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DYNAMIC MACROECONOMIC EFFECTS OF PUBLIC CAPITAL: EVIDENCE FROM REGIONAL ITALIAN DATA

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Abstract

This paper assesses the effects of public capital in Italy on the main macroeconomic aggregates: GDP, private capital and labour. A cointegrated vector autoregressive (VAR) model, in line with recent advancements in the field, allows us to take into account the complex nexus of direct and indirect links between the variables. We find a persistent increase in GDP in response to a positive shock to public capital; this result is mainly attributable to a strong stimulus exerted by public infrastructures on private capital (*crowding in*). The positive effects of public capital are quite pervasive across Italy, albeit to differing extents. In particular, a higher elasticity of GDP to public capital is estimated for the South, whereas marginal productivity turns out to be higher in the Centre-North. This suggests that public capital has a lower economic return in the South, bearing out the existence of a potential conflict between equity and efficiency goals. Finally, we indirectly document the existence of positive spillover effects at the regional level, allowing individual regions to benefit from the endowment of public capital in the rest of the country.

JEL classification: C32, H54, R53.
Key words: public capital, crowding in effects, Italian regional divides, VAR models.

Contents

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1. Introduction[1]

The issue of the contribution of public capital accumulation to economic growth comes up frequently in economic and political debates, the main goal being to establish if public capital is productive and to what extent. Increasing attention is also paid to the geographical allocation of expenditure, because a trade-off between equity (when government decides to invest more in depressed regions having the greatest need of infrastructures) and efficiency goals (when government decides to invest more in highly productive regions) may arise.

In line with more recent contributions in the empirical literature, this paper adopts an approach based on vector autoregressive (VAR) models to assess the effects of public capital on Italy's economic performance both in the country as a whole and in its main areas and regions. To implement the approach new regional public capital stock figures are estimated for different types of assets and covering a more recent period. The VAR approach was preferred to the traditional production function approach for its flexibility: in fact, it does not impose strong *a priori* restrictions on the dynamics of the process, allowing for both direct and indirect linkages between the model variables. Dynamic feedbacks are essential to better understanding the relationship between public capital and economic performance, since public capital may affect output either *directly* as an additional input in the production function or *indirectly* via its effects on private inputs, such as capital and labour. Accordingly, while focusing on the long run effect of government capital expenditure on output, this paper also provides some new evidence of whether public capital *crowds out* or *crowds in* private capital in Italy.

Section 2 reviews the empirical literature on this argument. Section 3 details the capital stock estimation methodology and reports some descriptive statistics. Sections 4 and 5 discuss, respectively, the econometric model and the estimation results. Section 6 concludes.

2. The empirical literature

In his seminal studies on the productivity of public capital in the United States, Aschauer (1989, a-b) adopted a single-equation static production function approach, in which public capital was treated as input, as well as labour and private capital. The author found a very large positive effect of public capital on *GDP*, suggesting that public investment would have paid for itself by

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[1] We greatly benefited from valuable comments by Luigi Cannari, Paola Casavola, Andrea Lamorgese, Fabio Quintiliani and other participants at seminars held in the Bank of Italy. The responsibility for the contents of the paper rests with the authors and not with the Bank of Italy.

means of additional tax revenues. A large body of empirical literature developed after these contributions; yet they failed to replicate such large effects and reached mostly inconclusive results.

This approach was heavily criticized from an econometrics viewpoint. As reported in Pereira (2000), since these production functions are based on non-stationary variables, OLS estimates are spurious in the absence of cointegration and may also suffer from simultaneity bias. So straightforward conclusions about causality cannot be drawn. Subsequently, some authors studied the more complex ways in which public capital can affect output and growth in a general equilibrium context (Baxter and King, 1993): *directly*, because investment in public capital is part of *GDP*; or *indirectly*, because public capital may influence other inputs, such as labour and private capital. The signs of these relations are *a priori* ambiguous: in other words, it is not obvious whether a greater availability of public capital reduces the need for private inputs (substitution effect) or increases the marginal productivity of private inputs, thereby lowering the marginal costs of production and potentially increasing the level of production (scale effect). At the same time, private inputs (labour and capital) may also influence public capital formation. For example, more private investment may increase taxable income, boosting in government resources and consequently public expenditure.

In order to manage the whole system of feedbacks, the use of VAR models is gradually becoming prevalent in the empirical literature. Studies adopting this approach mostly show a positive long-run response of output to a shock in public capital. Reverse causation appears to exist in the long run, suggesting that public capital should be treated as an endogenous variable. The majority of contributions focused on the United States. To our knowledge, only three studies (Mittnik and Neumann, 2001; Pereira, 2001; Kamps, 2005) extended the analysis to a group of OECD countries. Among these, only Kamps (2005) included Italy, finding a positive long-run elasticity of public capital with respect to private capital, a negative effect on employment, and a positive albeit not significant effect on *GDP*.

The empirical results for Italy are not straightforward, since they differ not only across methodologies but also within the same approach. Picci (1999) reports a positive relationship between public capital and output, following a production function approach as well as a cost function approach. Bonaglia *et al.* (2000) find a positive contribution of infrastructure to TFP growth, output and cost reduction, although the magnitude of the cost reducing effect does not appear large enough to outweigh the cost of the public capital, even with huge differences across areas (an almost null elasticity in the North-West and an elasticity of 0.49 in the South). More recently, Bronzini and Piselli (2009) adopted a production function approach, finding that there exists a long-run equilibrium between productivity levels and public capital and that regional productivity is found to be positively affected by the public infrastructure of neighbouring regions.

Lack of data generally makes an extension of the analysis to a regional level more complicated. Therefore, the studies have so far been concentrated on countries with a sufficient body of data (the United States and, more recently, Spain). While estimates for a country as a whole generally suggest the existence of positive effects of public capital on output, the empirical evidence with regional data is indeed weaker and more ambiguous. In particular, the sum of regional effects is usually lower than the aggregate effect. This divergence has stimulated more advanced econometric methodologies. Thus, more recently, empirical models have been enriched by adopting spatial econometric techniques, which explicitly take into account that a specific area may benefit from public capital endowed either in the same area (internal capital) or in the nearest ones (spillovers arising from external capital; Holtz-Eakin, 1993 and Holtz-Eakin and Schwartz, 1995). For Spanish regions, Pereira and Roca-Sagalés (2003) find that the contribution of public capital to *GDP* may be almost equally divided into one part internal capital and another part attributable to the capital endowment in the rest of the country.

3. Public capital data

3.1 – Capital stock estimates

Regional public capital data are not available in Italy. In order to evaluate the effect of public capital on the main macroeconomic variables in Italy's regions, they have to be estimated in line with the national series. As in Bonaglia and Picci (2000) and Montanaro (2003), we obtain regional public capital stock estimates by applying the perpetual inventory method (PI) to the regional investment series (millions of euros at 1995 constant prices).

The basic idea underlying this method is that the capital stock at the end of a period can be expressed as a function of: *i)* the capital stock at the beginning of the period; and *ii)* the gross investment during the service life. This requires a sufficiently long time series of public investment, with some problems in harmonizing different data sources. Considering that we do not have public investment series by region and type of works, we proceed to estimate them, by applying the regional shares in Istat's *Executed Public Works* (available from 1928 to 2001) to the aggregate national series. To preserve the continuity and homogeneity of the series for the entire period 1928-2001, we classify the data in: *i)* Transport infrastructures; *ii)* Public and social buildings; *iii)* Other works. Once the investment series from 1928 to 2001 has been estimated, we proceed to calculate the public capital stock for the years 1970-2001, substantially refreshing the data estimated by Montanaro (2003) and used in Bronzini and Piselli (2009).[2] To sum up, the data do not significantly differ from those already used in Picci (1999), La Ferrara and Marcellino (2000), Bonaglia *et al.* (2000), except when: *a)* they cover a more recent period; *b)* they are based on a longer investment series; and *c)* they avoid some reliability problems with the *Executed Public Works* data in the 1970s (see Montanaro, 2003 for further details).

If we assume that any capital good provides services that do not decline as it ages, then the good itself does not depreciate at a constant rate, but will be withdrawn on the basis of a distribution of retirements around the service life. In this case, we have the *gross capital stock* (see Rosa-Siesto, 1985; Baghli *et al*, 2006; OECD, 1992 and 2001), measured at year *i* as the sum of past investment weighted by survival probabilities. Each investment flow is valued at *as new* prices regardless of the age and actual condition of the assets. This gives us:

$$K_t^{GROSS} = \sum_{i=0}^{t-1} s_i I_{t-i}$$

where K_t^{GROSS} = gross capital at the end of the period (year *t*)
I_{t-i} = gross investment in the year *t-i*
s_i = survival rate at *i* of past investment.

The survival function s_i (i.e. what proportion of the original members of the group of assets are still in service at each year) is as follows:

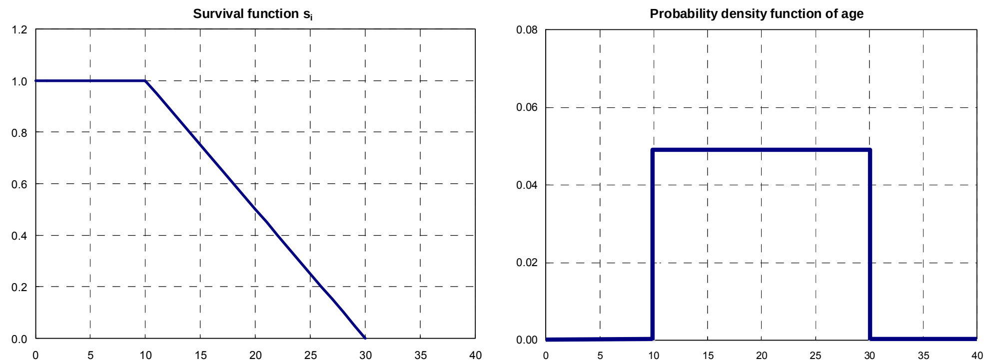
$$s_i = \begin{cases} 1 & ,0 \le i \le T/3 - 1 \\ 1 - \dfrac{i - T/3}{T - T/3}, & T/3 \le i \le T \end{cases}$$

where *T* is the maximum duration life, defined on the basis of the average duration life *M* and above assumptions as the solution of $M = 2/3 * T + 1/2$ and depending on the type of infrastructures (i.e. 40 years for roads and highways, on the basis of OECD estimates for public

[2] Assuming a maximum duration life *T* of about 40 years on average, the 1970 (monetary) stock entirely depends on investment made from 1928 onwards, regardless of the infrastructure endowments existing in the 1928. Even though past conditions may somehow have to do with present endowments – for instance, we can argue that the presence of old traced routes would make easier to realize a new road – after 40 years the (unknown) stock in 1928 is assumed to be completely withdrawn in an economic sense.

goods). Figure A (directly taken from Baghli *et al*, 2006) draws the survival function on the left and the corresponding probability density function of age (i.e. the probability to be withdrawn) on the right (in this case, T is hypothetically assumed to be equal to 30 years).

Figure A – Gross Capital: Specific Assumptions on Mortality and Efficiency



Alternatively, if we assume that the capital stock depreciates at a constant rate, the good in question provides a quantity of services which declines as it ages over its life span. Assuming the hypothesis of both survival function s_i and amortization plan *linear*, we then obtain the *net capital stock*, as:

$$K_t^{NET} = \sum_{i=0}^{t-1} s_i I_{t-i} d_i$$

where K_t^{NET} = net capital at the end of the period (year t)

I_{t-i} = gross investment in the year t-i

s_i = survival rate at i of past investment

$d_i = (1 - \frac{i}{T})$

In this paper we select the concept of *productive capital stock*, which allows us to take into account a decreasing efficiency of surviving assets over time. As in OECD (2001), the *productive capital* (expressed in standard efficiency units) is a measure of the capital services that the different types of assets give to the production process. In the literature the recommended measure of capital inputs for productivity analysis is:

$$K_t^{PROD} = \sum_{i=0}^{t-1} s_i I_{t-i} e_i$$

where K_t^{PROD} = productive capital at the end of the period (year t)

I_{t-i} = gross investment in the year t-i

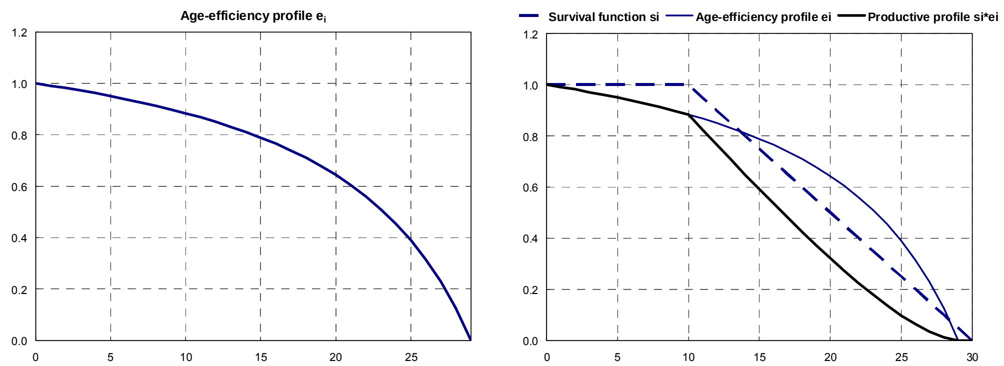
s_i = survival rate at i of past investment
e_i = efficiency of an i-period old asset.

We choose a hyperbolic shape for the age-efficiency profile (Figure B-left, taken from Baghli *et al*, 2006), in order to have a function decreasing over time:

$$e_i = \frac{T-1-i}{T-1-\beta i}$$

where we use β=0.75 (β is commonly assumed equal to 0.50 for machinery and equipment, not included in our analysis, and equal to 0.75 for both buildings and housing). Then the productive capital is the combination of both the survival of assets and the decrease in efficiency over their lifetime (Figure B-right, taken from Baghli *et al*, 2006).

Figure B – Productive Capital: Specific Assumptions on Mortality and Efficiency



For the private capital series, we use the regional capital stock estimates produced by Piselli (2001). Also in this case, the regional private stock is obtained using the PI method. We subtracted the government share from the private capital stock, in order to avoid considering public capital twice. Thus private capital does not include, for every year and region, the stock in non-housing buildings owned by “Other Services”, which covers government, education, health, etc. While this aggregate may include the stock owned by private subjects, this share is plausibly negligible.

3.2 – Descriptive analysis

According to our data, productive public capital accumulation – at constant prices – has been declining in Italy since the 1970s. After the slight recovery in the 1980s, it began to decline again in the period 1991 to 1995. From 1996 to 2001 the annual growth rate stabilized at around 1.5 per cent: it was stronger in the North (Figures 1 and 2, in the Appendix).

The decline in transport infrastructures capital was stark. After the strong rise in the early 1970s, it subsequently recorded an increasingly feeble trend: in recent years, its contribution was low with respect to the other groups of goods. In the South, growth vanished in the recent years, recording negative rates in 1999 and in 2001 (Figures 1 and 2). In the country as a whole, the share of transport infrastructures to total public capital declined from 40.3 per cent in 1980 to 33.5 per cent in 2000; in the North-West, it fell to 31.7 per cent (Table 9). Nevertheless, the contribution of public and social buildings to public capital growth was constant during the same period (Figure 1); it was smaller in the South (Figure 2).

The public capital share of total capital fluctuated at around 10 per cent, declining over time; in the South and in the Centre of Italy the decline was more marked (Figure 3 and Table 4). Differences between the areas of the country were significant: again in the year 2000, the public capital/*GDP* ratio of Southern Italy was around 45 percentage points higher than that of the North-West (Figures 4 and 5; Table 5). As regards the ratio of total public capital to regional resident population, the differences were slighter, but still significant: despite the recovery of the public investment process in more recent years, in the year 2000 every resident in the North-Western regions had a "virtual" stock of public capital that was around 20 per cent lower than the national average (Table 7). In terms of land area, the results are substantially different. In the year 2000, the ratio of public capital to land area in the North-West was higher than the national average, especially in Liguria and Lombardy (Table 6).[3]

It is worth remembering that these findings differ from analyses based on physical data. Among these, Ecoter (2000) shows that northern Italian regions are much more infrastructure-endowed than regions in the South. Golden and Picci (2005) try to interpret the differences between the two ways of estimating public goods (monetary *versus* physical data), assuming that a significantly higher cumulative expenditure with respect to physical endowments not only may be explained by *naturally* higher construction costs, but also hides some undue corruption and inefficiency costs. Probably this problem occurs when estimating public capital for Italian regions.

If *monetary* expenditure exceeds *effective* investment by a given percentage year by year, the PI method may overstate the level of the public capital that is actually available in the South. At the

[3] The right parameter to judge the public capital endowment may differ from one type of works to another. For public and social buildings, for example, we would rather consider public capital with respect to resident population. In fact, it is plausible that the decision to build a hospital or not depends more on the population density than on the land area. On the other hand, it's not easy to choose which variable to consider for transport infrastructures or hydraulic works, which provide as many services to the residents as to the area. Nevertheless, in the literature the most important transport infrastructures (roads, highways, railways) mostly referred to the land area (see SVIMEZ, 2002) or to the GDP.

same time, assuming that inefficiency gaps account for a roughly constant proportion of public capital expenditure in each period, they do not broadly affect the dynamics of public capital and the *elasticity* estimates obtained by implementing the VAR approach (see following sections).

4. The model specification

Based on the empirical literature (Pereira, 2000; Pereira and Roca-Sagalés, 2003; Kamps, 2005), we estimate a structural VAR model with four endogenous variables: *GDP*, private capital stock (K^P), public capital stock (K^G) and employment (*L*, in terms of standard units).[4] All the variables (in logs) are expressed at constant 1995 prices and cover the years 1970 to 2002; the labour input is adjusted for local human capital endowment, measured by average schooling years of the local population. The variables considered are either estimates consistent with National Accounts (*GDP* and *L*) or derived from them (K^P and K^G). The series are clearly non-stationary in levels, the positive trend in *L* being due to human capital accumulation rather than increases in the number of hours worked.

Before proceeding to the estimates, we briefly report the important issues of cointegration and identification of the innovations in the Impulse Response Functions (IRFs), already addressed by Pereira (2000) and Kamps (2005). Phillips (1998) shows that impulse responses and forecast error variance decompositions based on the estimation of unrestricted structural VAR models are inconsistent over long horizons in the presence of non-stationary variables. At the same time, vector error correction models (VECMs) yield consistent estimates of impulse responses and of forecast error variance decompositions if and only if the number of cointegration relations is consistently estimated. So we have to investigate the cointegration properties of the VAR system.

The starting point of the cointegration analysis (Kamps, 2005) is that any VAR(*p*) model in levels

$$X_t = A_1 X_{t-1} + A_2 X_{t-2} + \ldots + A_p X_{t-p} + \Phi D_t + \varepsilon_t \qquad (1)$$

can always be written in equivalent VECM form:

$$\Delta X_t = \Pi X_{t-1} + \Gamma_1 \Delta X_{t-1} + \Gamma_2 \Delta X_{t-2} + \ldots + \Gamma_{p-1} \Delta X_{t-p+1} + \Phi D_t + \varepsilon_t \qquad (2)$$

[4] Source: Prometeia regional estimates of GDP and our computations based on Prometeia regional employment estimates and Istat's Census data on education.

Since individual series were all initially found to be integrated of order 1, the determination of the cointegration rank was subsequently based on the indications provided by the Johansen trace-test. Following Lütkepohl (2001), the sequence starts with the null hypothesis that the cointegration rank is zero.[5] If this hypothesis cannot be rejected, then the testing sequence terminates and a VAR model in first differences is selected. At the other extreme, if all null hypotheses have to be rejected, then the variables can be regarded as (trend-) stationary in levels.

Table 11 displays the results for Italy and for each of the 18 regions considered in this paper.[6] Evidence of cointegration is found in all cases, the number of cointegrating relations at 5 per cent of significance ranging from 1 to 3. On the basis of this evidence, the choice of a VAR model in first differences, as adopted by Pereira (2000) for the United States and Pereira and Roca-Sagalés (2003) for Spain, appears to be unsupported by our data set. We thus estimate a VECM model for Italy and its geographical areas, including an intercept and linear trend in the deterministic component (both restricted to lie in the cointegration space). This choice implies the existence of a (log) linear trend in the data, a feature consistent with the dynamics of the series at a graphical inspection.

While usual information criteria led us to deem as optimal a lag order of 4 or 5, the lag order of the VECM model was set equal to 2 for all the models (corresponding to a 3rd order VAR in levels), and a subsequent analysis of residual cross-correlations confirmed the overall acceptability of this choice. The order of the model was selected by comparing both goodness of fit, mainly assessed by inspecting individual residual auto and cross-correlograms, and parsimony, considering that high order models would have rapidly exhausted the scarce degrees of freedom deriving from the relatively small time span of the series, thus implying less precise estimates of dynamic multipliers, due to the well know overparametrization problem of VAR models. Nonetheless, to check for robustness of our main findings, VECMs up to order 4 were fitted to the data. The results, available from the authors upon request, show that the pattern of structural long run responses to K^G shocks remain qualitatively unaffected across the different specifications.

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[5] As well explained by Kamps (2005), whose methodology we follow closely, we can distinguish three cases. *(i)* If the cointegration rank $r = 0$, then rank $(\Pi) = 0$ and the variables collected in X_t are not cointegrated. So there are k independent stochastic trends in the system and it is appropriate to estimate the VAR model in first differences, dropping X_{t-1} as regressor in Eq. 2. *(ii)* At the other extreme, if $r = k$, then rank $(\Pi) = k$ and each variable in X_t taken individually must be stationary. In other words, the number of stochastic trends, given by $(k - r)$, is equal to zero and it is possible to apply OLS either to the unrestricted VAR in levels (Eq. 1) or to its equivalent representation given by (2). *(iii)* In the intermediate case $(0 < r < k)$, the variables in X_t are driven by $0 < k - r < k$ common stochastic trends and rank $(\Pi) = r < k$. In this case, a VECM imposing the appropriate rank restriction should be the right model to estimate. The maximum likelihood approach developed by Johansen (1988, 1991) can be applied in order to estimate the space spanned by the cointegrating vectors.

[6] Because of problems in the continuity of the series, we have aggregated data for Piedmont-Valle d'Aosta and Abruzzo-Molise. Also, the regions considered here are 18 rather than 20 as in the NUTS II grouping.

5. The results

5.1 – Impulse-response analysis and the effects of public capital

Having made assumptions on the cointegrating rank, we give a structural interpretation of the VAR model, i.e., we derive IRFs from the reduced-form parameter estimates. This is equivalent to estimating the reaction of key macroeconomic variables to an unexpected change (innovation) in one variable (e.g. public capital).

The analysis can be based on the unrestricted VAR model in levels given by Equation (1). This model can serve in the structural analysis irrespective of whether the variables in X_t are stationary or not. The impulse-response analysis can simply proceed on the basis of the VAR(p) model in the representation (1), once we have put the parameters Π and Γ_j from the VECM (2) into the A_i matrices.

Pre-multiplying Equation (1) by the (k × k) matrix A_0, we obtain the structural form

$$A_0 X_t = A_1^* X_{t-1} + A_2^* X_{t-2} + \ldots + A_p^* X_{t-p} + A_0 \Phi D_t + Be_t \qquad (3)$$

where $A_i^* \equiv A_0 A_i$ for $i = 1, \ldots, p$, and $Be_t = A_0 \varepsilon_t$ describes the relation between the structural disturbances e_t (white noise and uncorrelated with each other, i.e., the variance-covariance matrix of the structural disturbances Σ is diagonal) and the reduced-form disturbances ε_t. The lower triangular matrix A_0 describes the contemporaneous relations among all the variables in the vector X_t.

To be meaningful in an economic sense and to analyze the dynamic causal linkages across the variables, the model must rely on orthogonal stochastic shocks. In other words, we have to identify the shocks to public capital that are not contemporaneously correlated with shocks to other variables, i.e., not subject to the reverse causation problem. As explained by Pereira (2000), this would result from knowing which part of public investment in each period is due to purely non-economic reasons. Let's imagine a policy function that relates public investment to the past but not current values of the other variables (private capital, *GDP* and labour). Being obviously uncorrelated with other innovations, the residuals from this policy function necessarily reflect the unexpected component in the evolution of public investment. In the context of the standard Choleski decomposition, this is equivalent to assuming that innovations in public investment lead to innovations in the other variables contemporaneously, but not vice versa.

Consequently, following a common procedure, we orthogonalize the VECM residuals using the inverse of the Choleski root of the variance-covariance matrix (standard Choleski decomposition). This is equivalent to assuming a recursive system of simultaneous causalities, in which it is necessary to have variables properly ordered by descending degree of exogeneity (Sims, 1980). We have a maximum degree of exogeneity when there are no responses of a variable to current shocks to the other variables.

In our case, public capital is reasonably assumed to represent the most exogenous variable. Then we have private capital, labour input and *GDP*, in descending order: $X \equiv [K^G, K^P, L, GDP]$. As suggested by Pereira (2000), it seems plausible that the private sector reacts rapidly to innovations in public investment decisions, while the reverse is not true, due to the time lags involved in information gathering and public decision-making. So in order to give the impulse response functions a structural interpretation, we identify the VAR models by assuming that the relation between the reduced-form disturbances ε_t and the structural disturbances e_t, i.e. $Be_t = A_0\varepsilon_t$, takes the following form (Kamps, 2005):

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} e_t^{K^G} \\ e_t^{K^P} \\ e_t^{L} \\ e_t^{GDP} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ a21 & 1 & 0 & 0 \\ a31 & a32 & 1 & 0 \\ a41 & a42 & a43 & 1 \end{bmatrix} \begin{bmatrix} \varepsilon_t^{K^G} \\ \varepsilon_t^{K^P} \\ \varepsilon_t^{L} \\ \varepsilon_t^{GDP} \end{bmatrix} \qquad (4)$$

In the equation (4), where we have six unknown parameters in the lower triangular matrix A_0 and four unknown parameters in the diagonal covariance matrix Σ of the structural disturbances ε_t, investment in public capital (K^G) is assumed not to react immediately to unexpected shocks to all the other macroeconomic variables. Private investment (K^P) is assumed to be predetermined with respect to the current unexpected fluctuations in employment and *GDP*, but it is potentially affected by contemporaneous shocks to public capital. The labour input (L) too is assumed to be predetermined with respect to *GDP*, but to react both to K^G and K^P.[7]

[7] As remarked by Hansen and Sargent (1980), Blanchard and Quah (1989), Lippi and Reichlin (1993, 1994), Christiano *et al* (2006) and Alessi *et al*. (2008), there may be an identification problem, when the structural shocks are nonfundamental, i.e. $N<q$, where N is the dimension of the covariance stationary zero-mean vector stochastic process x_t of observable variables and q is the dimension of the unobservable vector process u_t of structural shocks, which drives the stochastic process x_t, so that $x_t = C(L)u_t$. In other words, we have nonfundamental representations of a VAR when agents are able to use additional information to form expectations of future variables, thus anticipating the effects of any foreseen future intervention by the government ($N<q$). Since VAR representations are *fundamental* by construction, the nonfundamental structural shocks cannot be identified by estimating and inverting a VAR. We are conscious that a problem of nonfundamentalness may lie in our model as well as in every VAR model, and that fiscal policy is clearly a field in which, in general, structural models can produce nonfundamental representations since agents have rational

Figure 6 shows the impulse-response functions for the estimated model at the national level, and the corresponding 90 percent bootstrap confidence intervals. For Italy as a whole, a rise in the stock of public capital has positive and significant effects on *GDP* in the long run, which is qualitatively in line with Kamps' estimates.

Based on Pereira (2000), Pereira and Roca-Sagalés (2003), Kamps (2005) and Pina and St. Aubyn (2006), estimates of long-term elasticity of output to public capital (η_G) can be derived from the IRFs by dividing the *long-term response* (i.e. the response observed at a time horizon sufficiently long for IRFs to converge) of real *GDP* to a shock to public capital by the *long-run response* of public capital to a shock to public capital itself:

$$\eta_G = \frac{\Delta \log GDP}{\Delta \log K^G} \tag{5}$$

where Δ denotes a *long-term response*. The elasticity represents the total percentage-point change in the private-sector variables for each long-term percentage-point change in public investment.

In terms of long-term elasticity, the aggregate *GDP* is estimated to increase by 0.62 per one-percent increase in public capital (Table 12). The effect on private capital is also positive and accumulating over time, with a long-term elasticity of 0.54: so there is no evidence of *crowding out* effects, even in the short term, but rather significant *crowding in* effects (Table 13). Our estimates are rather precise, as witnessed by the 90 percent confidence intervals.

Based on the above defined elasticity value, a long-run measure of the marginal productivity of public capital (*MPG)* can be derived by multiplying (5) by the *GDP* to public capital ratio observed over the sample period (see the second column of Table 12):

$$MPG \equiv \frac{\Delta GDP}{\Delta K^G} = \eta_G \frac{GDP}{K^G} \tag{6}$$

Following this approach, our long-run marginal productivity estimate is 1.39 euros of *GDP* for each euro invested in public capital, corresponding to an annual rate of return of 1.6 per cent in a twenty-year horizon. In a nutshell, infrastructures appear to be a productive investment.

Comparing these results with previous evidence in the literature is not easy, due to the adoption of a range of different econometric concepts and techniques, sometimes referring to different notions of elasticity or marginal productivity. As a matter of fact, it must be noted that

expectations. As a consequence, an unexpected intervention in public capital by the government might not necessarily coincide with the fundamental shock identified in a VAR. Nevertheless, even though extremely interesting, this argument is not a goal of this paper.

using a very similar VAR model, Pereira and Roca-Sagalés (2003) estimate, on national aggregate data for Spain, a long-run elasticity of output to public capital of a comparable amount (0.53); adopting the same approach, Pereira (2000) finds out a positive effect of public investment (i.e. flow instead of stock data) also for the United States. For Italy as a whole and using different data, Kamps (2005) obtains a very large long-run effect of public capital on output.

Our VAR-based long-run elasticities display a greater magnitude when compared to values typically obtained in previous analyses implementing different econometric methods, even when based on Italian regional data. It is worth noting that empirical results for Italy are not easy to interpret, since they differ not only across methodologies (i.e. production or cost function, growth accounting), but also within the same approach (i.e. when estimating effects of public capital on output instead of productivity or TFP). For example, focusing on studies based on regional data similar to ours only, Picci (1999) reports an elasticity of 0.43 and 0.35 with fixed and random effects, respectively. When performing robustness checks, however, he finds weaker results. Bonaglia *et al*. (2000) find that public capital has no significant effects on productivity for the total Italian economy, albeit with huge differences across areas, with no effects in the North-West and an elasticity of 0.49 in the South. With a similar production function approach, La Ferrara and Marcellino (2000) even report a slightly negative impact of public capital. Using similar data, De Stefanis and Sena (2005) suggest instead that public capital has a significant impact on the evolution of total factor productivity, particularly in the Southern regions. Finally, Bronzini and Piselli (2009) find a long-run elasticity of 0.19 when calculated with respect to output.

That said, the greater magnitude obtained here does not depend on a different data set, since all the cited works use public capital based on Istat's *Executed Public Works* data. Instead, we are able to say that the difference is due to the diverse estimation methods employed. In particular, our VAR model accounts for both direct and indirect effects, i.e. captures the whole set of dynamic feedbacks among the variables in the system, whereas in a production function elasticities and marginal products are obtained *by maintaining the private inputs unchanged and excluding feedback effects*. Moreover, aggregate VAR models' estimates also capture *spatial spillovers*, while regional models on panel data estimate direct *average* effects of the public capital endowment *within* each region. This argument is similar to that of Munnell (1990), who found an elasticity of 0.35 when using data for the United States as a whole, but a lower value (around 0.15) when using state level data. In other words, we cannot interpret panel *average* estimates as *aggregate* estimates for Italy as a whole, since they miss indirect and spillover effects.

In order to disentangle the effects of transport infrastructures from those of other public works, we replicate separately our estimates for these two kinds of public capital. The results show that the estimated elasticity is even higher for transport infrastructures; at the same time, their marginal productivity, in line with a stricter link to economic activities, is three times higher compared with other kinds of public capital (4.2 against 1.4 per cent; Table 15), with a yearly rate of return of 7.5 per cent.

5.2 – The results for the Centre-North and the South

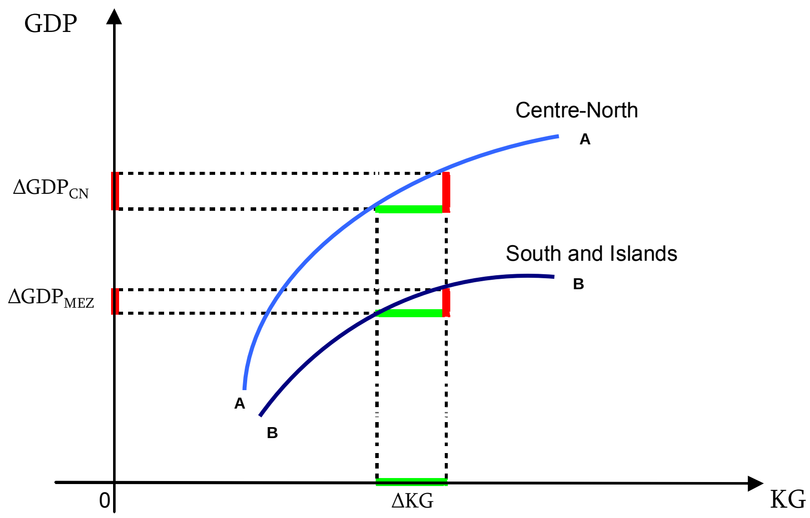
We are able to replicate the estimates for both the Centre-North and the South of Italy. Since the incidence of public capital on *GDP* is significantly higher in the less developed South, it is very interesting to verify how the results vary under different economic conditions, i.e., how different GDP / K^G ratios affect the results in terms of long-term elasticities and marginal returns. In accordance with the goal of the paper, the results are only shown for the effects of unforeseen shocks to public capital. Table 12 displays the long-run elasticity and the marginal productivity of public capital; Tables 13 and 14 show the results for private capital and employment.

The long-run responses of *GDP* to an innovation in public capital and the relative long-term elasticities (Equation 5) are positive in both areas and larger in the South (see the first column of Table 12) while, on the contrary, the marginal productivity of public capital (Equation 6) is higher in the Centre-North. As we have seen before, the difference between elasticity and marginal productivity depends on the role played by the GDP / K^G ratio. Let us suppose that we spend the same amount of euro (one euro more) in public capital both in the Centre-North and in the South. In the long run (defined as the time horizon over which the growth effects of innovations disappear, i.e., the accumulated impulse-response functions converge), the yield in terms of *GDP* is 1.11 euros in the former case and 0.84 in the latter, thus denoting a larger return from the investment in the Centre-North. To reconcile these results with the evidence of a higher elasticity in the South, we have to keep in mind that the incidence of public capital to *GDP* is much higher in the South (Table 5). This implies that, with the support of the theoretical Figure C and given the Equation (6), "CN" standing for the Centre-North and "MEZ" for the South and Islands, although $\eta_{CN} < \eta_{MEZ}$, the ratio GDP_{CN} / K^G_{CN} is so much higher than GDP_{MEZ} / K^G_{MEZ} that

$$MPG_{CN} \equiv \frac{\Delta GDP_{CN}}{\Delta K^G_{CN}} = \eta_{CN} \frac{GDP_{CN}}{K^G_{CN}} > \eta_{MEZ} \frac{GDP_{MEZ}}{K^G_{MEZ}} = \frac{\Delta GDP_{MEZ}}{\Delta K^G_{MEZ}} \equiv MPG_{MEZ} \qquad (7)$$

i.e., being the slope of the curve *AA* (Centre-North) in the Figure C higher than that of the curve *BB* (South and Islands), the *MPG* in the Centre-North is bigger than in the South.

Figure C – A Theoretical Example of Marginal Productivity and Elasticity of Output to Public Capital



From a policy perspective, our results suggest the possible existence of a conflict between equity (when government aims to sustain depressed areas such as the South) and efficiency goals (when public investment aims to sustain yet highly productive regions). However, it is worth remembering that the public capital series utilized here relies on (properly discounted) accumulated *monetary* expenditure and that, as a result, our model yields an estimate of the effect of monetary expenditure on output. To some extent, the lower *return to public capital expenditure* in the South may be caused by a less efficient transformation of monetary expenditure in “effective” public capital, due to higher costs of producing a unit of public capital and/or a lower efficiency in managing public expenditure and/or a higher level of corruption in completing public infrastructures. Under this hypothesis, with a higher efficiency in the South, the GDP / K^G ratio would probably result higher in the long run.

5.3 – The results for the regions

We are able to produce VAR estimates at regional level too. By adopting a specification in line with that used at the national level, we are able to assess the degree of spatial heterogeneity in long-term of output to public capital and gather some indirect evidence on the possible range of spatial externalities across the areas. For each of the 18 regions, positive estimates of the long term elasticity of *GDP* to K^G are obtained (see the first column of Table 12). Turning to marginal productivity, the impact of public capital appears to be stronger in the northern regions. In particular, the estimated coefficient is very high for Veneto and Piedmont.

Multiplying each regional marginal product by the share of public capital allocated in that region, we obtain an estimate of the individual regional contributions to the national marginal product (see the third column of Table 12); if the sum of the regional contributions is significantly lower than the aggregate marginal product for Italy as a whole, this provides evidence that the entire national effect of public capital expenditure cannot be fully captured by strictly regional estimates. On the basis of our results, the sum of the regional contributions accounts for 0.77 of the total effect of public capital on *GDP* identified at the aggregate level (Table 12). As suggested by Pereira and Roca-Sagalés (2003), we can interpret these results as follows: the regional models are not able to capture the effect of public capital on output in its entirety because of important spillover effects from the public capital endowment in other regions. Allowing explicitly for spillover effects in their regional models, Pereira and Roca-Sagalés (2003) find that over one half of the aggregate effects obtained for Spain as a whole is due to innovations in public capital allocated to other regions.

Although this comparison requires some caution, since the sum of the regional contributions accounts for 0.77 of the aggregate marginal productivity, while it is 0.44 in Pereira and Roca-Sagalés (2003) for Spain, we can argue that there are less spillover effects in Italy than in Spain. This conclusion, that is shown to apply to private capital and labour responses as well (Tables 14 and 15), could be tied to the circumstance that, with respect to Spain, a larger share of public investment in Italy has been devoted to works of smaller scale, instead of large-scale infrastructures whose benefits are more widespread nationwide.

6. Concluding remarks

Based on our estimates, the growth rate of the public capital stock in Italy has been declining since the 1970s. After a slight recovery in the 1980s, it dropped again at the beginning of the 1990s. The share of transport infrastructures to total public capital also fell over time. At the regional level, while public capital endowment per unit of *GDP* appears to be larger in the South, in more recent years the public capital growth rate has been higher in northern Italy.

According to our cointegrated VAR estimates, in the short run public capital is found to exert a positive impact on output and employment, as predicted by Keynesian models focusing on the counter-cyclical role of public investment spending as an instrument to sustain private sector employment. Non-Keynesian long-run positive effects of public capital on both private capital accumulation and *GDP* level are also found. Our analysis, in line with similar studies on other countries, accordingly provides evidence that investment in public capital is a powerful instrument to stimulate economic growth in the long run, a result to which a strong and sustained positive response of private capital clearly contributes; in other words, public and private capital appear to be complementary (*crowding in*). The larger long-run elasticities compared to other studies on Italian data do not depend on a different data set used, but are due to a different estimation method. In particular, our VAR based estimates capture the whole set of dynamic feedbacks among the variables in the system, whereas in a production function elasticities and marginal products are obtained by maintaining the private inputs unchanged and excluding feedback effects. Moreover, VAR models' aggregate estimates also capture spatial spillovers, while regional models on panel data estimate direct average effects of the public capital endowment within the regions.

When extended to the two main areas of the country, the analysis yields different results in terms of elasticity (higher in the South) and marginal productivity (higher in the Centre-North). Given the high elasticity estimates, the lower economic return to public capital expenditure in the South compared with the Centre-North could be at least partly related to lower efficiency of public sector expenditure in the South, implying that in this region a larger amount of resources has to be spent to yield a unit of effective capital. Under this hypothesis, raising public sector efficiency could provide a means to foster the productivity of public capital in the South.

At the regional level, our estimates indirectly document the plausible existence of spillover effects, allowing each region to benefit from public capital allocated in the rest of the country. Nevertheless, the magnitude of the spatial externalities is found to be less relevant in comparison with the findings of similar studies on Spanish regional data, giving prominence to the issue of what is the most appropriate sectoral and spatial allocation of public works in order to maximize spillover effects. We believe further research should address this argument.

Tables and figures

Table 1

GROSS PUBLIC CAPITAL

(percentages)

REGIONS	1980	1990	2000
Piedmont and Valle d'Aosta	5.4	6.1	6.9
Lombardy	9.8	10.5	11.3
Trentino-Alto Adige	2.5	2.8	3.4
Veneto	6.1	6.1	6.4
Friuli Venezia Giulia	2.7	3.1	3.0
Liguria	4.0	3.7	3.6
Emilia-Romagna	7.4	7.2	7.4
Tuscany	6.7	6.5	6.3
Umbria	1.9	1.8	1.6
Marche	2.9	2.7	2.6
Lazio	8.9	8.8	9.1
Abruzzo and Molise	4.5	4.2	3.9
Campania	7.7	7.9	7.7
Puglia	4.8	4.8	4.8
Basilicata	3.2	3.0	2.8
Calabria	6.6	6.1	5.5
Sicily	10.2	9.9	9.2
Sardinia	4.7	4.6	4.6
North West	*19.2*	*20.3*	*21.7*
North East	*18.6*	*19.3*	*20.2*
Centre	*20.5*	*19.8*	*19.6*
South and Islands	*41.6*	*40.6*	*38.5*
Italy	**100.0**	**100.0**	**100.0**

Source: based on Istat data.

Table 2

PRODUCTIVE PUBLIC CAPITAL

(percentages)

REGIONS	1980	1990	2000
Piedmont and Valle d'Aosta	5.5	6.2	7.0
Lombardy	9.9	10.7	11.5
Trentino-Alto Adige	2.5	2.9	3.5
Veneto	6.0	6.1	6.5
Friuli Venezia Giulia	2.7	3.2	3.1
Liguria	4.0	3.6	3.5
Emilia-Romagna	7.3	7.1	7.4
Tuscany	6.7	6.5	6.2
Umbria	2.0	1.8	1.6
Marche	2.9	2.7	2.6
Lazio	8.9	8.8	9.1
Abruzzo and Molise	4.5	4.2	3.9
Campania	7.7	7.9	7.6
Puglia	4.8	4.8	4.8
Basilicata	3.2	3.0	2.8
Calabria	6.6	6.1	5.3
Sicily	10.2	9.8	9.1
Sardinia	4.7	4.6	4.5
North West	*19.4*	*20.5*	*22.0*
North East	*18.5*	*19.3*	*20.4*
Centre	*20.5*	*19.7*	*19.5*
South and Islands	*41.6*	*40.5*	*38.1*
Italy	**100.0**	**100.0**	**100.0**

Source: based on Istat data.

Table 3

NET PUBLIC CAPITAL

(percentages)

REGIONS	1980	1990	2000
Piedmont and Valle d'Aosta	5.5	6.4	7.3
Lombardy	10.2	10.9	11.7
Trentino-Alto Adige	2.6	3.0	3.6
Veneto	5.9	6.1	6.6
Friuli Venezia Giulia	2.8	3.3	3.1
Liguria	3.9	3.5	3.4
Emilia-Romagna	7.2	7.1	7.5
Tuscany	6.6	6.4	6.1
Umbria	2.0	1.7	1.5
Marche	3.0	2.6	2.5
Lazio	8.9	8.8	9.2
Abruzzo and Molise	4.5	4.1	3.7
Campania	7.6	7.9	7.6
Puglia	4.8	4.9	4.8
Basilicata	3.2	2.9	2.7
Calabria	6.6	5.9	5.1
Sicily	10.2	9.8	8.9
Sardinia	4.7	4.6	4.5
North West	*19.6*	*20.8*	*22.5*
North East	*18.4*	*19.4*	*20.8*
Centre	*20.4*	*19.6*	*19.4*
South and Islands	*41.6*	*40.2*	*37.3*
Italy	**100.0**	**100.0**	**100.0**

Source: based on Istat data.

Table 4

PUBLIC CAPITAL: SHARE OF TOTAL CAPITAL

(percentages)

REGIONS	1980	1990	2000
Piedmont and Valle d'Aosta	7.8	8.2	8.1
Lombardy	7.4	7.4	6.9
Trentino-Alto Adige	11.1	11.9	11.9
Veneto	8.6	8.3	7.5
Friuli Venezia Giulia	13.0	13.8	12.2
Liguria	19.1	16.8	14.5
Emilia-Romagna	10.9	10.1	9.2
Tuscany	14.2	13.1	11.1
Umbria	15.5	13.7	11.3
Marche	13.8	12.2	10.6
Lazio	13.0	12.0	10.7
Abruzzo and Molise	17.4	15.6	13.5
Campania	10.6	10.0	9.2
Puglia	11.1	10.5	9.6
Basilicata	25.7	23.3	20.9
Calabria	22.5	20.0	16.7
Sicily	14.6	13.3	11.7
Sardinia	16.5	15.5	13.9
North West	*8.6*	*8.5*	*7.9*
North East	*10.3*	*10.1*	*9.2*
Centre	*13.7*	*12.5*	*10.9*
South and Islands	*14.8*	*13.5*	*12.0*
Italy	**12.0**	**11.2**	**10.1**

Source: based on Istat data.

Table 5

THE RATIO OF PUBLIC CAPITAL TO REGIONAL GDP

(percentages)

REGIONS	1980	1990	2000
Piedmont and Valle d'Aosta	27.3	33.5	37.4
Lombardy	24.5	25.6	26.7
Trentino-Alto Adige	56.4	66.5	75.2
Veneto	35.3	35.6	33.3
Friuli Venezia Giulia	57.8	69.2	62.4
Liguria	53.9	57.1	57.0
Emilia-Romagna	40.6	43.2	40.6
Tuscany	47.4	49.6	44.6
Umbria	64.8	64.5	55.4
Marche	56.8	56.7	48.1
Lazio	45.4	43.9	44.8
Abruzzo and Molise	92.9	88.0	80.0
Campania	55.1	59.6	58.0
Puglia	48.3	50.9	49.2
Basilicata	209.9	217.2	176.7
Calabria	149.1	142.4	120.4
Sicily	75.3	78.6	76.3
Sardinia	98.4	106.9	102.7
North West	*28.6*	*30.8*	*32.5*
North East	*41.9*	*45.2*	*43.2*
Centre	*48.9*	*48.6*	*45.9*
South and Islands	*78.7*	*80.9*	*76.1*
Italy	**48.4**	**50.1**	**48.3**

Source: based on Istat data.

Table 6

PUBLIC CAPITAL PER SQUARE KILOMETRE

(millions of euros)

REGIONS	1980	1990	2000
Piedmont and Valle d'Aosta	0.63	0.93	1.18
Lombardy	1.38	1.92	2.31
Trentino-Alto Adige	0.62	0.90	1.22
Veneto	1.10	1.45	1.71
Friuli Venezia Giulia	1.15	1.73	1.89
Liguria	2.48	2.95	3.23
Emilia-Romagna	1.11	1.41	1.64
Tuscany	0.98	1.23	1.34
Umbria	0.77	0.90	0.94
Marche	1.02	1.21	1.31
Lazio	1.73	2.23	2.60
Abruzzo and Molise	0.99	1.20	1.26
Campania	1.89	2.54	2.76
Puglia	0.83	1.09	1.22
Basilicata	1.07	1.30	1.37
Calabria	1.48	1.76	1.78
Sicily	1.33	1.67	1.76
Sardinia	0.65	0.84	0.93
North West	*1.11*	*1.52*	*1.83*
North East	*1.01*	*1.35*	*1.60*
Centre	*1.18*	*1.47*	*1.65*
South and Islands	*1.13*	*1.43*	*1.53*
Italy	**1.11**	**1.44**	**1.63**

Source: based on Istat data.

Table 7

PUBLIC CAPITAL PER CAPITA

(thousands of euros)

REGIONS	1980	1990	2000
Piedmont and Valle d'Aosta	4.0	6.0	7.8
Lombardy	3.7	5.2	6.1
Trentino-Alto Adige	9.6	13.9	17.7
Veneto	4.7	6.1	7.0
Friuli Venezia Giulia	7.3	11.3	12.6
Liguria	7.4	9.4	11.1
Emilia-Romagna	6.2	8.0	9.2
Tuscany	6.3	8.0	8.8
Umbria	8.0	9.4	9.7
Marche	7.0	8.2	8.7
Lazio	6.0	7.5	8.8
Abruzzo and Molise	9.7	11.6	12.1
Campania	4.7	6.2	6.6
Puglia	4.2	5.2	5.9
Basilicata	17.4	21.2	22.9
Calabria	10.8	12.8	13.3
Sicily	6.9	8.6	9.1
Sardinia	9.9	12.3	13.7
North West	*4.2*	*5.9*	*7.1*
North East	*6.0*	*8.1*	*9.4*
Centre	*6.4*	*7.9*	*8.8*
South and Islands	*7.0*	*8.6*	*9.2*
Italy	**5.9**	**7.7**	**8.6**

Source: based on Istat data.

Table 8

PUBLIC CAPITAL PER STANDARD LABOUR UNIT

(thousands of euros)

REGIONS	1980	1990	2000
Piedmont and Valle d'Aosta	7.6	9.7	10.9
Lombardy	7.1	7.7	8.2
Trentino-Alto Adige	17.1	18.8	22.2
Veneto	9.3	9.2	9.1
Friuli Venezia Giulia	14.5	18.5	17.8
Liguria	15.8	16.6	17.3
Emilia-Romagna	11.1	11.1	11.1
Tuscany	12.4	12.6	11.7
Umbria	15.6	14.8	13.0
Marche	12.4	12.1	11.4
Lazio	13.6	12.8	12.9
Abruzzo and Molise	20.9	19.8	18.5
Campania	11.8	13.3	13.0
Puglia	10.0	10.6	10.6
Basilicata	39.4	41.5	37.8
Calabria	29.2	27.5	24.6
Sicily	18.5	19.1	18.1
Sardinia	24.9	23.1	23.2
North West	*8.2*	*9.1*	*9.9*
North East	*11.3*	*11.8*	*11.9*
Centre	*13.1*	*12.8*	*12.3*
South and Islands	*17.4*	*17.8*	*17.0*
Italy	**12.6**	**13.0**	**12.9**

Source: based on Istat data.

Table 9

TRANSPORT INFRASTRUCTURES :
SHARE OF TOTAL PUBLIC CAPITAL

(percentages)

REGIONS	1980	1990	2000
Piedmont and Valle d'Aosta	39.8	36.0	32.8
Lombardy	32.1	29.6	26.5
Trentino-Alto Adige	43.2	37.3	30.1
Veneto	33.8	30.6	26.8
Friuli Venezia Giulia	32.4	34.8	33.6
Liguria	60.8	54.5	46.2
Emilia-Romagna	39.9	36.8	34.0
Tuscany	47.1	43.3	39.5
Umbria	59.8	56.1	48.9
Marche	49.0	46.6	40.3
Lazio	36.5	33.1	34.6
Abruzzo and Molise	46.6	45.0	40.7
Campania	36.4	32.4	30.7
Puglia	35.3	33.1	29.1
Basilicata	35.8	34.6	31.4
Calabria	42.6	41.1	37.2
Sicily	45.7	41.8	38.2
Sardinia	30.4	27.0	24.1
North West	*40.2*	*36.1*	*31.7*
North East	*37.3*	*34.6*	*31.0*
Centre	*44.0*	*40.3*	*38.1*
South and Islands	*39.9*	*36.9*	*33.5*
Italy	**40.3**	**37.0**	**33.5**

Source: based on Istat data.

Table 10

PUBLIC CAPITAL GROWTH BY TYPE OF WORKS
(changes and percentage points)

REGIONS	1981-1990				1991-2000			
	Transport (1)	Public and social buildings (1)	Other (1)	Total public capital (2)	Transport (1)	Public and social buildings (1)	Other (1)	Total public capital (2)
Piedmont and Valle d'Aosta	12.9	11.8	21.8	46.6	5.4	7.7	13.4	26.5
Lombardy	9.1	9.6	20.3	39.1	2.3	7.9	10.4	20.6
Trentino-Alto Adige	11.2	12.8	22.1	46.2	3.3	14.2	17.4	34.8
Veneto	6.3	8.7	16.3	31.3	1.0	6.8	10.1	18.0
Friuli Venezia Giulia	19.6	10.8	19.2	49.6	2.0	3.1	4.4	9.5
Liguria	4.2	6.8	8.2	19.2	-4.0	4.0	9.3	9.3
Emilia-Romagna	6.7	7.9	11.9	26.5	2.9	7.3	6.4	16.6
Tuscany	6.9	6.1	11.8	24.8	-0.3	4.1	5.1	8.8
Umbria	6.5	3.7	7.9	18.1	-5.1	2.8	6.6	4.3
Marche	6.4	4.7	7.7	18.9	-2.9	5.6	5.9	8.5
Lazio	6.0	3.7	18.9	28.6	7.3	3.3	6.0	16.5
Abruzzo and Molise	8.1	3.0	10.7	21.8	-2.2	3.1	4.1	5.0
Campania	7.0	4.0	23.0	34.0	1.0	4.4	3.3	8.7
Puglia	8.1	5.7	17.2	30.9	-0.3	3.4	9.4	12.5
Basilicata	6.2	2.1	13.2	21.5	-1.4	3.9	3.3	5.8
Calabria	6.4	1.1	11.8	19.3	-3.5	2.6	1.8	1.0
Sicily	6.8	2.5	16.3	25.6	-1.4	3.1	3.8	5.5
Sardinia	4.2	3.8	20.3	28.3	-0.3	2.9	8.3	10.9
North West	*9.2*	*9.6*	*18.2*	*37.1*	*2.1*	*7.1*	*11.1*	*20.3*
North East	*9.0*	*9.3*	*15.8*	*34.1*	*2.2*	*7.5*	*8.9*	*18.6*
Centre	*6.4*	*4.6*	*13.9*	*25.0*	*2.3*	*3.8*	*5.7*	*11.8*
South and Islands	*6.7*	*3.1*	*16.5*	*26.4*	*-1.1*	*3.4*	*4.6*	*6.9*
Italy	**8.5**	**6.8**	**17.1**	**30.5**	**5.3**	**9.5**	**11.4**	**17.3**

Source: based on Istat data. – (1) Percentage points. – (2) Percentage changes.

Table 11

COINTEGRATION TESTS

REGIONS	Trace statistic				Selected cointegration rank [a]
	H_0: $r = 0$	H_0: $r = 1$	H_0: $r = 2$	H_0: $r = 3$	
Piedmont and Valle d'Aosta	91.71	50.47	22.93	7.68	2
Lombardy	118.88	66.86	23.69	9.73	2
Trentino-Alto Adige	76.08	40.71	21.35	5.71	1
Veneto	94.21	51.33	29.39	11.76	3
Friuli Venezia Giulia	85.13	46.21	17.61	6.20	2
Liguria	67.01	34.91	14.62	3.69	1
Emilia-Romagna	84.67	54.67	29.72	11.53	3
Tuscany	119.81	62.56	30.96	4.28	3
Umbria	89.36	49.75	27.77	6.44	3
Marche	102.81	50.94	24.06	11.58	2
Lazio	79.36	51.15	28.72	10.00	3
Abruzzo and Molise	109.51	49.77	16.39	4.93	2
Campania	94.95	59.89	27.30	11.49	3
Puglia	81.86	43.11	22.38	5.78	2
Basilicata	80.59	49.13	22.10	4.58	2
Calabria	82.43	46.84	24.84	8.78	2
Sicily	104.37	47.18	19.49	9.33	2
Sardinia	81.94	42.59	19.15	7.00	1
Centre and North	*112.63*	*64.74*	*23.93*	*7.48*	*2*
South and Islands	*94.18*	*46.63*	*16.37*	*7.61*	*2*
Italy	**111.01**	**53.37**	**21.56**	**9.17**	**2**
Critical values[b]					
10%	60.0	39.7	23.3	10.7	
5%	63.7	42.8	25.7	12.5	
1%	70.9	48.9	30.7	16.2	

Notes: the underlying VAR model contains both an intercept and a linear deterministic trend; the lag order is set to 3 for all areas.
[a] The test decision is based on the asymptotic critical values reported in the bottom rows of the table. [b] The asymptotic critical values are taken from MacKinnon *et al.* (1999), Table V. The cointegration ranks reported in the table are chosen for a 5% significance level.

Table 12

LONG-TERM EFFECTS ON GDP OF REGIONAL PUBLIC CAPITAL

(percentage values and units of euros)

REGIONS	Elasticities (%) [a]	$\Delta GDP/\Delta K^G$ (euros) [b]	Contr. to aggregate $\Delta GDP/\Delta K^G$ [c]
Piedmont and Valle d'Aosta	0.62 (++)	1.86	0.13
Lombardy	0.05	0.21	0.02
Trentino-Alto Adige	0.69 (++)	1.04	0.03
Veneto	0.95 (++)	2.67	0.18
Friuli Venezia Giulia	0.25	0.36	0.01
Liguria	0.52	0.90	0.04
Emilia-Romagna	0.26 (+)	0.61	0.05
Tuscany	0.80 (+)	1.60	0.12
Umbria	0.54	0.84	0.02
Marche	0.56	0.98	0.03
Lazio	0.74 (+)	1.69	0.16
Abruzzo and Molise	0.09	0.10	0.00
Campania	0.51	0.86	0.08
Puglia	0.60 (++)	1.17	0.06
Basilicata	0.93 (++)	0.43	0.01
Calabria	0.48 (++)	0.34	0.02
Sicily	0.55 (++)	0.70	0.08
Sardinia	0.16	0.15	0.01
Centre and North	*0.40 (++)*	*1.11*	
South and Islands	*0.61 (++)*	*0.84*	
Italy	**0.62 (++)**	**1.39**	**1.07**
Total all regions as % of total Italy			**76.9**

Source: based on Istat data.

Notes: (+) (++) denotes that the 68% (90%) confidence interval does not include zero. The confidence intervals for the individual regions are computed using the bootstrap procedure. They refer to the impulse response estimates.

[a] The long-run elasticities give the long-run percentage change in private capital, employment and real *GDP* per 1% long-run change in public capital. They are obtained by dividing the long-run response of private capital, employment and real *GDP* to a shock to public capital, respectively, by the long-run response of public capital to a shock to public capital. In the computations, we set the response horizon n=500 which ensures that for all countries the impulse responses have converged to their long-run levels (Kamps, 2005).

[b] The regional marginal products in the table are obtained by multiplying the elasticities by the GDP / K^G ratio.

[c] The contributions to the aggregate marginal products are computed by weighting these figures using the share of public capital in that region in relation to total public capital in Italy.

Table 13

LONG-TERM EFFECTS ON PRIVATE CAPITAL OF AN IMPULSE ON REGIONAL PUBLIC CAPITAL

(percentage changes and units of euros)

REGIONS	Elasticities (%) [a]	$\Delta K^P/\Delta K^G$ (euros) [b]	Contr. to aggregate $\Delta K^P/\Delta K^G$ [c]
Piedmont and Valle d'Aosta	0.62 (++)	7.5	0.46
Lombardy	0.21 (++)	2.8	0.30
Trentino-Alto Adige	0.82 (++)	6.6	0.19
Veneto	0.24 (++)	2.9	0.18
Friuli Venezia Giulia	0.27	1.8	0.06
Liguria	0.32	1.7	0.06
Emilia-Romagna	0.37 (+)	3.6	0.26
Tuscany	0.78 (+)	5.7	0.37
Umbria	-0.01	-0.1	0.00
Marche	0.62 (++)	4.9	0.13
Lazio	0.51	4.1	0.36
Abruzzo and Molise	0.45	2.7	0.11
Campania	0.72 (+)	7.1	0.56
Puglia	0.66 (++)	6.1	0.30
Basilicata	0.82 (++)	2.9	0.09
Calabria	0.36 (++)	1.6	0.10
Sicily	0.67 (++)	4.8	0.47
Sardinia	0.31 (+)	1.9	0.09
Centre and North	*0.48 (++)*	*4.8*	
South and Islands	*0.65 (++)*	*4.6*	
Italy	**0.54 (++)**	**4.7**	**4.09**
Total all regions as % of total Italy			**87.7**

Source: based on Istat data.

Notes: (+) (++) denotes that the 68% (90%) confidence interval does not include zero. The confidence intervals for the individual regions are computed using the bootstrap procedure. They refer to the impulse response estimates.

[a] The long-run elasticities give the long-run percentage change in private capital, employment and real *GDP* per 1% long-run change in public capital. They are obtained by dividing the long-run response of private capital, employment and real *GDP* to a shock to public capital, respectively, by the long-run response of public capital to a shock to public capital. In the computations, we set the response horizon n=500 which ensures that for all countries the impulse responses have converged to their long-run levels (Kamps, 2005).

[b] The regional marginal products in the table are obtained by multiplying the elasticities by the K_{priv} / K^G ratio.

[c] The contributions to the aggregate marginal products are computed by weighting these figures using the share of public capital in that region in relation to total public capital in Italy.

Table 14

LONG-TERM EFFECTS ON LABOUR OF AN IMPULSE ON REGIONAL PUBLIC CAPITAL

(percentage changes and units of euros)

REGIONS	Elasticities (%) [a]	$\Delta L/\Delta K^G$ (euros) [b]	Contr. to aggregate $\Delta L/\Delta K^G$ [c]
Piedmont and Valle d'Aosta	0.24	0.03	0.002
Lombardy	0.38 (++)	0.05	0.006
Trentino-Alto Adige	0.62 (++)	0.04	0.001
Veneto	1.12 (++)	0.13	0.008
Friuli Venezia Giulia	0.06	0.00	0.000
Liguria	0.60	0.04	0.001
Emilia-Romagna	0.36 (+)	0.04	0.003
Tuscany	0.76 (+)	0.07	0.004
Umbria	1.52 (++)	0.11	0.002
Marche	0.27 (+)	0.02	0.001
Lazio	0.79 (+)	0.07	0.006
Abruzzo and Molise	-0.61 (+)	-0.03	-0.001
Campania	0.24	0.02	0.002
Puglia	0.89 (++)	0.09	0.004
Basilicata	0.91 (++)	0.02	0.001
Calabria	0.52 (++)	0.02	0.001
Sicily	0.50 (++)	0.03	0.003
Sardinia	0.34	0.02	0.001
Centre and North	*1.09 (++)*	*0.10*	
South and Islands	*0.53 (++)*	*0.03*	
Italy	**0.79 (++)**	**0.06**	**0.053**
Total all regions as % of total Italy			**83.5**

Source: based on Istat data.

Notes: (+) (++) denotes that the 68% (90%) confidence interval does not include zero. The confidence intervals for the individual regions are computed using the bootstrap procedure. They refer to the impulse response estimates.

[a] The long-run elasticities give the long-run percentage change in private capital, employment and real *GDP* per 1% long-run change in public capital. They are obtained by dividing the long-run response of private capital, employment and real *GDP* to a shock to public capital, respectively, by the long-run response of public capital to a shock to public capital. In the computations, we set the response horizon n=500 which ensures that for all countries the impulse responses have converged to their long-run levels (Kamps, 2005).

[b] The regional marginal products in the table are obtained by multiplying the elasticities by the L/K^G ratio.

[c] The contributions to the aggregate marginal products are computed by weighting these figures using the share of public capital in that region in relation to total public capital in Italy.

Table 15

LONG-TERM EFFECTS ON MAIN AGGREGATES OF AN IMPULSE ON TRANSPORT INFRASTRUCTURES

(percentage changes and units of euros)

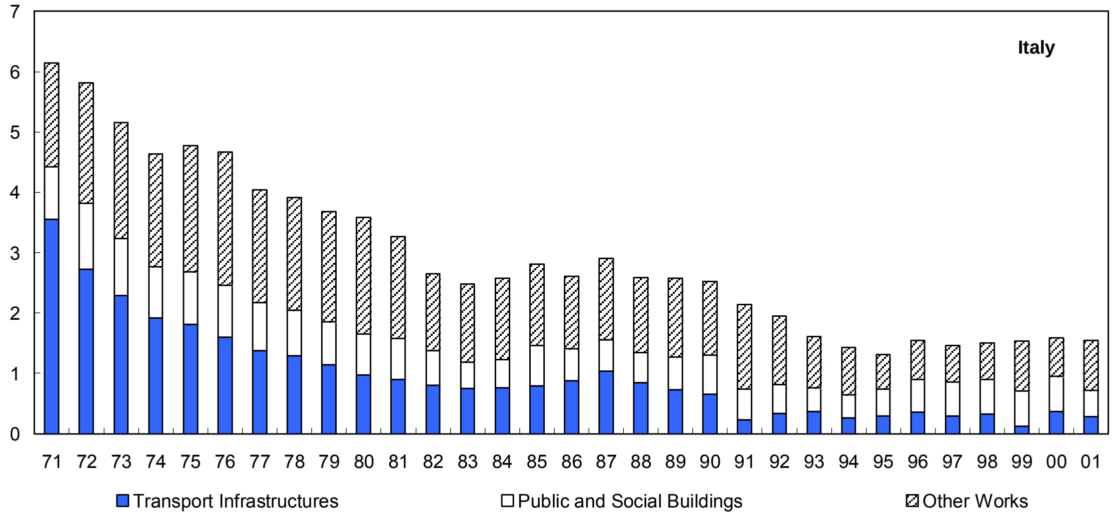
VARIABLES	Elasticities (%) [a]	$\Delta X/\Delta K^G$ (euros) [b]	Contr. to aggregate $\Delta X/\Delta K^{G}$ [c]
GDP			
Italy	0.70 (++)	4.2	
Centre and North	0.30 (+)	2.3	1.38
South and Islands	0.48 (++)	1.8	0.74
Private Capital			
Italy	0.54 (++)	15.0	
Centre and North	0.46 (++)	14.4	8.6
South and Islands	0.55 (++)	12.3	5.0
Labour			
Italy	0.56 (++)	0.13	
Centre and North	0.89 (++)	0.24	0.15
South and Islands	0.43 (++)	0.07	0.03

Source: based on Istat data.
Notes: (+) (++) denotes that the 68% (90%) confidence interval does not include zero. The confidence intervals for the individual regions are computed using the bootstrap procedure. They refer to the impulse response estimates.
[a] The long-run elasticities give the long-run percentage change in private capital, employment and real *GDP* per 1% long-run change in public capital. They are obtained by dividing the long-run response of private capital, employment and real *GDP* to a shock to public capital, respectively, by the long-run response of public capital to a shock to public capital. In the computations, we set the response horizon n=500 which ensures that for all countries the impulse responses have converged to their long-run levels (Kamps, 2005).
[b] The regional marginal products in the table are obtained by multiplying the elasticities by the *GDP* (or K_{priv} or L) / K^{TRASP} ratio.
[c] The contributions to the aggregate marginal products are computed by weighting these figures with the share of public capital in that region in relation to total public capital in Italy.

Figure 1

PUBLIC CAPITAL GROWTH IN ITALY, BY TYPE OF WORKS

(changes and percentage points)

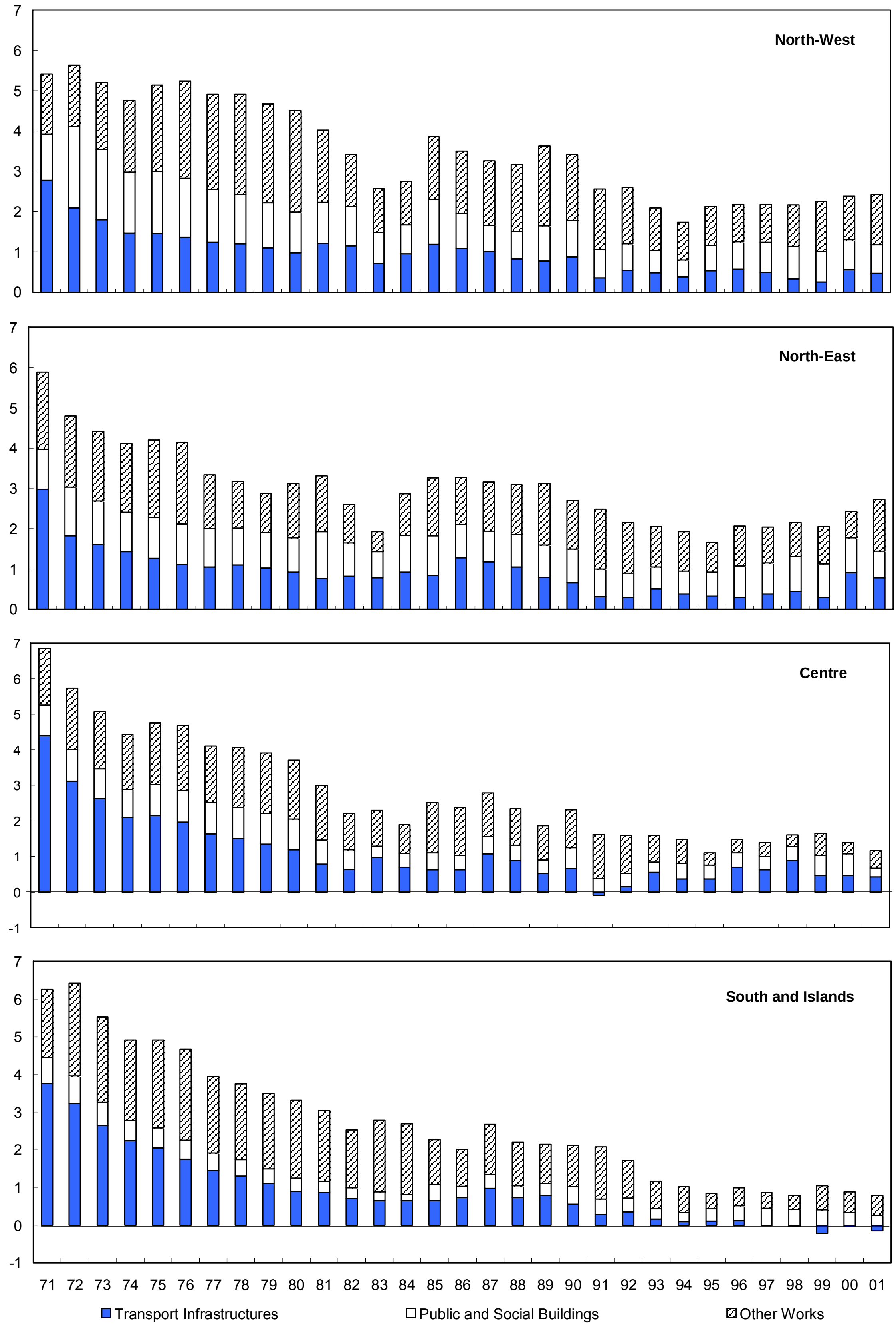


Source: based on Istat data.

Figure 2

PUBLIC CAPITAL GROWTH BY TYPE OF WORKS AND GEOGRAPHICAL AREA

(changes and percentage points)

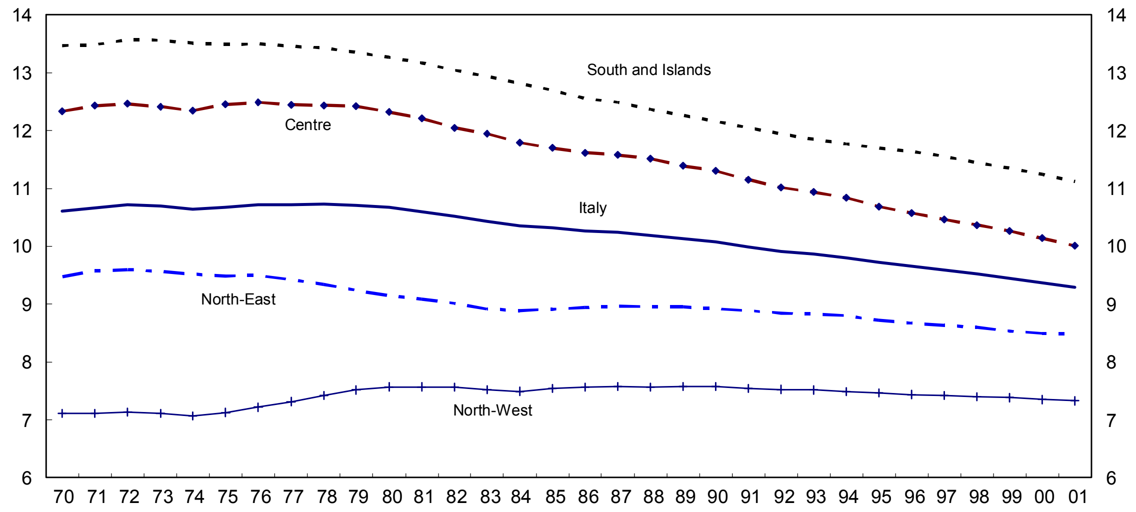


Source: based on Istat data.

Figure 3

PUBLIC CAPITAL: SHARE OF TOTAL BY GEOGRAPHICAL AREA

(percentages)

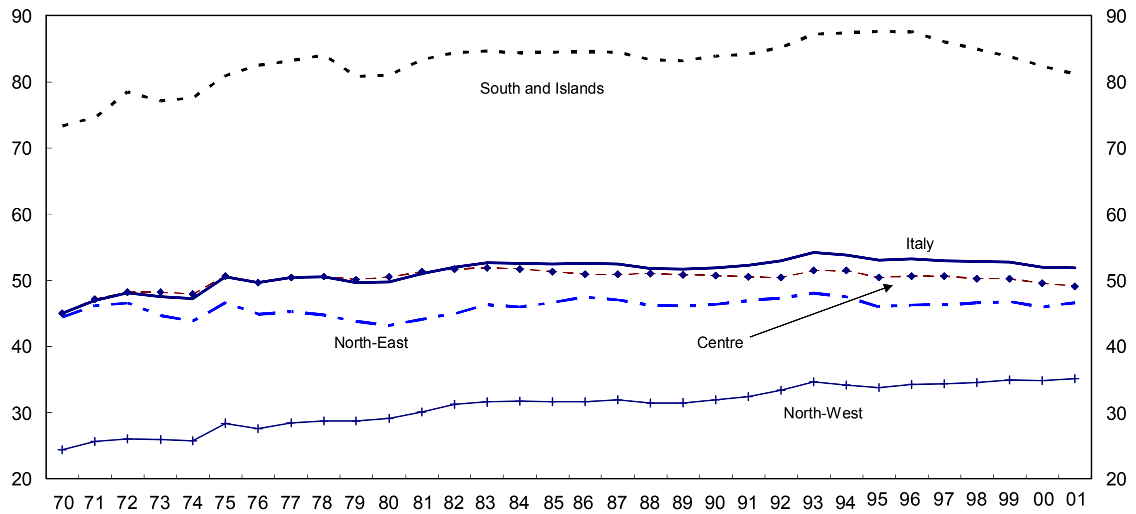


Source: based on Istat data.

Figure 4

PUBLIC CAPITAL: SHARE OF GDP BY GEOGRAPHICAL AREA

(percentages)

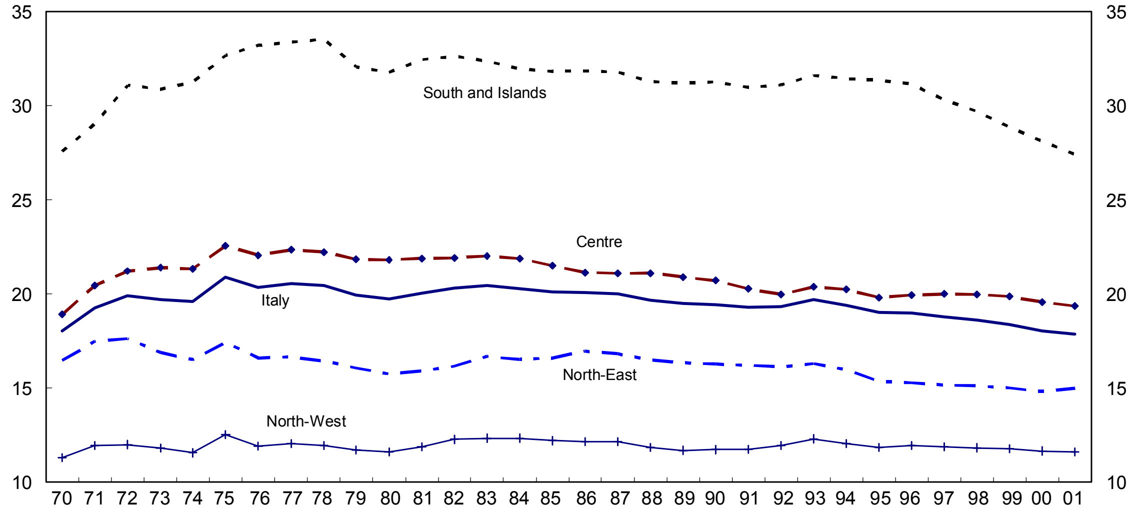


Source: based on Istat data.

Figure 5

TRANSPORT INFRASTRUCTURES PUBLIC CAPITAL:
SHARE OF GDP BY GEOGRAPHICAL AREA

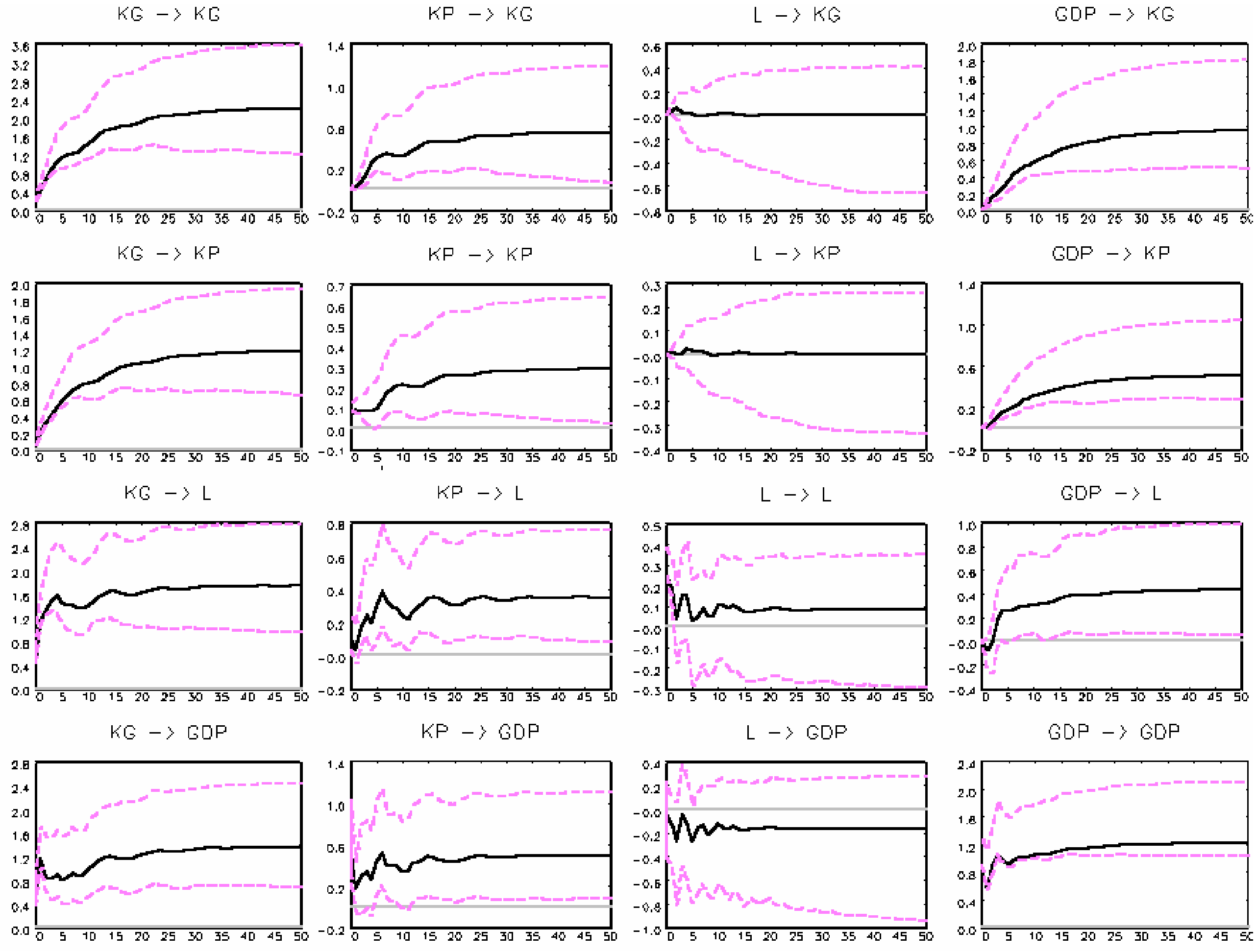
(percentages)



Source: based on Istat data.

Figure 6

IMPULSE-RESPONSE FUNCTIONS FOR ITALY



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