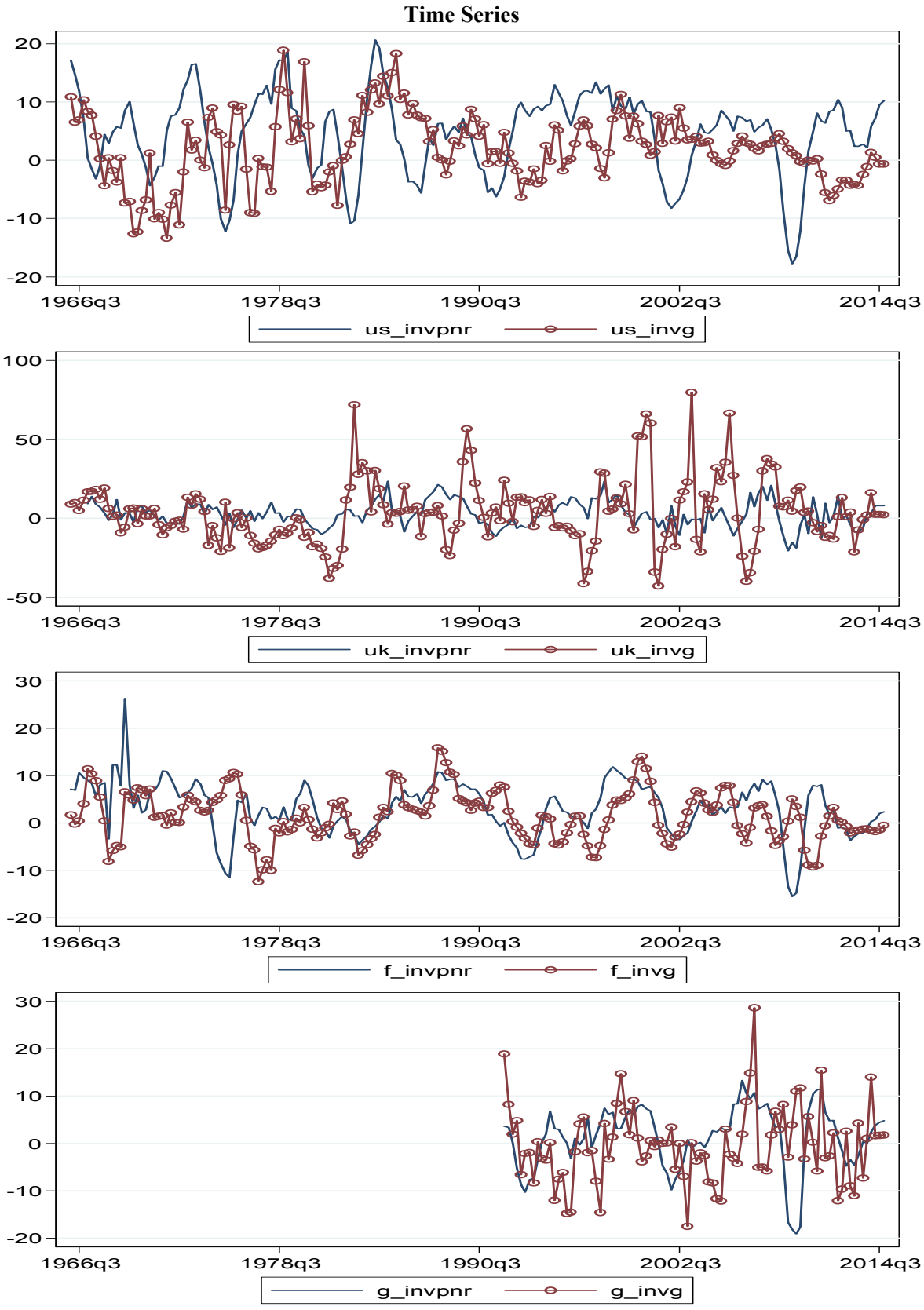
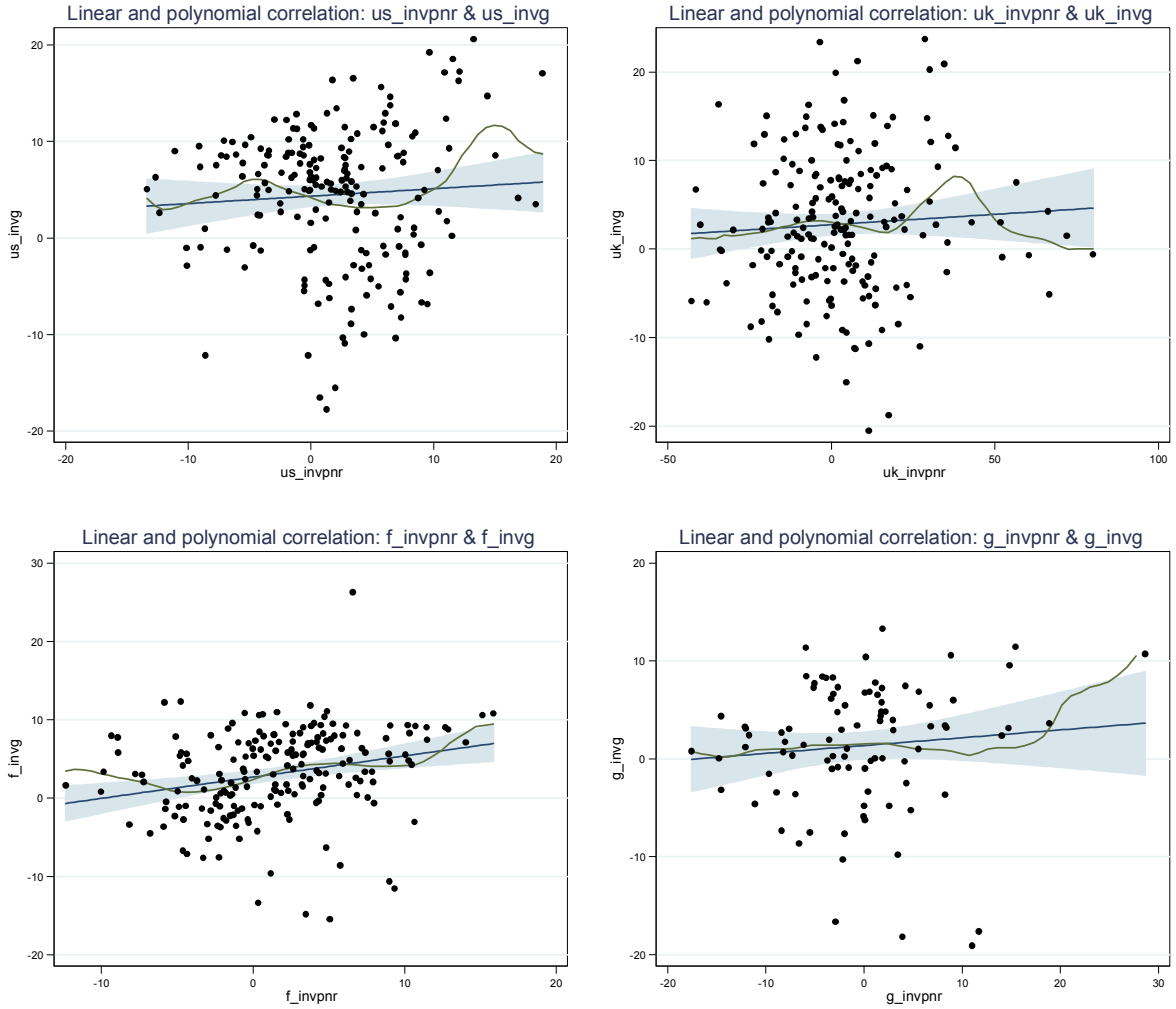

Time Series
20
10
0
-10
-20
1966q3
1978q3
1990q3
2002q3
2014q3
us_invpnr
us_invg
100
50
0
-50
uk_invpnr
uk_invg
30
f_invpnr
f_invg
g_invpnr
g_invg

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

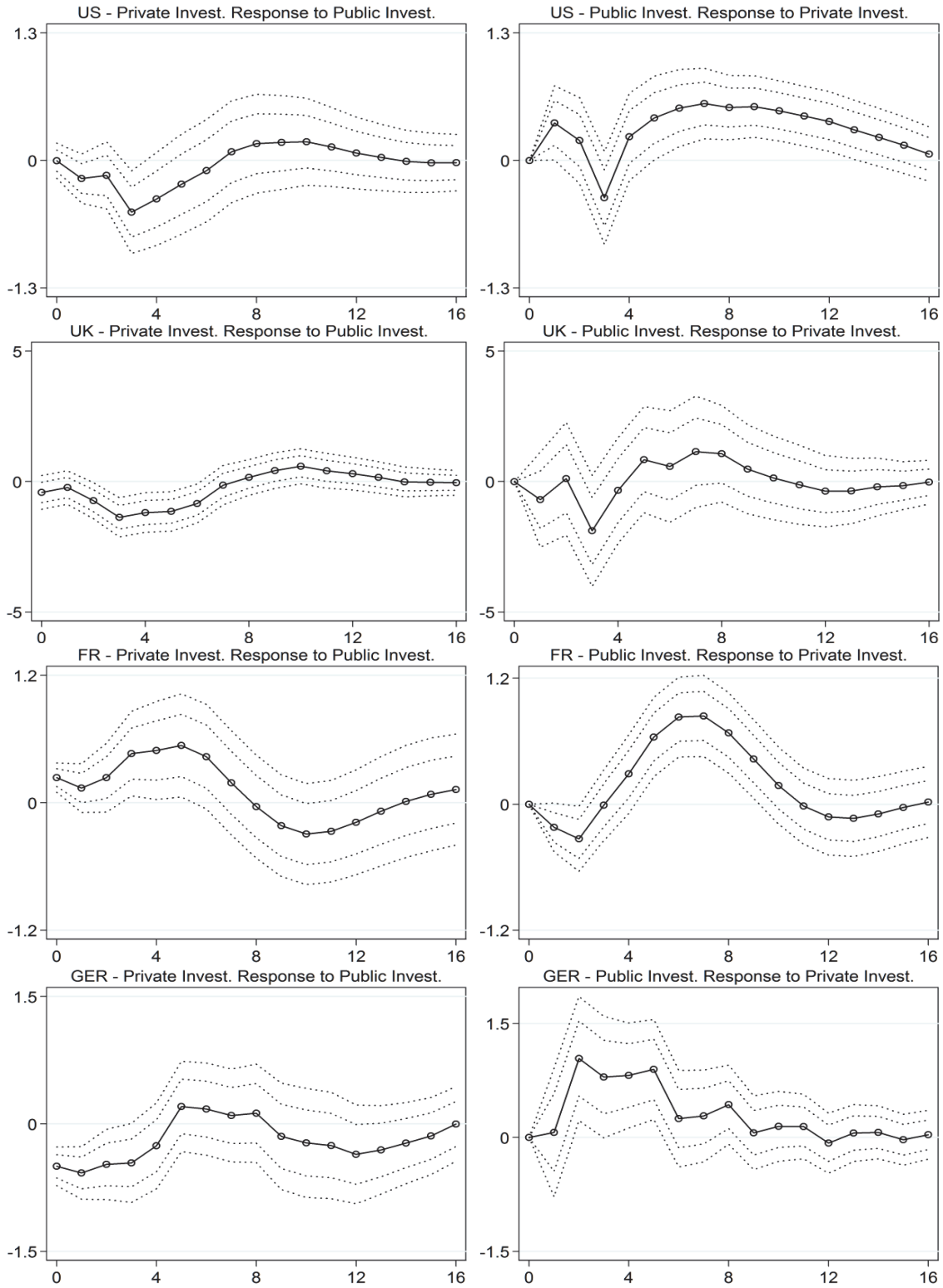
The length of the time span that we considered (almost five decades for the United States, France and the United Kingdom, more than two for Germany) may be responsible for the lack of a clear correlation between public and private investment over the period. Indeed, the existence of structural breaks 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 ε_t^2 and prior conditional variances σ_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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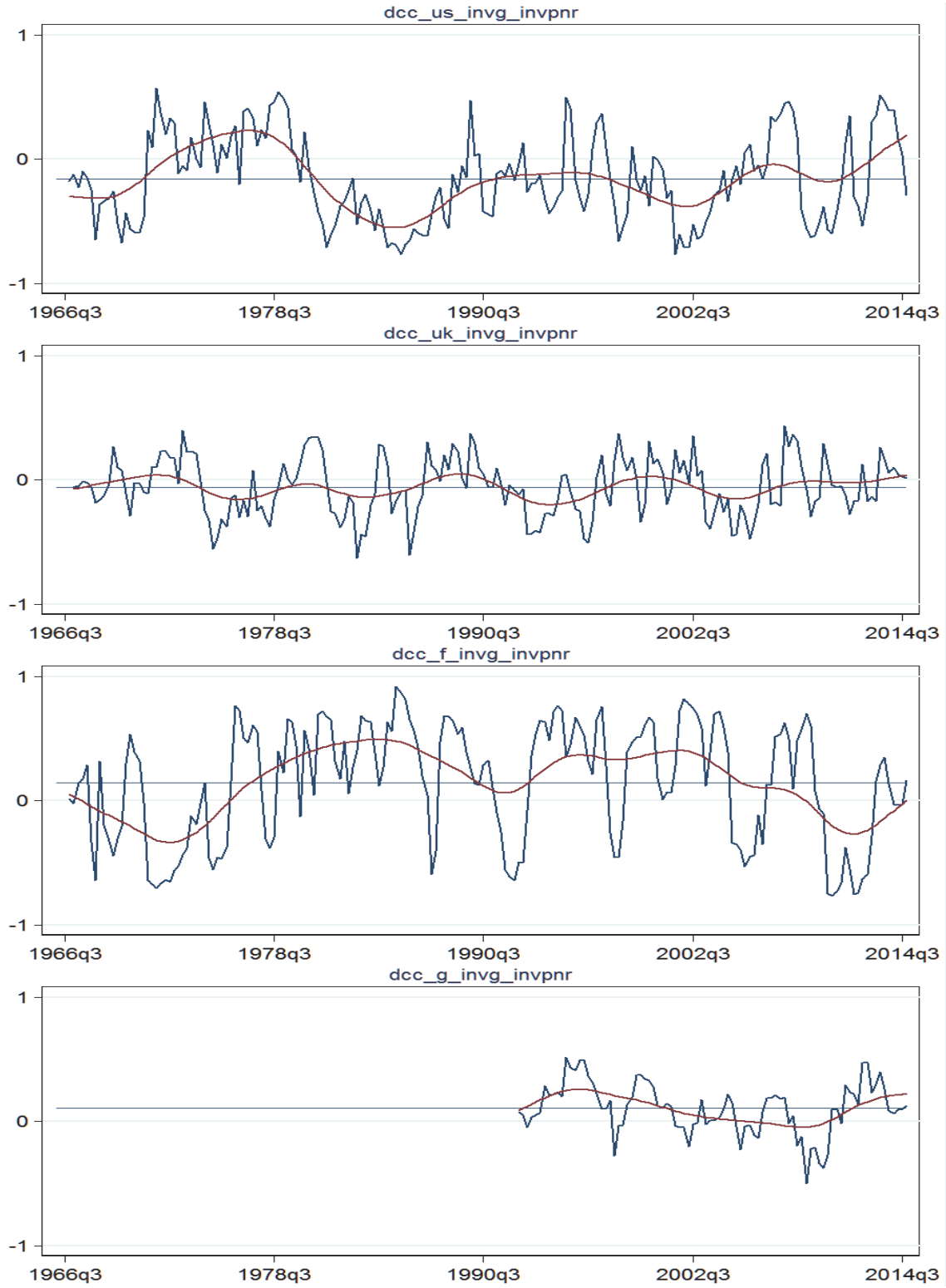
[6] DCC correlations for Germany give only a small crowding-in effect.

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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