Macroeconomic Rates of Return of Public and Private Investment: Crowding-in and Crowding-out Effects*

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Abstract

Using annual data from 14 European Union countries, plus Canada, Japan and the United States, we evaluate the macroeconomic effects of public and private investment through VAR analysis. From impulse response functions, we are able to assess the extent of crowding-in or crowding-out of both components of investment. We also compute the associated macroeconomic rates of return of public and private investment for each country. The results point mostly to the existence of positive effects of public investment and private investment on output. On the other hand, the crowding-in effects of public investment on private investment vary across countries, while the crowding-in effect of private investment on public investment is more generalised.

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1. Introduction

In this paper we address two key questions: does public investment have a significant effect on GDP, via computing macroeconomic rates of return, and does public investment induce more private investment. In other words, we ask if crowding-in prevails or else, if the main result is crowding-out. From a theoretical perspective, a rise in public investment can have two effects on private investment. First, the increase of public investment needs to be financed, which may imply more taxes or impose a higher demand for funds from the government in the capital markets, therefore causing interest rates to rise. This would reduce the amount of savings available for private investors and decrease the expected rate of return of private capital, leading to a crowding-out effect on private investment. Second, public investment can create additional favourable conditions for private investment, for instance, by providing or promoting relevant infrastructure such as roads, highways, sewage systems, harbours or airports. The existence of infrastructure facilities may increase the productivity of private investment, which can then take advantage of better overall infrastructures and potentially improved business conditions. This would result in having a crowding-in effect on private investment.

Macroeconomic rates of return this have been previously computed by Pereira (2000) and Pina and St. Aubyn (2005), but this method has not been widely used in the literature. Building on such framework, and in order to tackle the main issue of the paper, we evaluate the macroeconomic effects of public and private investment through a Vector Autoregression analysis using annual data from 14 European Union countries, plus Canada, Japan and the United States. We use impulse response functions to assess the extent of crowding-in or crowding-out of both components of investment.

Our work contains some innovative features worth mentioning. First, and for the first time in the literature, public partial and total investment rates of return derived from a VAR procedure are systematically computed and compared across countries and periods of time. Secondly, we extend our analysis and methodology towards the consideration of innovations in private investment, and therefore we are also able to compute private investment rates of return. This allows us to analyse not only the

more studied question of private investment being crowded in or out by public investment, but also the effects of private investment on public capital formation decisions.

The paper is organised as follows. In Section Two we briefly review some of the literature and previous results. Section Three outlines the methodological approach used in the paper both regarding the VAR specification and the analytical framework to compute the macroeconomic rates of return. In Section four we present and discuss our results. Section Five summarise the paper's main findings.

2. Literature and stylised facts

2.1. Related literature

The relevance of public investment is usually stressed in the implementation of budgetary measures taken by governments, notably its particular growth enhancing potential. For instance, in the European Union (EU), in the context of the recent discussions about the revision of the Stability and Growth Pact, some proposals have called for the exclusion of public investment from the budget deficit threshold established under the Maastricht Treaty. Moreover, the significance of public investment has been further illustrated by the idea of the Golden Rule, suggesting that such spending should only be financed by issuing government debt, and also by the imposition of formal rules that budget deficits cannot exceed public investment.[1]

Since Aschauer's (1989a, 1989b) initial contributions regarding the derivation of the elasticity of output with respect to public capital stock, there has been considerable interest in measuring the effects of public investment on aggregate economic activity, as well as in assessing whether public investment crowds in or crowds out private investment. The results of Aschauer (1989b) indicated that for the US, public investment had an overall crowding-in effect on private investment, and that public

[1] Musgrave (1939) discussed the appropriateness of financing via government debt, the so-called self-liquidating investments, which he critically considered to be limited.

and private capital could be seen as complementary.[2] Therefore, the related relevant economic policy question seems to be whether or not public government investment is productive and does contribute positively to growth, either directly or indirectly via private investment decisions.

Some related studies have addressed the effects of public investment on GDP, and the crowding-in hypothesis in the context of VAR analysis. For instance, Voss (2002) estimates a VAR model with GDP, public investment, private investment, the real interest rate, and price deflators of private and public investment, for the US and Canada, for the period 1947-1996. According to the reported results, innovations to public investment crowd out private investment. Mittnik and Neumann (2001) estimate a VAR with GDP, private investment, public investment and public consumption for six industrialised economies. Their results indicate that public investment tends to exert positive effects on GDP, and that there is no evidence of dominant crowding-out effects.

Argimón, González-Páramo and Roldán (1997) present results that support the existence of a crowding-in effect of private investment by public investment, through the positive impact of infrastructure on private investment productivity, for a panel of 14 OECD countries. Additionally, Perotti (2004) and Kamps (2004) assess the output and labour market effects of government investment in a VAR context.

2.2. Some stylised facts

The share of both public and private investment in GDP varies across our country sample and also throughout the time sample dimension. These developments are summarised in Table 1.

[Insert Table 1 here]

[2] The high output elasticity estimated by Aschauer with respect to public capital was later criticised on econometric grounds.

Overall, the public investment-to-GDP ratio has declined for most countries in the sample. On the other hand, a somewhat different pattern emerges in the cases of Greece, Italy and Portugal, where the public investment-to-GDP ratio either increased, particularly in the 1980s and in the 1990s, or did not decrease significantly. For instance, the rising of the public investment ratio in Spain can be compared to the historical decreases that occurred over the period in such countries as Austria, Belgium, Germany and Denmark. These developments have to be seen against the background of a catching-up effort undertaken by countries like Greece, Portugal, and Spain after EU accession, while in other more mature European economies public investment ratios were already on a downward path.[3] Additionally, it is also possible to observe a decline from quite above-average sample levels in the investment ratio for the case of Japan, and a rather stable ratio for the US.

In terms of private investment ratios, some heterogeneity also prevails in our country sample. For instance, in 1970, private investment-to-GDP ratios ranged from around 15 per cent in such countries as the UK, the US and Sweden, to around 24 per cent in the cases of Finland, Spain; the ratio even went as high as 28 per cent in the case of Japan. In more recent years, the private investment-to-GDP in Spain was above average, while some upward trends were visible from the second half of the 1990s onwards in countries such as France, Ireland, Italy, Spain and the US.

3. Methodology

3.1. VAR specification

We estimate a small four-variable VAR model for each country throughout the period 1960-2005. The variables in the VAR are the logarithmic growth rates of real public investment, *Ipub*, real private investment, *Ipriv*, real output, *Y*, and total economy employment, *E*. Therefore, the VAR model in standard form can be written as

$$X_t = c + \sum_{i=1}^{p} A_i X_{t-i} + \varepsilon_t . \qquad (1)$$

[3] Greece entered the EU in 1981, with Portugal and Spain following suit in 1986.

X_t denotes the (4×1) vector of the four endogenous variables given by $X_t \equiv \left[\Delta \log Ipub_t \quad \Delta \log Ipriv_t \quad \Delta \log Y_t \quad \Delta \log E_t\right]'$, c is a (4×1) vector of intercept terms, A is the matrix of autoregressive coefficients of order (4×4), and the vector of random disturbances $\varepsilon_t \equiv \left[\varepsilon_t^{Ipub} \quad \varepsilon_t^{Ipriv} \quad \varepsilon_t^{Y} \quad \varepsilon_t^{E}\right]'$ contains the reduced form OLS residuals. The lag length of the endogeneous variables, p, will be determined by the usual information criteria.

By imposing of a set of restrictions, it is possible to identify orthogonal shocks, η, for each of the variables in (1), and to compute these orthogonal innovations via the random disturbances:

$$\eta_t = B\varepsilon_t . \tag{2}$$

The estimation of (1) allows *Cov(ε)* to be determined. Therefore, with the orthogonal restrictions and by means of an adequate normalisation we have *Cov(η)=I*, where $I = (4\times4)$ identity matrix, and we can write

$$Cov(\eta_t) = Cov(B\varepsilon_t) = BCov(\varepsilon_t)B', \tag{3}$$

$$I = BCov(\varepsilon_t)B'. \tag{4}$$

Since B is a square $(n\times n)$ matrix, which in our case has dimension four, B has then sixteen parameters that need to be identified. By imposing orthogonality, from (4) only ten parameters can be determined, essentially from the four variances and from the six covariances.[4] For the complete identification of the model we need at least six more restrictions. The use of a Choleski decomposition of the matrix of covariances of the residuals, which requires all elements above the principal diagonal to be zero,

[4] A *n*-variable VAR provides automatically *n(n+1)/2* restrictions and an identical number of known parameters, which requires an additional $(n^2-n)/2$ restrictions to be imposed on the system in order to identify all the n^2 parameters.

provides the necessary additional six restrictions, and the system is then exactly identified.

We can then impose a lower triangular structure to B^{-1},

$$B^{-1} = D = \begin{bmatrix} d_{11} & 0 & 0 & 0 \\ d_{21} & d_{22} & 0 & 0 \\ d_{31} & d_{32} & d_{33} & 0 \\ d_{41} & d_{42} & d_{43} & d_{44} \end{bmatrix}, \tag{5}$$

which makes possible to write the residuals ε_t as a function of the orthogonal shocks in each of the variables:

$$\varepsilon_t = D\eta_t \,. \tag{6}$$

Our VAR is ordered from the most exogenous variable to the least exogenous one, with public investment ordered first. As a result, a shock in public investment may have an instantaneous effect on all the other variables. However, public investment does not respond contemporaneously to any structural disturbances to the remaining variables due, for instance, to lags in government decision-making. In other words, private investment, GDP and employment affect public investment sequences with a one-period lag. For instance, a shock in private investment, the second variable, does not have an instantaneous impact on public investment – only on output and employment.

Moreover, this ordering implies that private investment responds to public investment in a contemporaneous fashion, but not to shocks to the other variables. Indeed, one can recall that governments typically announce their spending and investment plans in advance, in the context of their budgetary planning. Therefore, economic agents can use such information in making their investment decisions. Additionally, private investment affects GDP contemporaneously. Employment is the least exogenous variable, and it is assumed that its shocks do not affect the other variables

simultaneously. Moreover, it does react contemporaneously to shocks to the remaining variables in the model.

3.2. Macroeconomic rates of return

Based on impulse response functions, we compute four different rates of return:

- r_1, the partial rate of return of public investment;
- r_2, the rate of return of total investment (originated by an impulse to public investment);
- r_3, the partial rate of return of private investment;
- r_4, the rate of return of total investment (originated by an impulse to private investment).

The partial rate of return of public investment is computed as suggested by Pereira (2000). Following an orthogonal impulse to public investment, we can compute the long-run accumulated elasticity of Y with respect to public investment, *Ipub*, derived from the accumulated impulse response functions of the VAR, as

$$\varepsilon_{Ipub} = \frac{\Delta \log Y}{\Delta \log Ipub}. \tag{7}$$

The above mentioned long-run elasticity is the ratio between the accumulated change in the growth rate of output and the accumulated change in the growth rate of public investment, which will be obtained from the estimation of the country-specific VAR models.

The long-term marginal productivity of public investment is given by

$$MPIpub \equiv \frac{\Delta Y}{\Delta Ipub} = \varepsilon_{Ipub} \frac{Y}{Ipub}. \tag{8}$$

Then r_1, the partial-cost dynamic feedback rate of return of public investment, is obtained as the solution for:

$$(1+r_1)^{20} = MPIpub\ . \tag{9}$$

As discussed by Pina and St. Aubyn (2005, 2006), this rate could either overestimate or underestimate the return on public investment, as public investment can either crowd in or crowd out private investment respectively. Suppose, for example, that more public capital induces more private investment. The total investment that caused the detected product increase exceeds the public effort, and if one only considers the latter, the rate of return is overstated.

Since private investment also changes, the long-term accumulated elasticity of *Y* with respect to *Ipriv* can also be derived from accumulated impulse response functions of the VAR in a similar fashion:

$$\varepsilon_{Ipriv} = \frac{\Delta \log Y}{\Delta \log Ipriv}, \tag{10}$$

and now the long-term marginal productivity of private investment is given by

$$MPIpriv \equiv \frac{\Delta Y}{\Delta Ipriv} = \varepsilon_{Ipriv} \frac{Y}{Ipriv}\ . \tag{11}$$

Therefore, computing the marginal productivity of total investment, *MPTI*, implies taking into account both the long-term marginal productivity of public and private investment, as follows:

$$MPTI = \frac{\Delta Y}{\Delta Ipub + \Delta Ipriv} = \frac{1}{MPIpub^{-1} + MPIpriv^{-1}}\ . \tag{12}$$

Following Pina and St. Aubyn (2006), we compute a rate of return of total investment. The rate of return of total investment (originated by an impulse to public investment), r_2, is obtained as the solution for:

$$(1+r_2)^{20} = MPTI\,. \qquad (13)$$

In our described benchmark framework we use 20 years to compute both the partial and the total rates of return. In other words, we assume an average life of 20 years for a capital good. For instance, while the average life of a personal computer could be three or four years, the life expectancy of a bridge is certainly to be measured in decades.

The partial rate of return of private investment, r_3, is computed in a way analogous to r_1. Using the accumulated impulse responses of the VAR following an impulse on private investment, a long-run output elasticity is obtained, and then a marginal productivity and a rate of return can be calculated. As public investment may also respond positively or negatively to private efforts, a rate of return of total investment, r_4, is also estimated.

4. Empirical analysis

4.1. Data

We use annual data for 14 EU countries (sample in parenthesis): Austria (1960–2005), Belgium (1970–2005), Denmark (1960–2005), Germany (1960–2005), Finland (1960–2005), France (1970–2005), Greece (1960–2005), Ireland (1970–2005), Italy (1970–2005), the Netherlands (1969–2005), Portugal (1960–2005), Spain (1970–2005), Sweden (1970–2004) and the UK (1970–2005), plus Canada (1970–2004), Japan (1970–2004), and the United States (1970–2004). In order to estimate our VAR for each country, we use information for the following series: GDP at current market prices; price deflator of GDP; total employment in the economy; general government gross fixed capital formation at current prices, used as public investment; and gross fixed capital formation of the private sector at current prices, used as private investment.

GDP and investment variables are transformed into real values using the price deflator of GDP and the price deflator of the gross fixed capital formation of the total

economy, respectively [5]. All data are taken from the European Commission Ameco database.[6]

4.2. VAR estimation

In the estimation of each country's VAR, its GDP, public investment and private investment are used in real terms. All variables enter the VAR as logarithmic growth rates. Moreover, the unit root analysis that we undertook showed that these first differenced variables are mostly stationary, I (0) time series. Table 2 shows unit root test stastistics.

[Insert Table 2 here]

Note that we chose not to estimate a "levels VAR" or to infer possible co-integration vectors. In fact, there is no theoretical reason to expect a long-run relationship between public investment, private investment and GDP, or between any two of these three variables, and to force this relationship could introduce an unwanted structure into our empirical endeavour.

The chosen VAR order used in the estimation of each model was selected with the Akaike and the Schwarz information criteria. Those tests led us to choose a more parsimonious model with only one lag for most of the countries, which helped avoid the use of too many degrees of freedom. With such specifications we usually could not reject the null hypothesis of no serial residual correlation. In addition, we did not reject the null hypothesis of normality of the VAR residuals in most cases. The diagnostic tests regarding residual autocorrelation and normality are also reported in Table 3.

[Insert Table 3 here]

[5] Due to the lack of information on a price deflator for private investment, we use the same deflator to compute both public and private investment variables.
[6] The data sources are explained in the Appendix.

Additionally, for the case of Germany we included a dummy variable that takes the value of one in 1991 and zero otherwise in order to capture the break in the series related to German reunification. This variable is highly statistically significant in all equations. Moreover, for all cases we chose to privilege the absence of autocorrelation of the residuals, even in the eventuality of the residuals being non-normal.[7] As can be seen from Table 3, all *p*-values exceed ten per cent. Therefore, even at a significance level of 10 per cent, the null hypothesis of no residual autocorrelation cannot be rejected for all countries.

4.3. The rates of return

Table 4 reports the computed output elasticity and the rates of return of public and private investment for each country for the respective period of available data. Overall, one can observe that the output elasticity of private investment is always positive and higher than the output elasticity of public investment.

[Insert Table 4 here]

In those cases where rates of return can be calculated or, in other words, whenever the marginal productivity is positive, the partial rate of return of public investment is mostly positive, with the exceptions of Belgium, France, Ireland and Spain. Taking into account the induced effect on private investment, the total rate of return associated with public investment is generally lower, with the exception of Spain, and slightly negative for the cases of Denmark, Greece and Canada.

Regarding private investment (panel b) of Table 4), we can notice that partial marginal productivity is positive for all countries. The same is true for the associated total marginal productivity, which takes into account the effects of private investment on public investment. The partial rates of return of private investment are mostly positive, with the exception of Denmark, where the rate is moderately negative. The

[7] Indeed, Lutkepohl (2005, pp. 297) points out that the assumption of normality does not impinge on the asymptotic properties of the estimated VAR parameters.

total rate of return of private investment is mostly somewhat below the partial rate of return, albeit slightly higher in the cases of Greece, Sweden and the US.

Another relevant assessment is to compare the above-mentioned reported results for the entire period with the results for a more recent period, 1980-2005. This division of the sample can be relevant if one bears in mind that, for instance, in some countries the investment efforts, both in the public sector and in the private sector, were higher in the 1960s and 1970s, whereas these priorities occurred somewhat later in the 1980s in other countries. The heterogeneity of public and private-to-GDP ratios reported in Section Two should also be noted in this context.

This alternative set of results (see the Annex) provides some additional insights. For instance, in terms of public investment one can observe an overall decline in the partial rates of return in this more recent sub-period, except in the cases of France and Spain. To take one example, we see that while for the entire period the partial rate of return of public investment in Germany was around 8.5 per cent, it decreased to 4.4 per cent in the second sub-period. This may be related to the high level of investment made in a period still close to reconstruction, a situation that other European countries also experienced. For the total rate of return of public investment in the sub-period 1980-2005, there is also mostly a decline vis-à-vis the entire period, although some relevant increases can be seen for France, Greece and Italy.

Regarding private investment in the sub-period 1980-2005, there is a decline in the partial rate of return of ten countries and an increase in seven others. The more relevant changes in the partial rates of return of private investment are the increases estimated in Finland, the Netherlands and Portugal, while significant decreases are computed for the cases of Austria, Germany, Greece, Italy, Spain and the US.

4.4. Crowding-in and crowding-out effects

On the basis of the values of the partial marginal productivity of public investment, it is possible to determine the impact of public investment on output. That information, taken from Table 4, is displayed on the horizontal axis of Figure 1. Additionally, on the vertical axis we plot the marginal effects of public investment on private

investment, which allows us to assess the possible existence of crowding-in or crowding-out effects of public investment on private investment. Such effects can be easily derived from

$$\frac{\Delta Ipriv}{\Delta Ipub} = \frac{\varepsilon_{Ipub}}{\varepsilon_{Ipriv}} \frac{Ipriv}{Ipub} . \qquad (14)$$

[Insert Figure 1 here]

As Figure 1 demonstrates, public investment has a crowding-in effect on private investment in 9 of the 17 countries analysed. Of the 8 countries in which there is a crowding-out effect on private investment, half (Belgium, France, Ireland and Spain) still experience a slight output expansion, while Canada, Italy, the Netherlands, and the UK show a contractionary effect.

Figure 2 shows the values of the marginal productivity of private investment and the marginal effects of private investment on public investment. This chart is useful in visualising both the effect of private investment on output and the existing crowding-in or crowding-out effects of private investment on public investment.

[Insert Figure 2 here]

Figure 2 also reveals that private investment has a crowding-in effect on public investment for most of the countries in the sample, while it crowds out public investment in the cases of Greece, Sweden and the US. In addition, private investment has an expansionary effect on output for all countries in the sample. The effects of both public and private investment impulses for all countries are summarised in Figure 3.

[Insert Figure 3 here]

Note that some important differences arise when only the most recent period is considered (1980-2000, see results in the Annex). For this sub-sample, one can

observe a decline in the partial rate of return of public investment for most countries. For instance, for Germany there is a decrease from around 11 per cent in the period 1960–2005 to 7.7 per cent in the period 1980–2005, alongside with a drop in the long-run accumulated elasticity of output with respect to public investment. On the other hand, an increase in the partial rate of return of public investment can be detected for France and Spain. Moreover, the total rate of return associated with public investment, when such a comparison is possible, decreases for eight countries (Austria, Finland, Germany, Portugal, Spain, the UK, Japan and the US), and increases for five countries (Denmark, France, Greece, the Netherlands and Canada).

Turning to the effects of private investment in the most recent period, it is possible to see an overall decline in the partial rates of return, which occurs for ten out of the 17 countries in the sample. Relevant increases in the partial rate of return of private investment were observed in Finland, Ireland, the Netherlands and Portugal.

Regarding the total rate of return associated with private investment, negative returns were computed in the period 1980–2005 for Denmark, Italy and Canada, rather like the case of the full sample period. Additionally, the total rate of return of private investment also declined more substantially in Austria, Germany, Italy, Spain and the US.

Finally, we also performed a sensitivity analysis by using only ten years for both public and private investment, and also by assuming differentiated horizons, with twenty and ten years respectively for public and for private investment. The results, not reported in the paper, provided similar overall conclusions.

5. Conclusion

Public investment can either crowd in or crowd out private investment. In strong crowding-out cases, it is possible that increased public investment could lead to a decrease in GDP. In our paper, by estimating VARs for 14 European Union countries, plus Canada, Japan and the United States, we conclude that, between 1960 and 2000:

- public investment had a contractionary effect on output in five cases, with positive public investment impulses leading to a decline in private investment (crowding-out) in four cases (Canada, Great Britain, Italy and the Netherlands);
- on the other hand, expansionary effects and crowding-in prevailed in eight cases (Austria, Germany, Denmark, Finland, Greece, Japan, Portugal and the US).

When it is possible to compute it, the partial rate of return of public investment is mostly positive, with the exceptions of Belgium, France, Ireland and Spain. Taking into account the induced effect on private investment, the total rate of return associated with public investment is generally lower, with the exception of Spain, and slightly negative for the cases of Denmark, Greece and Canada. The computation of these rates of return allows us to refine our analysis. In some cases the increase in GDP was not sufficiently high to compensate for the total investment effort. This was the case of increases in public investment, from 1980 to 2000, with seven countries (Austria, Belgium, Finland, Portugal, Sweden, Canada and the US) recording a negative total rate of return, compared with only two cases (Denmark and Italy) of negative total returns when a private investment impulse was considered.

Private investment impulses, by contrast, were always expansionary in GDP terms, and public investment responded positively in all but three countries when the whole period was considered (Greece, Sweden and the US). There were very few cases of negative private investment rates of return, either partial or total – Denmark and Italy, and also Austria from 1980 to 2005.

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Appendix – Data sources

Original series	Ameco codes *
Gross Domestic Product at current market prices, thousands national currency.	1.0.0.0.UVGD
Price deflator of Gross Domestic Product, national currency, 1995 = 100.	3.1.0.0.PVGD
Employment, total economy, 1000 persons.	1.0.0.0.NETN
Gross fixed capital formation at current prices; general government, national currency.	1.0.0.0.UIGG
Gross fixed capital formation at current prices; private sector, national currency.	1.0.0.0.UIGP
Price deflator gross fixed capital formation; total economy, national currency; 1995 = 100.	3.1.0.0.PIGT

Note: * series from the EC AMECO database.

Tables and figures

Table 1 – Public and private investment -to-GDP ratios

	Public investment-to-GDP ratios				Private investment-to-GDP ratios			
	1970	1980	2005	Average 1960-05	1970	1980	2005	Average 1960-05
AUT	4.8	4.2	1.1	2.9	19.8	20.4	19.7	19.9
BEL	4.1	4.5	1.8	2.4	20.4	18.0	17.6	17.3
DEU	4.8	3.7	1.3	2.7	21.5	19.5	15.8	19.1
DNK	4.4*	3.2	1.9	2.2	19.9	16.5	17.6	17.7
ESP	2.5	1.8	3.5	3.0	23.7	20.5	25.7	20.3
FIN	4.2	3.6	3.0	3.4	23.7	23.1	16.2	20.1
FRA	3.7	3.2	3.3	3.3	20.1	19.7	16.1	17.3
GBR	4.8	2.6	2.1	2.2	14.7	16.1	14.3	15.5
GRC	2.7	2.1	3.1	2.8	23.1	26.6	21.5	20.3
IRL	4.0	5.6	3.8	3.2	18.5	22.3	21.7	17.7
ITA	2.8	3.0	2.7	2.8	22.5	22.1	16.8	18.7
NLD	5.0	3.7	3.0	3.3	22.0	18.2	16.3	18.0
PRT	2.1	4.0	2.9	2.9	22.4	25.6	18.2	22.1
SWE	7.8	5.2	3.1 #	4.1	16.0	15.8	12.9 #	14.9
CAN	4.0	3.0	2.7 #	2.9	17.6	20.6	17.6 #	18.1
JAP	8.0	9.4	4.9 #	7.6	28.1	22.5	18.9 #	21.7
USA	3.2	2.7	2.6 #	2.6	14.7	17.6	16.0 #	15.9
Maximum	8.0 (JAP)	9.4 (JAP)	4.9 (JAP)	7.6 (JAP)	28.1 (JAP)	26.6 (GRC)	25.7 (ESP)	22.1 (PRT)
Minimum	2.1 (PRT)	1.8 (ESP)	1.1 (AUT)	2.2 (GBR)	14.7 (USA)	15.8 (SWE)	12.9 (SWE)	14.9 (SWE)

Source: EC, AMECO Database, updated on 14 November 2005. * - 1971. # - 2004.

Table 2 – Unit root tests, variables in first differences: Augmented Dickey-Fuller test statistics

	dlog(Y)		d(E)		dlog(Ipub)		dlog(Ipriv)	
	t-Statistic	critical value	t-Statistic	critical value	t-Statistic	critical value	t-Statistic	critical value
Austria	-4.97	*-3.59*	-3.48	*-3.59*	-5.23	*-3.59*	-6.57	*-3.59*
Belgium	-4.84	*-3.59*	-3.67	*-3.59*	-4.87	*-3.64*	-4.27	*-3.64*
Denmark	-5.76	*-3.59*	-4.14	*-3.59*	-4.73	*-3.65*	-3.78	*-3.68*
Finland	-3.84	*-3.59*	-3.97	*-3.59*	-6.56	*-3.59*	-3.78	*-3.59*
France	-3.18	*-2.93*$	-3.63	*-3.59*	-4.45	*-3.64*	-3.70	*-3.64*
Germany	-4.71	*-3.59*	-6.18	*-3.59*	-4.33	*-3.59*	-4.34	*-3.59*
Greece	-4.85	*-3.59*	-5.85	*-3.59*	-6.57	*-3.59*	-5.68	*-3.59*
Ireland	-3.74	*-3.59*	-2.41	*-2.60*#	-2.22	*-2.62*#	-4.39	*-3.64*
Italy	-4.31	*-3.59*	-3.64	*-3.59*	-6.91	*-3.64*	-4.64	*-3.64*
Netherlands	-3.19	*-2.93*$	-4.79	*-3.59*	-4.62	*-3.64*	-3.90	*-3.64*
Portugal	-3.83	*-3.59*	-4.58	*-3.59*	-5.49	*-3.59*	-4.66	*-3.59*
Spain	-3.41	*-3.59*	-2.25	*-2.60*#	-4.16	*-3.64*	-3.46	*-2.95*$
Sweden	-4.11	*-3.59*	-4.67	*-3.59*	-3.65	*-3.59*	-3.32	*-2.95*$
United Kingdom	-5.25	*-3.59*	-5.07	*-3.59*	-3.80	*-3.64*	-3.58	*-2.95*$
Canada	-4.26	*-3.59*	-4.08	*-3.59*	-5.70	*-3.59*	-4.89	*-3.59*
Japan	-2.88	*-2.60*#	-3.32	*-3.59*	*-2.93*$	*-3.59*	-3.05	*-2.93*$
United States	-4.96	*-3.59*	-5.07	*-3.59*	-3.65	*-3.59*	-6.05	*-3.59*

Note: critical values are for 1% level unless otherwise mentioned.

– 10% level; $ – 5% level.

Table 3 – Diagnostic tests, dynamic feedbacks VAR

	Autocorrelation test (p-value) [1]	Normality test (p-value) [2]	Number of lags	Number of observations
Austria	0.270	0.000	2	43
Belgium	0.350	0.473	1	34
Denmark	0.162	0.657	1	33
Finland	0.161	0.526	1	44
France	0.165	0.407	1	34
Germany	0.471	0.016	3	41
Greece	0.200	0.323	1	44
Ireland	0.465	0.507	1	34
Italy	0.772	0.107	1	34
Netherlands	0.820	0.790	1	35
Portugal	0.422	0.049	1	44
Spain	0.343	0.186	2	33
Sweden	0.383	0.407	1	33
United Kingdom	0.599	0.633	1	34
Canada	0.787	0.301	1	43
Japan	0.965	0.100	2	43
United States	0.288	0.035	3	42

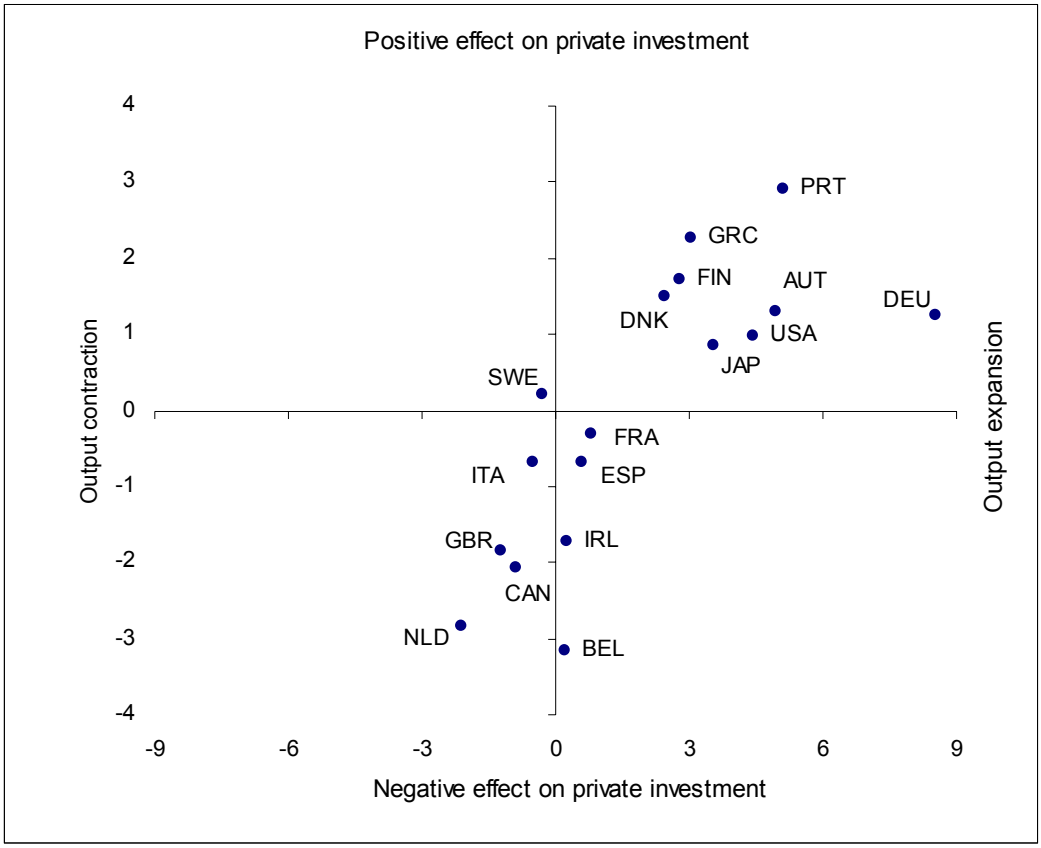
Notes: We considered the maximum VAR order to be three. For Germany we included a dummy variable that takes the value one in 1991 and zero otherwise. For Finland and Sweden, a similar dummy variable for 1992 was not statistically significant.
1 – Multivariate residual serial correlation LM test. For the null hypothesis of no serial autocorrelation (of order 1) the test statistic as an asymptotic chi-square distribution with k^2 degrees of freedom (16 in our case).
2 – Multivariate Jarque-Bera residual normality test. For the null hypothesis of normality, the test statistic as an asymptotic chi-square distribution with 8 degrees of freedom.

Table 4 – Long-run elasticities, marginal productivity and rates of return (full period)

a) Impulse on public investment					
	Output elasticity	*MPIpub*	Partial rate of return (%)	*MPTI*	Total rate of return (%)
Austria	0.143	4.964	8.34	2.159	3.92
Belgium	0.006	0.227	-7.14	-0.105	na
Denmark	0.005	2.461	4.61	0.983	-0.08
Finland	0.096	2.781	5.25	1.026	0.13
France	0.027	0.818	-1.00	1.187	0.86
Germany	0.234	8.526	11.31	3.793	6.89
Greece	0.086	3.047	5.73	0.932	-0.35
Ireland	0.008	0.244	-6.81	-0.334	na
Italy	-0.014	-0.507	na	-1.580	na
Netherlands	-0.069	-2.093	na	1.146	0.68
Portugal	0.015	5.111	8.50	1.310	1.36
Spain	0.017	0.584	-2.64	1.854	3.13
Sweden	-0.013	-0.312	na	-0.260	na
United Kingdom	-0.027	-1.239	na	1.463	1.92
Canada	-0.026	-0.898	na	0.838	-0.88
Japan	0.269	3.535	6.52	1.897	3.25
United States	0.116	4.424	7.72	2.242	4.12
b) Impulse on private investment					
	Output elasticity	*MPIpriv*	Partial rate of return (%)	*MPTI*	Total rate of return (%)
Austria	0.369	1.858	3.15	1.659	2.56
Belgium	0.185	1.065	0.31	1.045	0.22
Denmark	0.162	0.915	-0.44	0.890	-0.58
Finland	0.214	1.066	0.32	1.035	0.17
France	0.240	1.393	1.67	1.323	1.41
Germany	0.498	2.610	4.91	2.306	4.27
Greece	0.311	1.530	2.15	1.596	2.36
Ireland	0.327	1.852	3.13	1.458	1.90
Italy	0.196	1.046	0.22	0.884	-0.61
Netherlands	0.214	1.190	0.87	1.076	0.36
Portugal	0.268	1.212	0.97	1.178	0.82
Spain	0.424	2.087	3.75	1.903	3.27
Sweden	0.154	1.030	0.15	1.156	0.73
United Kingdom	0.213	1.378	1.62	1.293	1.29
Canada	0.209	1.153	0.72	1.108	0.52
Japan	0.515	2.372	4.41	1.868	3.17
United States	0.241	1.514	2.10	1.671	2.60

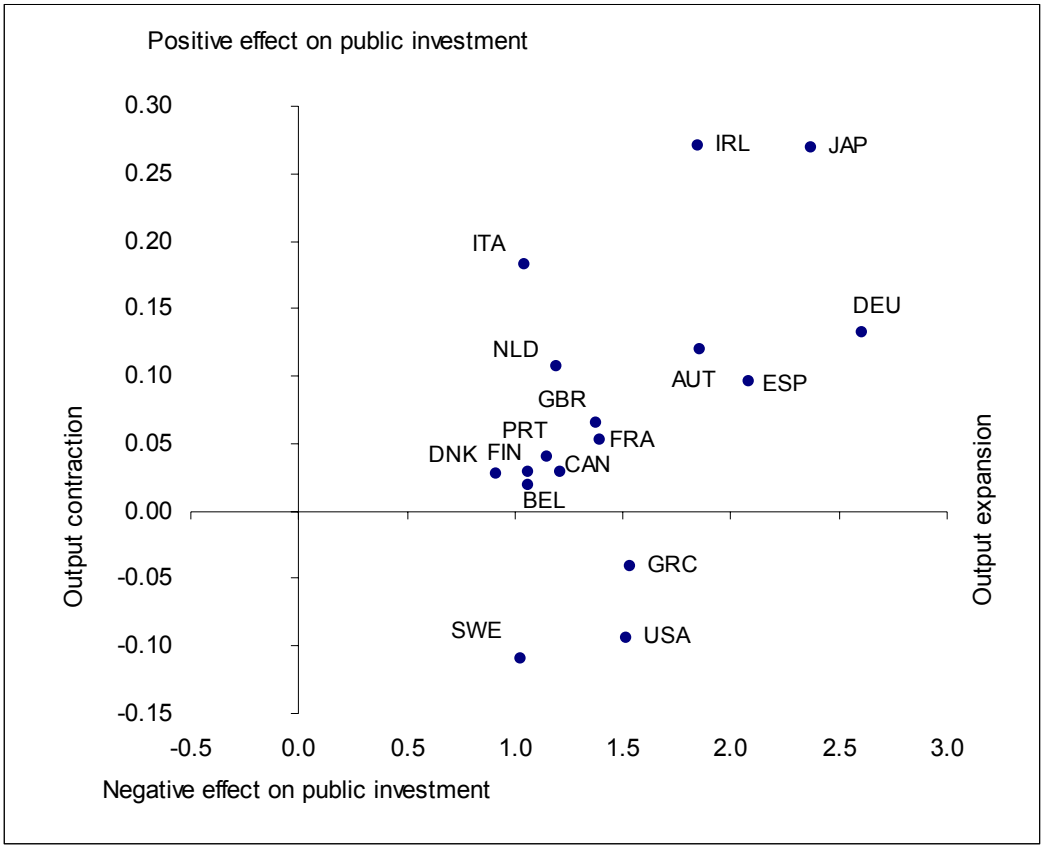
Notes: na – not available. The rate of return cannot be computed in this case since the marginal productivity is negative, see, for instance, equation (12) in the text. *MPIpub* – marginal productivity of public investment. *MPIpriv* – marginal productivity of private investment. *MPTI* – marginal productivity of total investment.

Figure 1 – Public investment: marginal productivity (horizontal) and marginal effect on private investment (vertical), (1960-2005)



Note: AUT – Austria; BEL – Belgium; CAN – Canada; DEU – Germany; DNK – Denmark; ESP – Spain; FIN – Finland; FRA – France; GBR – United Kingdom; GRC – Greece; IRL – Ireland; ITA – Italy; JAP – Japan; NLD – Netherlands; PRT – Portugal; SWE – Sweden; USA – United States.

Figure 2 – Private investment: marginal productivity (horizontal) and marginal effect on public investment (vertical), (1960-2005)



Note: AUT – Austria; BEL – Belgium; CAN – Canada; DEU – Germany; DNK – Denmark; ESP – Spain; FIN – Finland; FRA – France; GBR – United Kingdom; GRC – Greece; IRL – Ireland; ITA – Italy; JAP – Japan; NLD – Netherlands; PRT – Portugal; SWE – Sweden; USA – United States.

Figure 3 – Summary of public and private investment effects (1960-2005)

Public investment impulse

Effect on priv. inv. / Effect on output	Crowding-in	Crowding-out
Expansionary	AUT, DEU, DNK, FIN, GRC, JAP, PRT, USA	BEL, ESP, FRA, IRL
Contractionary	SWE	CAN, GBR, ITA, NLD

Private investment impulse

Effect on pub. inv. / Effect on output	Crowding-in	Crowding-out
Expansionary	AUT, BEL, CAN, ESP, DEU, DNK, ESP, FIN, GRB, IRL, ITA, JAP, NLD, PRT	GRC, SWE, USA
Contractionary	-	-

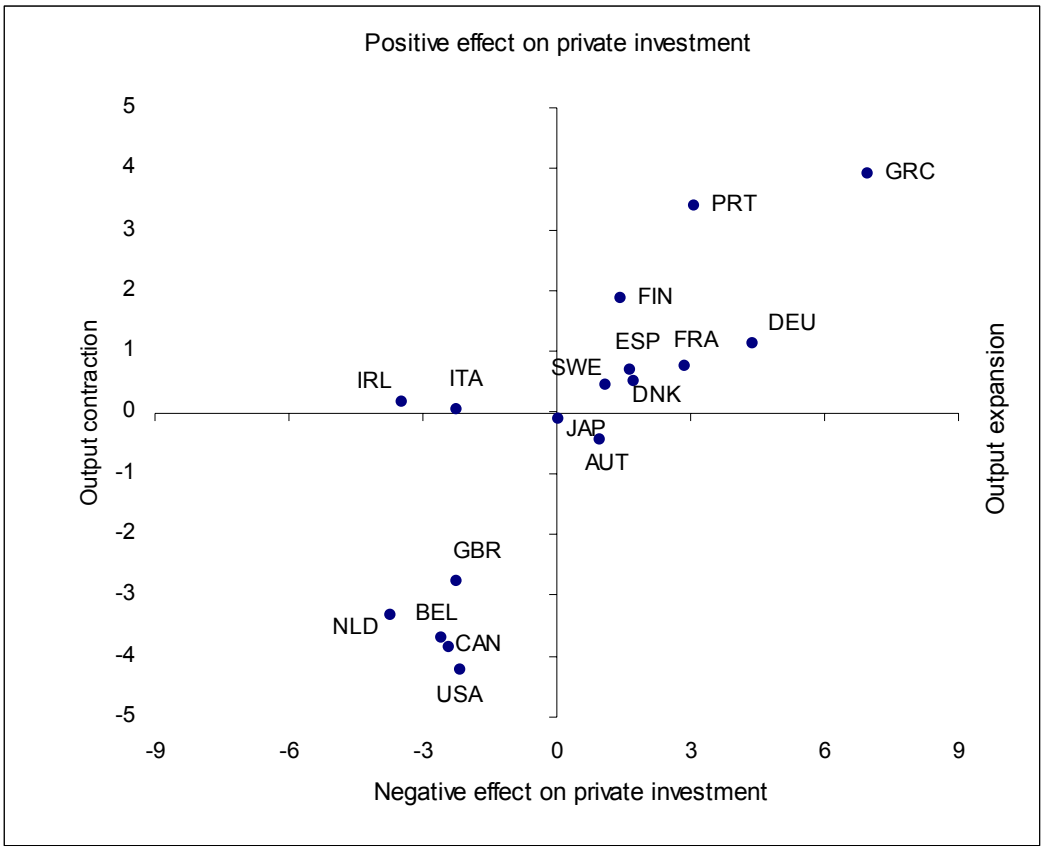
Annex

Table A1 – Long-run elasticities, marginal productivity and rates of return (1980-2005)

a) Impulse on public investment					
	Output elasticity	*MPIpub*	Partial rate of return (%)	*MPTI*	Total rate of return (%)
Austria	0.001	0.029	-16.16	0.033	-15.62
Belgium	-0.045	-2.143	na	0.667	-2.01
Denmark	0.033	1.734	2.79	1.149	0.70
Finland	0.046	1.435	1.82	0.498	-3.43
France	0.091	2.852	5.38	1.627	2.46
Germany	0.096	4.407	7.70	2.079	3.73
Greece	0.217	6.971	5.73	1.417	1.76
Ireland	-0.101	-3.474	na	-2.994	na
Italy	-0.061	-2.226	na	-2.114	na
Netherlands	-0.112	-3.698	na	1.589	2.34
Portugal	0.108	3.068	5.77	0.700	-1.76
Spain	0.054	1.629	2.47	0.962	-0.19
Sweden	0.040	1.083	0.40	0.753	-1.40
United Kingdom	-0.043	-2.259	na	1.282	1.25
Canada	-0.066	-2.403	nd	0.845	-0.84
Japan	0.068	0.952	-0.24	1.774	2.90
United States	-0.066	-2.597	nd	0.956	-0.22
b) Impulse on private investment					
	Output elasticity	*MPIpriv*	Partial rate of return (%)	*MPTI*	Total rate of return (%)
Austria	0.192	0.987	-0.07	1.000	0.00
Belgium	0.182	1.088	0.42	1.057	0.28
Denmark	0.146	0.856	-0.77	0.820	-0.99
Finland	0.274	1.512	2.09	1.438	1.83
France	0.225	1.377	1.61	1.290	1.28
Germany	0.273	1.482	1.99	1.486	2.00
Greece	0.217	1.133	0.63	1.211	2.36
Ireland	0.381	2.243	4.12	1.805	3.00
Italy	0.087	0.494	-3.47	0.417	-4.28
Netherlands	0.386	2.206	4.04	1.995	3.51
Portugal	0.284	1.334	1.45	1.218	0.99
Spain	0.269	1.372	1.59	1.416	1.75
Sweden	0.163	1.126	0.60	1.263	1.17
United Kingdom	0.216	1.404	1.71	1.355	1.53
Canada	0.166	0.940	-0.31	0.928	-0.37
Japan	0.476	2.284	4.21	1.655	2.55
United States	0.166	1.051	0.25	1.038	0.19

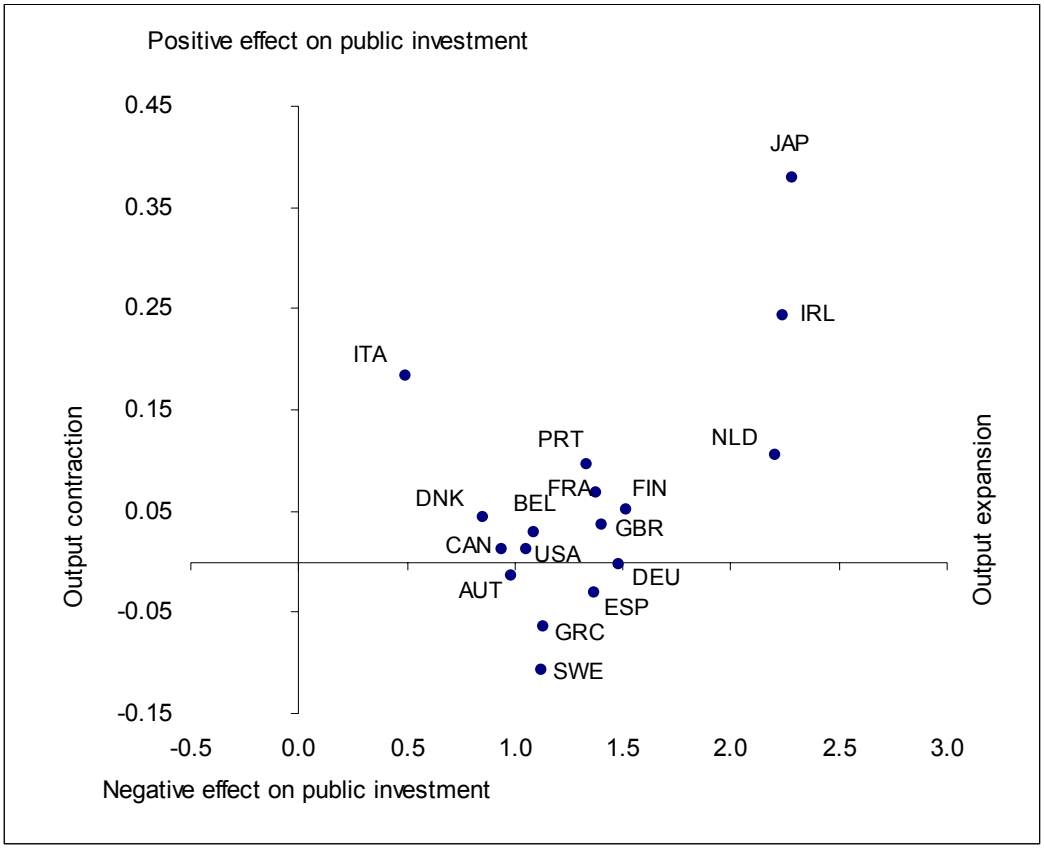
Notes: na – not available. The rate of return cannot be computed in this case since the marginal productivity is negative, see, for instance, equation (12) in the text. *MPIpub* – marginal productivity of public investment. *MPIpriv* – marginal productivity of private investment. *MPTI* – marginal productivity of total investment.

Figure A1 – Public investment: marginal productivity (horizontal) and marginal effect on private investment (vertical), (1980-2005)



Note: AUT – Austria; BEL – Belgium; CAN – Canada; DEU – Germany; DNK – Denmark; ESP – Spain; FIN – Finland; FRA – France; GBR – United Kingdom; GRC – Greece; IRL – Ireland; ITA – Italy; JAP – Japan; NLD – Netherlands; PRT – Portugal; SWE – Sweden; USA – United States.

Figure A2 – Private investment: marginal productivity (horizontal) and marginal effect on public investment (vertical), (1980-2005)



Note: AUT – Austria; BEL – Belgium; CAN – Canada; DEU – Germany; DNK – Denmark; ESP – Spain; FIN – Finland; FRA – France; GBR – United Kingdom; GRC – Greece; IRL – Ireland; ITA – Italy; JAP – Japan; NLD – Netherlands; PRT – Portugal; SWE – Sweden; USA – United States.

Figure A3 – Summary of public and private investment effects (1980-2005)

Public investment impulse

Effect on priv. inv. / Effect on output	Crowding-in	Crowding-out
Expansionary	DEU, DNK, ESP, FIN, FRA, GRC, PRT, SWE	AUT, JAP
Contractionary	IRL, ITA	BEL, CAN, GBR, NLD, USA

Private investment impulse

Effect on pub. inv. / Effect on output	Crowding-in	Crowding-out
Expansionary	BEL, CAN, DNK, FIN, FRA, GRB, IRL, ITA, JAP, NLD, PRT, USA	AUT, DEU, ESP, GRC, SWE
Contractionary	-	-