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Comparing macroeconomic returns on human and public capital: An empirical analysis of the Portuguese case (1960–2001)

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Abstract

The impact of human and public capital on growth is a major issue in economic theory and in policy evaluation. Using a cointegrated vector autoregression (VAR), we estimate a Cobb-Douglas production function for Portugal with public and human capital. Return rates are then computed with and without dynamic feedbacks. Without these, human capital yields a return comparable to private investment, and smaller than public investment. Considering dynamic feedbacks, private capital responds positively to a shock in public capital, but negatively to a shock in human capital. Consequently, the dynamic feedbacks return on human capital is much lower than on public capital.

JEL classification: I20; H54; O47

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1. Introduction

Policies to promote growth, in the European Union (EU) and elsewhere, are usually based on the belief that human capital formation and public investment have a long-lasting effect

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on aggregate production. This belief underlies the EU regional policy, whereby structural funds co-finance an important number of government programs in the less prosperous member states, in what concerns public investment (roads, railways, airports and ports, schools and hospitals and other public infrastructure) as well as human capital formation (in both the formal education system and training). It becomes therefore essential, from a policy evaluation point of view, to have a quantified measure of the impact of both human capital and public investment on the growth performance of receiving economies. A similar argument applies to the assessment of national fiscal policy in virtually every country, since public investment and public expenditure on education are important items in government budgets.

A second motivation for this paper stems from the current debate on fiscal rules in Europe, especially as regards the treatment of public investment. Some economists argue that this kind of spending is discouraged under the rules of the stability and growth pact (SGP), and that public investment should therefore be excluded from the deficit definition to which ceilings apply. Blanchard and Giavazzi (2004), for instance, propose a golden rule applying to net public investment. Critics of the golden rule, among other arguments, point out its vulnerability to creative accounting, warn that a preferential treatment of physical investment could bias expenditure decisions against spending on education and R&D, and stress that what matters is the overall capital stock, be it private or public (see e.g. Buti, Eijffinger, & Franco, 2003). Against this background, it is clearly important to assess how "productive" public capital really is, especially by comparison with private capital and human capital. It is also relevant to study the impact of public investment on the overall (physical) capital stock.

In the economic literature, it is not taken for granted that public investment has a significant impact on growth. The works of Aschauer (1989a,b) on the US economy suggested a particular explanation of the productivity slowdown felt at the time—that it was due to a decline in public investment. Aschauer's results relied on static ordinary least squares (OLS) regressions performed with series that are not usually stationary. As it is now well understood, OLS regressions may lead to spurious results if there is no cointegration among the variables and are not immune to the reverse causality problem—public capital may well be caused by output, and not the contrary. Vector autoregressive (VAR) analysis has become a more usual tool, as it allows for the endogeneity of both production and public capital and for dynamic effects between the variables.[1] In general terms, Batina's (2001) inferences from the more recent empirical literature—that public capital has a positive but not tremendous effect on economic growth, that some types of public investment have more impact than others, and that, in statistical terms, it is perfectly possible to find little or no effect of public investment, "even after careful statistical work has been done" (p. 125)—seem an adequate synthesis.

Results for the Portuguese economy do not abound. Ligthart (2000) estimates a production function associated to a cointegrating vector (CV) in a VAR. The estimated

[1] Crowder and Himarios (1997) and Pereira (2000) applied VAR analysis to the US case. Batina (1999) deals with cointegration and dynamic causality issues by resorting to dynamic ordinary least squares (DOLS). See also Flores de Frutos, Gracia-Díez and Pérez-Amaral (1998) and Pereira and Roca (2001) for Spain, Evaraert (2003) for Belgium, and Ligthart (2000) and Pereira and Andraz (2002, 2004) for Portugal.

public capital elasticity of output is rather high, between 0.37 and 0.39. Pereira and Andraz (2002), also using a VAR methodology, find important positive long run effects of aggregate public investment in transportation infrastructures on production, employment and private investment. The rate of return to public investment is close to 16%. In Pereira and Andraz (2004), they present results in more detail together with sectoral and regional disaggregations.

Country-specific studies concerning human capital and growth are scarce, probably because human capital data is seldom available on an annual basis. Consequently, effects on growth have often been estimated by resorting to cross-sectional regressions.[2] The dependent variable is usually GDP, either in levels or in growth rate terms, and a proxy for "human capital" is included among the explanatory variables (e. g. school enrolment rates or the average number of schooling years). Not all studies find a significant and positive relationship between human capital and growth, so there remains considerable uncertainty concerning the magnitudes involved. De la Fuente (2003), who follows a production function approach comparable to ours, finds that, in EU countries, a 1% increase in average years of schooling implies a percentage increase in the GDP level between 0.394 and 0.587. In what concerns Portugal, Teixeira (1996), Teixeira and Fortuna (2003) and Pina and St. Aubyn (2002) were the sole country-specific studies known to us that estimate the human capital contribution to economic growth. The GDP level elasticity with respect to average years of schooling is similar across these studies—between 0.36 and 0.48.

This paper computes rates of return on public and on human capital for Portugal, using a new annual data set on GDP and four production factors: labor, private (physical) capital, public capital and human capital. The CV in a VAR is interpreted as an aggregate Cobb-Douglas production function. While this vector forms the basis to compute rates of return in a *ceteris paribus* way (i.e., holding other inputs constant), the estimated VAR also allows us to consider the dynamic responses of all the variables in the system to a structural shock to public or human capital, giving rise to what we call the dynamic feedbacks rate of return.

From a methodological point of view, our work contains two main innovative features. First and foremost, we study the importance of public and human capital in a unified, coherent framework, rather than separately, as is common in the literature. In this way we are in a position to compute rates of return on each of those inputs which are comparable and which control for the contribution of the other input. Second, we consider alternative definitions of rates of return, clarifying the underlying assumptions. This enables us to compare magnitudes that previous studies had computed in isolation.

The remainder of this study is organized as follows. In Section 2 we present the production function to be estimated, and discuss the computation of rates of return under alternative assumptions. In Section 3 we describe our dataset and report the empirical results. Section 4 discusses the main policy implications from our study. Section 5 concludes.

[2] Previous studies have mostly used series available at a 5 or 10-year frequency, like those provided by Barro and Lee (2000), Cohen and Soto (2001) or De la Fuente and Doménech (2000). Krueger and Lindahl (2001), Sianesi and Van Reenen (2003) and De la Fuente and Ciccone (2002) survey the empirical literature on the influence of human capital formation on growth.

2. The aggregate production function and the returns to investment

We specify a Cobb-Douglas production function:

$$Y(t) = A[\exp(H(t))]^{\gamma}(\mathrm{KP}(t))^{\alpha}(\mathrm{KG}(t))^{\beta}L(t)^{1-\alpha-\beta}, \tag{1}$$

where Y, KP and KG denote GDP, the private capital stock and the public capital stock (all in real terms), L stands for employment, H measures human capital (average years of schooling) and A is a scale parameter. As in many other studies (e.g De la Fuente, 2003 or Evaraert, 2003), we assume constant returns to scale across KP, KG and L. The semi-elasticity γ indicates the percentage increase in output that would result from one more year of schooling for the average worker. This formulation is reminiscent of the well-known Mincerian wage equations (percentage increase in wages due to one more year of schooling), and has been previously adopted in some macroeconomic studies as well (e.g. Jones, 2002).

Both for investment in public capital and in human capital, we compute two different rates of return (r.o.r.), the "*ceteris paribus* (cp) r.o.r." and the "dynamic feedbacks (df) r.o.r.", denoted by $r^{i,j}$ (i = KG, H; j = cp, df).

The computation of $r^{\mathrm{KG,cp}}$ is based on the discounted value of the stream of increases in Y due to a unit investment in the present (time 0), *holding all other inputs constant*. Formally, it is the value of r that solves

$$\int_0^{\infty} \frac{\partial Y(t)}{\partial KG(t)} \mathrm{e}^{-\delta t}\mathrm{e}^{-rt}\mathrm{d}t = 1, \tag{2}$$

where the marginal productivity stems from the production function, and δ is the rate of depreciation. Assuming, as an approximation, that the Y/KG ratio stays constant, we obtain:

$$r^{\mathrm{KG,cp}} = \beta\frac{Y}{\mathrm{KG}} - \delta. \tag{3}$$

Dropping the *ceteris paribus* assumption, $r^{\mathrm{KG,df}}$ considers how the other inputs respond to an increase in KG. This response is important for the assessment of the merits of public investment, particularly as regards whether public capital crowds in or out private capital. Following Pereira (2000) and Pereira and Andraz (2002, 2004), $r^{\mathrm{KG,df}}$ draws on the impulse response functions (IRFs) generated by a shock to KG, in a VAR with output and the several inputs. Formally, denoting gross public investment by IG and the differences relative to the no-shock baseline by d^{b}, we compute the value of r that solves

$$\int_0^{\infty} d^{\mathrm{b}}Y(t)\mathrm{e}^{-rt}\mathrm{d}t = \int_0^{\infty} d^{\mathrm{b}}\mathrm{IG}(t)\mathrm{e}^{-rt}\mathrm{d}t. \tag{4}$$

Eqs. (2) and (4) differ in the way of calculating the increases in output and public investment, which in turn hinges upon whether the *ceteris paribus* assumption is appropriate, or whether dynamic feedbacks should be accounted for instead. Against $r^{\mathrm{KG,df}}$, one may point out that if private investment is crowded in (out), its cost should be included in (deducted from) the right-hand side of Eq. (4), rather than ignored. On the other hand, the

Table 1
Parameter values used to compute the human capital *ceteris paribus* r.o.r. ($r^{H,\text{cp}}$)

Parameter	Value	Description	Source
u_s	0.051	Unemployment rate of the population aged 15–19 not having completed upper secondary education, 2001	OECD (2003), p. 297.
u_t	0.05	Unemployment rate, Eurostat definition, 2001	AMECO[a], May 2004.
τ	0.125	Ratio teachers/students, upper secondary, 2001.	OECD (2003), p. 330.
$Y(0)$	99540	GDP at 1995 market prices, 10^6 euros, 2001	AMECO, May 2004
POP(0)	7006022	Population aged 15–64, 2001.	Pereira (2003)
$L(0)$	4848412	Civilian employment, persons, 2001	AMECO, May 2004
G	0.037	Output per person aged 15–64 average growth rate, 1960–2001	AMECO, May 2004 and Pereira (2003).

[a] AMECO—Annual Macro Economic Database, European Commission.

output effects of such crowding in (or out) should be, to some extent, credited to public investment, as they would not take place in its absence—a shortcoming of $r^{\text{KG,cp}}$. Taking an agnostic approach, we will compute both rates of return.

As for human capital formation, we compare the macroeconomic costs and benefits stemming from the decision of a 16-year-old to stay one more year at school. Following the literature (e.g. De la Fuente, 2003), the opportunity cost of studying and the direct costs of education (mainly teachers' wages) are viewed as the two main costs of schooling; we innovate, though, in converting labor costs to money terms using the marginal productivity of labor, rather than through off-model computations. Equating benefits (output gains) to costs yields:

$$\int_0^\infty \frac{\partial Y(t)}{\partial H(t)} \mathrm{d}H(t)\mathrm{e}^{-rt}\mathrm{d}t = [(1-u_s)+\tau(1-u_t)](1-\alpha-\beta)\frac{Y(0)}{L(0)} \tag{5}$$

The term in square brackets is the amount of labor diverted from other activities: u_s is the unemployment rate for 16-year-olds, τ is the teacher/student ratio and u_t is the unemployment rate for teachers. This quantity is then multiplied by the marginal productivity (investment in human capital taking place at time 0). As we assume that human capital formation falls on the young, benefits ignore human capital depreciation (e.g. due to retirement).

Using $\partial Y(t)/\partial H(t)=\gamma Y(t)$ and $\mathrm{d}H(t)=1/\text{POP}(t)$—where POP($t$) is the population aged 15–64—and assuming a constant growth rate (g) of the Y/POP ratio, Eq. (5) can be written as

$$\frac{\gamma Y(0)}{\text{POP}(0)}\int_0^\infty \mathrm{e}^{(g-r)t}\mathrm{d}t = [(1-u_s)+\tau(1-u_t)](1-\alpha-\beta)\frac{Y(0)}{L(0)}, \tag{6}$$

and $r^{H,\text{cp}}$ is the value of r that solves it. Using values from Table 1, $r^{H,\text{cp}}$ becomes a function of production function parameters only:

$$r^{H,\text{cp}} = 0.037 + \frac{0.648\gamma}{1-\alpha-\beta}. \tag{7}$$

The computation of $r^{H,\text{df}}$ is similar to that of $r^{\text{KG,df}}$. Denoting investment in human capital by *IH*, $r^{H,\text{df}}$ is the value of *r* that solves

$$\int_0^{\infty} d^{\mathrm{b}}Y(t)\mathrm{e}^{-rt}\mathrm{d}t = \int_0^{\infty} d^{\mathrm{b}}\mathrm{IH}(t)\mathrm{e}^{-rt}\mathrm{d}t. \tag{8}$$

3. Data and empirical results

3.1. Data

We use annual data for the period 1960–2001. GDP at 1995 market prices (*Y*) and civilian domestic employment (*L*) come from the AMECO database (May 2004). Variable *H* is measured by Pereira's (2003) series for the average years of schooling of the Portuguese population aged between 15 and 64. The author anchored his series in census data and computed figures for years between censuses using data from different national sources on school conclusion, migration, mortality rates and retiring population. The use of interpolations or estimations was therefore kept to a minimum. Series for KG and KP were obtained by the perpetual inventory method with rates of depreciation gradually increasing over time (as in Kamps, 2003). The underlying investment series come from national sources—Banco de Portugal (1997) and Instituto Nacional de Estatística.

3.2. Empirical results[3]

Our empirical work is based on production function (1) written in condensed form:

$$y(t) = \mu + \gamma H(t) + \alpha \mathrm{kp}(t) + \beta \mathrm{kg}(t), \tag{9}$$

where *y*, kp and kg are per worker ratios in log terms (e.g. $y = \log(Y/L)$). Augmented Dickey-Fuller tests suggest that all four variables in Eq. (9) are non-stationary, I(1) series. If there were a stable relationship between inputs and output then one would expect those four variables to cointegrate, and the normalized coefficients of the cointegrating vector would give us estimates of α, β and γ. Hence, we start by testing for the existence, and number, of CVs. We then estimate a cointegrated VAR, yielding the parameters of the CV(s) and the implied values for $r^{\text{KG,cp}}$ and $r^{H,\text{cp}}$. Finally, drawing on the IRFs to structural shocks in human or public capital, we compute $r^{\text{KG,df}}$ and $r^{H,\text{df}}$.

Following the Johansen (1988) procedure, we estimated an unrestricted VAR:

$$\Delta X_t = c + \Phi D_t + \sum_{i=1}^{p} \Gamma_i \Delta X_{t-i} + \Pi X_{t-1} + \varepsilon_t, \tag{10}$$

[3] Econometric results presented in this section were obtained using GiveWin and PcGive 10. See Doornik and Hendry (2000, 2001) for a complete description of this software, as well as of the several tests performed. More details about the construction of capital stocks, the dataset itself, and about results are available from the authors on request.

Table 2
Cointegration tests

r, number of CVs	Trace test	Maximum eigenvalue test	Trace test (T-nm)	Maximum eigenvalue test (T-nm)
0	64.00 (0.001)[a]	34.11 (0.004)[a]	57.75 (0.004)[a]	30.78 (0.016)[b]
1	29.89 (0.049)[b]	16.52 (0.204)	26.97 (0.105)	14.91 (0.308)
2	13.37 (0.102)	9.65 (0.241)	12.06 (0.155)	8.71 (0.319)
3	3.72 (0.054)	3.72 (0.054)	3.36 (0.067)	3.36 (0.067)

The null hypothesis is indicated in the first column. The alternative hypothesis is that the number of CVs exceeds r or that it equals $r + 1$, in the cases of the trace test and of the maximum eigenvalue test, respectively. The tests denoted (T-nm) include a small sample correction suggested by Reimers (1992). P-values are within brackets.
[a] Denote rejection at a 1% level.
[b] Denote rejection at a 5% level.

Table 3
Estimated cointegrating vectors

	Likelihood ratio test of restrictions		Y	H (γ)	kg (β)	kp (α)
1. No restrictions		Estimated parameter	−1.0	0.0563	0.148	0.557
		Standard error	0.0	0.0643	0.373	0.198
		Ceteris paribus r.o.r.		0.160	0.267	0.185
2. Imposed elasticity of kp and imposed semi-elasticity of H	$\chi^2(2) = 0.2978$ (P-value: 0.8611)	Estimated parameter	−1.0	0.0660	0.294	0.350
		Standard error	0.0	0.0	0.071	0.0
		Ceteris paribus r.o.r		0.156	0.568	0.090

where X_t is the vector (kg, kp, H, y)’. The VAR includes an unrestricted constant, c, allowing for linear growth in the data, and two unrestricted dummy variables, $D1_t$ and $D2_t$. The first, equal to 1 in 1960–1974, takes into account the structural break in growth that occurred in the mid-seventies, while the second, taking value 1 from 1986 onwards, corresponds to the growth resurgence following Portuguese entry to the European Community. The VAR order, p, was set to 1, considering a residuals normality test and three information criteria (Schwarz, Hanann-Quinn and Akaike).

Table 2 summarizes results from four tests used to determine the number of CVs. Even if one of the trace tests suggests that there could be two CVs, the other three tests clearly point to a single CV, implying that matrix Π in Eq. (10) has rank 1. Estimation by full information maximum likelihood of a VAR with one cointegration relationship yielded results for the CV parameters and their standard errors presented in Table 3, line 1.

The normalized CV contains the production function parameters, allowing us to compute the *ceteris paribus* rates of return.[4] The r.o.r. on private investment ($r^{\mathrm{KP,cp}}$), 18.5%, turns out to be higher than recent estimates for the US economy.[5] The estimated $r^{\mathrm{KG,cp}}$, 26.7%,

[4] Using Eq. (3), $r^{\mathrm{KG,cp}}$ was computed with 2001 values for Y/KG and δ. A similar methodology was applied to the computation of $r^{\mathrm{KP,cp}}$. The assumed rates of depreciation are 0.04 and 0.07, respectively.
[5] Congressional Budget Office (1998) mentions different studies where it varies between 7 and 11%.

Table 4
Accumulated response functions to a 0.01 impulse in kg

	Year 1	Year 10	Year 20	Year 30	Year 40
H response	0.0021	−0.0013	−0.0025	−0.0028	−0.0029
kg response	0.0100	0.0110	0.0113	0.0114	0.0114
kp response	0.0069	0.0043	0.0035	0.0032	0.0032
y response	0.0017	0.0028	0.0032	0.0033	0.0033

exceeds $r^{\mathrm{KP,cp}}$. The value for $r^{H,\mathrm{cp}}$ – from Eq. (7) – suggests that human capital formation is also fairly profitable, yielding a return of 16%, close to private investment's.

An even higher estimated elasticity for public capital is obtained if we jointly impose the restrictions $\alpha = 0.35$ and $\gamma = 0.066$ (Table 3, line 2). These restrictions stem from assuming $r^{\mathrm{KP,cp}} = 0.09$, a figure closer to the estimates for the US economy, and a human capital elasticity equal to the average point of the interval [0.394; 0.587], in line with De la Fuente (2003)—recall the discussion in Section 1. This joint hypothesis is not rejected at a 86.11% level. The value for $r^{\mathrm{KG,cp}}$ becomes 56.8%, due to the new estimate for β (0.294). Though giving rise to an impressive r.o.r., this elasticity is actually smaller than those estimated by Aschauer (1989a,b) for the US and by Ligthart (2000) for Portugal. Even so, in further analysis we use the non-restricted cointegrated VAR (Table 3, line 1).

To estimate $r^{\mathrm{KG,df}}$ and $r^{H,\mathrm{df}}$, one needs to identify structural shocks to kg and *H*. It is assumed that public capital does not respond contemporaneously to any structural disturbances to the remaining variables in the VAR, due to the lags involved in government decision-making (as in Pereira, 2000). This amounts to an orthogonalisation of shocks using a Cholesky decomposition, with kg ordered first. As regards human capital, the decision of whether to pursue further studies is viewed as potentially responsive to innovations in any of the remaining variables: for instance, shocks to output or to physical investment (private or public) may influence labor market conditions and thus the trade-offs between taking up a job or staying at school. In turn, *y*, kp and kg are assumed to be only affected by innovations in *H* with a lag—a possible justification being that the economic benefits from a better-educated population are only to be reaped when students leave school and start working. In a Cholesky decomposition, we thus order *H* last. However, as the literature offers no guide for identifying shocks to *H*, some sensitivity analysis will also be conducted.

Table 4 summarizes the accumulated IRFs generated by a 0.01 shock to kg. The response of output is positive in the short and in the long run: 40 years into the future, when IRFs have essentially converged, output per worker is about 0.33% above the baseline. Our results also show that public capital innovations crowd in private investment. The private capital stock per worker is approximately 0.32% above the baseline in the long run. On the other hand, public investment seems to crowd in human capital investment in the short run, but crowd it out in the long run—*H* is almost 0.003 years of schooling below the baseline after 40 years. Converting percent deviations into absolute, constant euro terms, we find that $r^{\mathrm{KG,df}}$ equals 37.3%.[6]

[6] More precisely, we use a discrete-time counterpart of Eq. (4), where deviations of gross public investment follow from the deviations of the capital stock, taking depreciation into account.

Table 5
Accumulated response functions to a unit impulse in H

	Year 1	Year 10	Year 20	Year 30	Year 40
H response	1.000	0.949	0.931	0.927	0.925
kg response	0.000	0.015	0.020	0.021	0.022
kp response	0.000	−0.039	−0.052	−0.055	−0.056
y response	0.000	0.016	0.022	0.023	0.024

Comparing this result to the 15.9% r.o.r. computed by Pereira and Andraz (2002, 2004), our estimate seems almost 2.5 times bigger. However, though both figures take dynamic feedbacks into account, they are not comparable for a number of reasons: the VAR specifications are different; we consider all public investment, while they only study transportation infrastructures; most importantly, their r.o.r. is based on long-run impacts, while we consider the full path of dynamic responses. A better, albeit still imperfect, comparison can be made by looking at the "total marginal product" of public investment—the ratio between the long-run responses of the levels of output and public investment, both measured in constant euros. Pereira and Andraz (2002, 2004) report a value of 9.5, whereas we obtain 14.6—still bigger, but by a much smaller margin.

Its high r.o.r. makes Portuguese public investment pay for itself by generating additional fiscal revenues. Assuming that output is taxed at a rate of 35% (as in Pereira & Andraz, 2002) and government bonds pay interest at a rate of 6%, then public investment pays itself back in only 13 years.

Table 5 present the impulse responses of H, kg, kp and y to a unit shock in H. Over time, there is a positive but small response of output—an increase of less than 3% in the long run. In fact, human capital investment is found to crowd out private physical investment, private capital per worker becoming almost 6% lower. There is also some gradual weakening of the effort in human capital investment, more than 7% of the initial impulse being lost in the long run. The overall impact on output is therefore the net effect of the growth in H and in kg (which is crowded in to some extent), and of the reduction in kp.[7] Computing $r^{H,\mathrm{df}}$ over the time span of the IRFs, the result is a modest 2.7%.[8]

4. Policy discussion

Though the decision to pursue studies beyond compulsory education (or even to fulfill it) is private, financing is overwhelmingly public: in 2000, the government share in total expenditure on education reached 92.4% in the EU average and 98.6% in Portugal (Afonso & St. Aubyn, in press). Hence, both public gross fixed capital formation (GFCF) and investment in human capital are major components of Portuguese government spending (worth

[7] In a sensitivity analysis, we simulated shocks to H under all the possible orderings of H, kp and y, keeping kg first throughout. The response of kp (crowding out) was qualitatively similar to that reported above but generally stronger, leading to slight decreases in output (long run losses between 2 and 12%).

[8] One converts into absolute terms the percent gains in output and generates a series for investment in constant euros from the IRF of H and from the marginal productivity of labor (recall Eq. (5)).

3.8% and 5.6% of GDP in 2000), and the analysis of their macroeconomic returns entails important policy implications.

In a general equilibrium framework (e.g. Baxter & King, 1993), public spending may have contrasting effects on private investment: if the former exerts a positive effect on the marginal productivity of private capital ("productive" public spending) then crowding in will in general take place, and an impulse to public spending will therefore induce a strong increase in output. If, instead, such beneficial effect in private marginal productivity is absent ("wasteful" public spending, from a production viewpoint), then crowding out is to be expected,[9] and the impact on output will be weakly positive, at best. Interestingly, our empirical results illustrate both possibilities.

Public GFCF in Portugal is found to crowd in its private counterpart—a conclusion also drawn by Pereira and Andraz (2002, 2004), in a VAR model, and by the European Commission (2003), through an analysis of Granger-causality. An impressive $r^{\mathrm{KG,df}}$ of 37.3% follows, above an already high *ceteris paribus* return of 26.7%.

Several policy implications ensue. First, the emphasis on infrastructural improvement laid since Portugal joined the EU, and started to benefit from structural funds, seems well justified. Between 1989 and 2008, three approved Community Support Frameworks (CSFs) have implied an annual public expenditure averaging 3.6% of GDP, roughly two thirds of which funded by the EU (Dias, Lopes, Martins, Pina & St. Aubyn). More that half of this money (58.7%) has been channeled to physical infrastructures, against a mere 17% for training of the workforce. Second, in the light of the political vulnerability of public investment in times of fiscal retrenchment, the empirical findings here reported lend support to fiscal frameworks that include a golden rule, and run against the counterargument that private capital is crowded out. Finally, and in a similar vein, fiscal consolidation efforts which fall disproportionately on public investment may severely hamper growth prospects, and are in all likelihood counterproductive even in narrow fiscal terms, due to lost revenue. A caveat to be born in mind, however, is that in most of our sample period Portugal had a blatant infrastructural deficit, which is probably no longer the case, though insufficiencies persist. It cannot therefore be excluded, as Pereira and Andraz (2004) caution (p. 240), that in the future returns on public capital will become smaller.

Results for human capital were less clear-cut. Though the estimated $r^{H,\mathrm{cp}}$ (16%) is fairly high, and close to private capital's, shocks to years of schooling were found to induce a negative dynamic response of private investment, leading to a disappointing 2.7% return with dynamic feedbacks.

It may be the case that a strong causal relationship from education to growth does not exist. For example, Pritchett (2001) presents evidence of a *negative* cross-sectional correlation between education measures and economic growth, whereas Bills and Klenow (2000) suggest that even the positive relationship found between schooling enrollments and subsequent growth could be due to other growth factors omitted from the analysis and to

[9] Crowding-out may also occur if public spending, though "productive", exceeds some optimal threshold—for instance, if high public investment induces an excessive capital stock (Aschauer, 1989b). Notice that the labels "productive" versus "wasteful" need not correspond to capital versus current spending: expenditure on education belongs to current spending, and may be highly productive, whereas misguided infrastructure investment may add nothing to private capital profitability.

reverse causality. This view is not incompatible with the presence of human capital in our estimated CV: average years of education and GDP per worker would tend to grow together, but independent innovations in human capital would not drive significant economic growth.

An alternative explanation for the low $r^{H,\mathrm{df}}$ is that the quality of education may be at least as important as its quantity—as noted by Barro (2001), among others. Portugal fares poorly on this count: empirical evidence suggests that the Portuguese education system is not efficient, as students tend to underperform in international tests.[10] It could then be the case that simply increasing the average number of years of schooling does not really create the necessary skills for growth. Our response functions to impulses in human capital are actually consistent with a crowding out scenario typical of public expenditure without a strong productive impact. This explanation carries strong policy implications in what concerns education policy and the way the educational system is organized in Portugal: the emphasis should shift from quantitative expansion to the pursuit of efficiency gains, i.e., achieving better results with a given amount of spending. The careful examination and reassessment of teaching standards in secondary school, especially in key knowledge areas (the languages, sciences and mathematics) and the open assessment of school performance to identify best practices susceptible of further dissemination are examples of this type of policies.

Finally, a number of caveats have to be born in mind against an overly pessimistic view on the effect of education on Portuguese economic growth. First, crowding out of private investment also means that the associated costs are not incurred, an aspect which $r^{H,\mathrm{df}}$ fails to capture (recall Section 2). Second, Krueger and Lindahl (2001) point out that measurement errors in education attenuate the estimates of the effect of schooling on GDP growth. Finally, it is possible that the relationship is not linear, and that different schooling levels have a different impact on GDP, so that taking average years of schooling as a proxy for human capital could well be too much of a simplification.

5. Conclusion

In this paper, we estimated and compared macroeconomic returns from investing in three different capital stocks—physical private capital, physical public capital and human capital. This was done in a VAR framework, and in what concerns Portugal. Measuring and comparing the contribution of public and human capital to economic growth is of paramount policy importance in the Portuguese case—a recipient of EU structural funds which aim to improve public infrastructure and labor qualification as a means to foster real convergence. In a more general setting, this is an issue of great relevance both for national fiscal policies around the world, and for the European regional policy, whose geographical coverage has been vastly widened by the recent EU enlargement.

We distinguish between a *ceteris paribus* and a dynamic feedbacks rate of return. In the light of the former, investing in public capital yields a return of 26.7%, being more profitable in growth terms than private or human capital investment (returns of 18.5 and

[10] Afonso and St. Aubyn (in press) and St. Aubyn (2003) show that Portuguese student results are poor both in absolute terms and when resources devoted to their education are taken into account.

16%, respectively). When dynamic feedbacks are taken into account, it is found that public investment stimulates private investment, so that growth effects are amplified and a return of 37.3 is achieved. The opposite holds for human capital investment: it crowds out private investment, and a poor rate of return (2.7%) ensues.

In policy terms, our results favor a positive evaluation of the EU structural funding effects on the Portuguese economy, especially in what concerns the improvement of physical infrastructures. Moreover, they lend support to a view of fiscal discipline where special provisions are made for public investment. Results presented are also supportive of an emphasis on education quality, as opposed to mere increases in the quantity of resources allocated to the educational system. Without satisfactory quality standards, it could well be the case that an increasing number of average schooling years does not translate into a proportional increase in labor force skills.

This study was made possible by the availability of an annual series of average years of schooling in Portugal. It would be very interesting to evaluate comparative returns for other countries using the same methodology followed here. Resorting to more disaggregated data (e. g. public investment by function or schooling by levels) to assess returns also seems a fruitful avenue for further research.

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