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EFFICIENCY IN THE PROVISION OF PUBLIC AND PRIVATE CAPITAL IN 15 OECD COUNTRIES

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In this paper we use a sample of 15 OECD countries to examine whether provision of public and private capital satisfies conditions of intertemporal efficiency over the 1970-1995 period. We find robust evidence that private and public capital have followed criteria of efficient resource allocation in all countries. The estimated output elasticities of private and public capital display little variation across countries, and reach mean values of 0.19 and 0.055. Consequently, average rates of return to both factors are estimated at about 5-5.5%. All along we estimate a positive and significant intertemporal elasticity of substitution of consumption in all countries.

Keywords: Infrastructures, private capital, investment.

(*JEL* E6, H54)

1. Introduction

An influential stream of the economic literature has emphasized that present levels of public capital, and more specifically infrastructures, may be sub-optimal compared to those that prevailed two or three decades ago. If public capital exercises a positive impact on private production, the concern in many economies has been that productivity or cost performance of private firms may have suffered from a shortage of public infrastructures. One of the reasons that made some economists come to such conclusion was the fact that in many industrialized countries, although not all of them, there coincided a slowdown

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in productivity growth with an important decline in the ratio of public capital to output.

Although in its own it is controversial to quantify the strength of the effect of public capital on productive performance, there seems to be some consensus that public capital is a productive input into private production. Probably, initial estimates of production functions by Aschauer (1989a,b) or Munnell (1990) where far too optimistic about the contribution of public capital to private production. Later studies, as Holtz-Eakin (1994) and García-Mila, McGuire and Porter (1996), questioned both the magnitude and, inclusively, the basic underlying question whether public capital is a productive input or not. Despite the fact that there is lot of research in the nineties which either supports or questions the early conclusions reached by Aschauer and other authors (see the excellent surveys by Gramlich (1994) or de la Fuente (1996)), it seems pointless to conclude that public capital is not productive.

The most usual approach to analyze the effects of public capital on private productive performance has been to estimate production functions (usually in Cobb Douglas form) or to make growth accounting exercises. None of these approaches is entirely satisfactory to conclude about the adequacy of public capital provision, because they are not able to identify on solid statistical or econometric grounds if a change in public capital endowment is sub-optimal or not[1]. To answer to these questions one needs to resort to models of intertemporal optimization, which provide the rules for efficient capital provision. One possibility is to use a dual approach based on the optimization of aggregate cost or benefit functions, incorporating theoretical restrictions derived from the envelope conditions (some examples are Berndt and Hanson (1992) or Morrison and Schwartz (1996)). A different possibility is the one pursued in this paper, which follows Otto and Voss (1998) (OV hereafter) that use a natural extension of the consumption-based asset pricing (CAPM) literature on the empirical analysis of Euler equations. In this setting investment returns are modeled using production vari-

[1] In addition, as Finn (1993), Balmaseda (1996) or Gramlich (1996) have pointed out the very high rates of return that are implicit in many production function estimates have to be seen with caution. These supernormal rates of return of public capital arrive to 100% and are many times 70% higher than private rates of return. Why are governments so myopic as to leave unexploited these investment possibilities?

ables, in a way closely related to Cochrane's (1991) production-based asset pricing model.

The estimation of Euler equations has some advantages that are worth mentioning. First, as pointed out by OV these conditions derive from models of intertemporal behavior where the maintained hypothesis is that capital provision (public or private) has been efficient. Second, the parameters to estimate are the same output elasticities of private and public capital that can be recovered from production functions. Third, this approach uses information about the dynamics of the relative prices of private and public investment goods, which is not processed while estimating production functions. Finally, although usually public capital is considered as an external input into private production, the efficiency conditions given by the Euler equations treat the government decision of public investment as endogenous.

In this paper we extend the work by OV in two directions. First, we estimate their model extending the sample to fifteen OECD countries, to see if their results and conclusions for Australia are also valid for other advanced countries. Second, we build on these authors' work estimating a key parameter related to the elasticity of intertemporal substitution that they restrict, even though they recognize that this is not ideal. To this end, we also follow results for Australia in Boscá, Cutanda and Escribá (2004), that showed using the same data than OV, that it is possible to obtain an economically reasonable (and statistically significant) estimate of this parameter. In this paper we confirm this result under two different estimation strategies. Our first approach is just to use the same system of equations than OV, but estimating this parameter rather than restricting it to a certain value. The second approach consists, as in Boscá, Cutanda and Escribá (2004), in adding to the system of estimated equations the standard consumption Euler equation. To do so we adopt a general equilibrium approach, as OV implicitly do, assuming that the stochastic discount factor for the representative firm is the same as for the representative consumer and equal to a gross real interest rate.

We derive and identify the conditions for efficient resource allocation for an economy with both a private and a public capital sector in an intertemporal and general equilibrium setting. Then we estimate the model with instrumental variables (using a GMM estimator) to deal with endogeneity problems. These conditions produce a set of moment conditions that can be tested, as we effectively do, using Sargan tests of the overidentifying restrictions. We find that the accumulation of both types of capital has followed criteria of efficient provision. This result is common to the fifteen OECD countries in our sample, independently of whether we restrict or estimate the parameter related to the intertemporal elasticity of substitution, i.e. no matter which estimation strategy we adopt. These results give full support to OV's claim that relative investment goods prices are an important factor (usually not considered in the analysis of production functions) to evaluate investment decisions. Consequently, we find that there have not been excessive rates of return to public investment, nor systematic or significant differences between private and public rates of return in any country. The reason behind this result is that in those countries where public investment has been reduced along the sample period, the price of public investment goods has risen relative to the price of aggregate output. All along, in these countries the prices of private investment goods have become less expensive relative to output prices.

The estimation approach does make an important difference in the case of the output elasticities and rates of return to both types of capital. In both cases, i.e. restricting or estimating the parameter related to the intertemporal elasticity of substitution, we obtain at first glance reasonable levels of both rates of return and output elasticities. However, in the first case, we estimate investment returns for both types of capital around 8.5% per annum for the average OECD country, and output elasticities around 23% and 7% for private and public capital, respectively. In the second case, these figures are 5% for both rates of return and 19% and 5.5% for the private and the public output elasticities, respectively. A result in favor of the second strategy is that the values implicit in our estimations for the elasticity of intertemporal substitution do not display much variation across countries, ranging between 1.5 and 4.5 in most of them[2].

In this paper we have used a sample of 15 OECD countries with data for the 1970-1995 period. The structure of the paper is as follows. In section 2 we present the theoretical model and discuss the testable efficiency conditions. Section 3 presents the data, that are taken or elaborated from the OECD *Business Sector Database* (BSDB), and makes some econometric considerations. The last two sections present, respectively, the empirical results and the conclusions.

[2] Generally, this parameter is difficult to estimate precisely. For a description of the problems associated with its estimation see Cooley and Prescott (1995).

2. Efficiency conditions in the provision of capital

Consider an economy that produces output with two inputs, capital and labor. There are two capital sectors in the economy, private and public, according to the ownership of the input. Both capital sectors obey similar, although not necessarily identical, processes of accumulation and depreciation. The framework we are using is the one by Arrow and Kurz (1970) followed also by OV, where public ownership of capital is warranted given that services of public capital may suffer, for instance, from large fixed costs or from congestion. Additionally, public investment will be considered as endogenous as private investment, given that both will be determined according to similar optimization processes.

In this simplified world with two capital sectors ($i = 1, 2$), the Euler equations that can be derived from a standard optimization problem for a representative firm, i.e. from a model of capital demand, take the form[3]:

$$E_t \left(\frac{1}{1 + i^r_{i,t+1}} R_{it+1} \right) = 1, \qquad i = 1, 2. \qquad [1]$$

where $1 + i^r_{i,t+1}$ is the gross real interest rate relevant to investment decisions (or the stochastic discount factor relevant for firms in sector i), R_{it+1} is the gross rate of return to each capital good, and E_t is the expectations operator conditional on information available at time t.

From a model of intertemporal consumption optimization we can derive the following Euler equation:

$$E_t \left(\left(1 + i^r_{t+1} \right) m_{t+1} \right) = 1. \qquad [2]$$

where, $1 + i^r_{t+1}$ is the stochastic discount factor relevant for the representative consumer and m_{t+1} is the intertemporal marginal rate of substitution for the representative consumer.

The conditions for efficient resource allocation estimated by OV are obtained by assuming a common stochastic discount factor for the aggregate economy. Thus, these conditions are:

$$E_t \left(m_{t+1} R_{it+1} \right) = 1, \qquad i = 1, 2. \qquad [3]$$

[3]Notice that in this simplified economy, public capital is a given input for the firm that is provided by an optimizing public sector, that is taking private capital as given.

However, it is also possible to estimate the system of three equations in [1] and [2], with the only requirement of having a gross real interest rate that captures properly the common stochastic discount factor to all economic agents in the economy[4]. In any case, if data for a given country satisfy the Euler equations in [3] or the Euler equations in [1] and [2] this would mean that capital provision has followed efficiency criteria.

To estimate and test the efficiency conditions in equations [1] and [2] or [3] it is necessary to specify functional forms for the gross rate of return to each capital good, R_{it+1}, and for the intertemporal marginal rate of substitution for the representative consumer, m_{t+1}. In this respect we follow exactly the same parameterization employed by OV. With respect to the gross rate of return, in our world with two capital sectors we can define a different rate of return to each capital good. Labeling p_{it} the relative price of the investment good $i(i = 1, 2)$ and output at time t, f_{it+1} the marginal productivities and δ_{it} the depreciation rates, the gross real return for investment in sector i is:

$$R_{it+1} = \frac{1}{p_{it}} \left[f_{it+1} + (1 - \delta_i)\, p_{it+1} \right] \qquad [4]$$

Notice that, once estimated, the rates of return in equation [4] present some advantages with respect to other measures in evaluating the optimality of capital provision. First of all, they take explicitly into account the variation in relative prices between the (private or public) investment good and output. Second, the rates of return of both types of capital can be directly compared, so that it can be investigated if there are what Finn (1993) and Gramlich (1994) defined as supernormal returns to public investment. To compute the real return of private and public capital defined in expression [4] we need three ingredients. First, data about the relative prices of investment goods and output; second, the depreciation rates of both types of capital and third, a procedure to compute the marginal productivities of private and public capital. As we will see later, we have available series of relative prices and depreciation rates. To estimate the marginal productivities of capital we need to define a concrete functional form for the aggregate production function. The most standard function

[4] Notice that this is equivalent to the standard approach in the empirical consumption literature.

used in the literature is the Cobb-Douglas production function with constant returns to scale in all factors:

$$Y_t = A_t K_{1,t}^{\rho_1} K_{2,t}^{\rho_2} N_t^{1-\rho_1-\rho_2} \quad [5]$$

where Y is total aggregate output, A_t the technical efficiency parameter, K_1 the stock of private capital, K_2 the stock of public capital, and N total labor in both sectors. Contrary to other studies that analyze the effect of public capital, our measure of output will be total aggregate output instead of production of the private sector[5]. Given that public capital contributes to both private and public output, it seems more adequate to recover the rates of return considering total output instead of private output alone.

With respect to the intertemporal marginal rate of substitution, in the case of a representative consumer with an intertemporally separable utility function, it can be defined as[6]:

$$m_{t+1} \equiv \beta \frac{u'(c_{t+1})}{u'(c_t)} \quad [6]$$

where c_t is per capita real consumption[7], β is the subjective discount factor, supposed constant and $u\prime$ is marginal utility. Additionally, we assume the usual constant relative risk aversion utility function (CRRA):

$$u(c) = \frac{c^\sigma}{\sigma} \quad [7]$$

with $\sigma \# 1$. Notice that $1/(1-\sigma)$ is the intertemporal elasticity of substitution and $1-\sigma$ the coefficient of relative risk aversion.

Then, the conditions for efficient resource allocation in [3] can be expressed as:

$$E_t \left[\beta \left(\frac{c_{t+1}}{c_t} \right)^{\sigma-1} \left(\frac{1}{p_{it}} \right) \left[\rho_i \frac{Y_{t+1}}{K_{it+1}} + (1-\delta_i) p_{it+1} \right] \right] = 1, i = 1, 2 \quad [8]$$

[5] Although our empirical results are obtained using total GDP as the output measure, we did not find remarkable differences when we employed other output measures that exclude public sector output.
[6] See Hall (1978).
[7] We express consumption in per capita terms given that we have a representative agent optimal consumption model with aggregate data. This is a standard practice in the empirical literature of aggregate consumption (see Deaton (1992)).

where we have made use of the fact that in a Cobb-Douglas production function the marginal productivity of capital is $f_{it+1} = \rho_i \frac{Y_{t+1}}{K_{it+1}}$. The efficiency conditions summarized in expression [8] can be estimated directly. As a result we get estimates of the output elasticities of both types of capital, ρ_i, without estimating directly the aggregate production function. Additionally, also the utility parameters β and σ are susceptible of being estimated. The strategy followed by OV is to restrict these parameters to certain reasonable values, rather than estimating them. The reason is that, although this is not ideal (as they explicitly recognize), their attempts to estimate them yielded no sensible economic results. The value chosen by these authors for the subjective discount factor, β, does not seem controversial (it implies a discount rate of approximately 4% per annum), but the implicit value of the intertemporal elasticity of substitution seems more problematic[8]. Conceivable the elasticity of intertemporal substitution may display a high variation across countries, so that it is worth trying to estimate this parameter[9]. As a consequence, in the empirical section we will estimate two versions of the equations in [8]. First, setting σ at the same value as OV for all countries and, second, estimating it in addition to the output elasticities.

Nevertheless, as we showed previously, there is another possibility to try to get reasonable estimates of σ. Under the assumption that the

[8] The empirical investigation on consumption with aggregate data has not been very fruitful in providing a generally accepted value for the elasticity of intertemporal substitution. For the USA case, Hall (1988) obtains a value near to zero and Epstein and Zin (1991) obtain a value near to 1. Campbell and Mankiw (1989) obtain intermediate values, after allowing consumption growth to be affected by income changes. On the other hand, the empirical investigation on consumption with microeconomic data produces higher values for this elasticity (ranging between 2 and 3). This is the case, for instance, in Attanasio and Weber (1989) or Shea (1995) after controlling for individual characteristics. Finally, from a different perspective, Chapman (1997) finds a strong and positive relationship between consumption growth and real yields, arguing that the reason for the results in Hall (1988) and Campbell and Mankiw (1989) may be due to weaknesses in the particular instrumental variables estimation.

[9] Campbell and Mankiw (1991) obtain an estimate of the elasticity of intertemporal substitution that is as often positive as negative and it is never statistically significant. Their work covers a sample of five advanced countries (Canada, France, USA, United Kingdom and Japan).

stochastic discount factor for producers and consumers is a common gross real interest rate, equations [1] and [2] become:

$$E_t\left[\frac{1}{1+i^r_{t+1}}\left(\frac{1}{p_{it}}\right)\left[\rho_i\frac{Y_{t+1}}{K_{it+1}}+(1-\delta_i)\,p_{it+1}\right]\right]=1, i=1,2 \qquad [9]$$

$$E_t\left((1+i^r_{t+1})\beta\left(\frac{c_{t+1}}{c_t}\right)^{\sigma-1}\right)=1. \qquad [10]$$

The system of three Euler equations in [9] and [10] can be estimated for each country separately, obtaining estimates of the two output elasticities and of the coefficient related to the intertemporal elasticity of substitution. One advantage of this strategy is that in order to estimate a very important parameter from the preferences sphere, it seems appealing to include the consumption Euler equation where it is crucial. The disadvantage is that we need to rely on some concrete real interest rate series to perform these estimations. In any case it is not clear which strategy is preferable, restricting a crucial parameter at *arbitrary* values, or relying on an *arbitrary* interest rate to estimate this parameter.

3. Data and econometric issues

Most of the variables used in this work have been taken from the OECD *Business Sector Database* (BSDB). The statistical information in the BSDB is available on a quarterly basis, with a high degree of homogeneity and it is expressed at constant prices, although the base year is not the same for all countries. From the sample of countries at our disposal, we have ruled out some of them because of lack of some of the relevant variables in part or all of the period of analysis. So, from the BSDB we have taken the series of GDP, gross fixed capital formation of the private and public sectors, final private consumption, long run nominal interest rates and output and investment deflators[10]. On the other hand, the quarterly series of population have been obtained interpolating the corresponding annual series taken from the OECD *National Accounts.*

As OV, the ex-ante real interest rate we use in the empirical analysis is estimated. Concretely, we have followed the method proposed in

[10] As OV, we consider investment prices as exogenous. In any case, given that we are going to use an instrumental variables estimator, the results are robust to endogeneity of the relevant variables.

Boscá, Doménech and Taguas (1999) to calculate the long run real interest rates. In summary, our estimated ex-ante real interest rate is given by the following expression:

$$i_t^r = \bar{i} + \widehat{u}_t \quad [11]$$

where $\widehat{u}_{it}$ is the residual from a linear regression of the ex-post real interest rate in each country[11] regressed on a constant and the inflation rate, and $\bar{i}$ is the mean of the ex-post real interest rate for the 1985-95 period. We have chosen this period because it constitutes, approximately, an entire business cycle and there are no atypical fluctuations of the inflation rate over it, as is the case in the 1970's with the oil shocks. In Table 1 we present the average interest rates obtained for each country in the sample for the 1970-1995 period.

TABLE 1
Real Interest Rates.
Average values. 1970-1995

Country	*Gross Real Interest Rate*
Australia	1.060
Austria	1.045
Belgium	1.058
Canada	1.068
Germany	1.047
Denmark	1.074
Spain	1.058
Finland	1.058
France	1.056
U. Kingdom	1.048
Ireland	1.064
Italy	1.045
Japan	1.050
Sweden	1.047
USA	1.042
Average	1.055

This method produces values for the real interest rates that are very similar to the ex-post interest rates, except in the second half of the 1970's, where, generally, the former are positive. This is a very important feature, given that the ex-post real interest rates have been

[11] The nominal interest rate used in this work is the long run interest rate available in the BSDB; which coincides with the same series in the OECD *Economic Outlook*. It is a rate for long run assets relatively homogeneous across countries, with an approximated maturity of 10 years.

negative in many countries over the 1973-79 period, because of the very high inflation rates due to the supply-side shocks. For this reason, we think that it is not a good idea to use the ex-post interest rate as an approximation to the long run rate relevant to investment decisions[12]. We consider that long run inflation expectations in these years were taking into account that the unusual inflation rates were going to return, sooner or later, to more reasonable levels (at least if we think that the relevant period for investment decisions is a long one). In this situation, long run inflation expectations could be notably lower than observed inflation rates, producing a negative correlation between current inflation and the difference between *ex-ante* and *ex-post* interest rates. In any case, since what should be the correct measure for the *ex-ante* real interest rate is controversial, we have checked that our results are not sensible to other definitions. Concretely, we have checked that our tests of the efficiency hypothesis are not sensible to estimating our models using the ex-post real interest rate.

With respect to the construction of the capital stocks, in the BSDB there exist official data (or estimations) for some countries, but only for the gross private productive capital stock. In any case, there does not exist such kind of data for the net private productive capital stock and for the public capital stock. Given that the relevant capital stock is the net stock[13], it has been necessary to use other statistical sources when it was possible, or to construct the stocks from the public and private investment flows from the BSDB[14]. To sum up, we have used official capital stock data from the OECD publication Flows and Stocks of Fixed Capital, for the countries where these series were available. Concretely, we have taken from this source the net productive private stock for Australia, Belgium, Canada, Germany, Denmark, Finland, France, Sweden and the United States[15]. With regard to public capi-

[12] Additionally, other alternative techniques (filtering the inflation rate to get its trend component, adjusting an ARIMA model for it, etc..) do not solve the problem of getting several years in the middle of the 1970's where the estimated real interest rates are negative either.

[13] See Ward (1976) for an exact definition of the gross and net capital stocks. In the calculation of the gross capital stock a unit of productive equipment disappears only at the end of its assumed life period. In contrast, when the net capital stock is constructed the equipment is assumed to depreciate all along its life period.

[14] Private and public investments flows in the BSDB are perfectly coherent with the same series in other OECD official statistics, as the *National Accounts* or the *Economic Outlook.*

[15] In the cases where the lapse of time of these series was not complete, we have extrapolated them backwards or forwards using the perpetual inventory method.

tal, we have used the official OECD series for Australia, Belgium, Canada, Denmark, Finland, France and Sweden. For the remaining countries the series of public and private capital have been constructed using the perpetual inventory method[16].

With regard to the estimation of the efficiency conditions in the provision of capital (expressions [8] or, alternatively, [9] and [10]), it is necessary to assume an expectations formation mechanism. If expectations are rational, the 2×1 (or 3×1) error vector, u_{t+1}, has the usual asymptotic properties and should not be correlated with any variable known in period t. For this reason, the model needs to be estimated by instrumental variables techniques, to guarantee the consistency of the estimators. In practice, estimation has been done by the Generalized Method of Moments[17] (see Hansen (1982)). Then, if z_t is a $q \times 1$ vector of instrumental variables, there are $2q$ (or $3q$) orthogonality conditions, $E_t\left[u_{t+1} \otimes z_t\right] = 0$, that should be satisfied. The fulfillment of these conditions, that we will check using Sargan tests of the overidentifying conditions, ensures that the model is well specified (i.e. goodness of fit of the model). This is so, because non-rejection of these conditions guarantees that the error term behaves according to the maintained efficiency hypothesis (i.e. that the error term is not correlated with any variable known in t). In this sense, verification of these conditions guarantees that the resulting error term is well behaved, and so, that the model fits the data.

Because of these orthogonality conditions it is necessary to be very careful in choosing the instruments. The real interest rate is an obvious candidate to be used as instrument, given its presumably high relationship with investment returns. Thus, depending on the country

[16] Both the official capital stocks and the stocks constructed from the investment flows have been obtained on an annual basis. In a second step, we generated the quarterly series by interpolation using the investment flows. Obviously, we checked that the base year of the official stocks coincided with the base year of the BSDB flows. The interested reader can find more information about the construction of the capital stocks in the Appendix.

[17] Recent research (see Dominguez and Lobato (2004)) doubts whether the estimation by GMM of non-linear models stated as conditional moment restrictions generates consistent estimators. However, we have not used the estimator proposed by these authors for several reasons. First, because according to the Monte Carlo evidence presented by these authors (Table 1, p. 1068), the bias, the standard error and the root mean squared error are lower with GMM than with their proposed estimator, in the case of the sample size and behavioural assumptions of the relevant variables we employ in our setting. Second, because it is still not possible to perform formal inference with this estimator.

and on the specific estimated model our sets of instruments contain a constant and different combinations of lags of the real interest rate, lags of the gross growth rates of relative investment prices, lags of the price weighted output-capital ratios, and lags of the gross growth rates of output or of per capita consumption.

With respect to the dating of the instruments, we do not introduce in the regression analysis any lag dated before $t-1$ for any of the instruments. In this way we avoid the well-known problems due to temporal aggregation of consumption data, that produces a first order MA structure in the error term (see Ermini (1988) and Christiano, Eichenbaum and Marshall (1991)) and the possibility of serial correlation. In any case, we check the results with the Sargan test of the overidentifying restrictions, which constitutes the basic test to support the maintained hypothesis of an efficient provision of capital[18]. As is well known, this is a test of the joint hypothesis of efficiency according to our theoretical model and of the rational expectations hypothesis, with the same interpretation as the familiar test of the permanent income hypothesis usual in the consumption literature.

Finally, as is obvious looking at equations [8] or, alternatively, [9] and [10] the models are non-linear. Given the biases generated by the usual linearization procedures, we have chosen to discard the use of any of them, estimating all the equations non-linearly and jointly. On the other hand, we have always estimated the production function parameters, setting the depreciation rates at annual rates of 4.8% and 6.8% for public and private capital, respectively, if the series have been constructed. Alternatively, when we use official OECD data, we set the depreciation rates according to the consumption of fixed capital implicit in these series. The subjective discount rate, β, is set in all of our estimated models at 0.99, implying an annual discount rate of 4% given the quarterly periodicity of the data. With respect the parameter σ, in the models where it is not estimated, it is set at -1.0, implying a coefficient of relative risk aversion of 2.0 (and an elasticity of intertemporal substitution of 0.5).

[18] There could be a certain concern with our estimated models about formal inference. Fundamentally, this concern could arise because of the nonstationarity of some of the series involved (mainly the capital output ratios). OV discuss extensively this issue concluding that their results are reliable. Moreover, results in Andrews and McDermont (1995) and Ogaki and Reinhart (1998a) show that the stationarity assumption can be relaxed to obtain asymptotic results for nonlinear GMM models.

4. Empirical results

We start our empirical analysis presenting in Table 2 the estimation results[19] for the efficiency conditions in equations [8], under the assumption that the parameter related to the intertemporal elasticity of substitution, s, is set at –1.0. As can be appreciated, we present results for two different sets of instruments that provide quite similar estimates of the output elasticities of private and public capital and of the rates of return. The first set of instruments is a constant and lags 3rd to 5th of the interest rate[20], while the second set adds to first one lags 3rd and 4th of p_{it}/p_{it-1}[21]. Following usual practice in the literature, the criteria we have adopted in the selection of the instruments is goodness of fit (measured with the significance levels of the Sargan test), combined with theoretical plausibility of the estimated parameters[22]. With the second set of instruments the private capital output elasticity is 0.239 on average, while the public capital elasticity is 0.074. The average rates of return are approximately 8.6% and 8.9% per annum for private and public investment, respectively. Notably, there are not striking differences in these numbers across countries, and also there are no important discrepancies between private and public rates of return in any country of the sample. These estimates seem quite reasonable for at least three reasons. First, the capital output elasticities imply an output elasticity of labor around 0.69 for the average country, which matches well with labor income shares in many advanced countries. Second, these figures imply much lower estimates of public capital output elasticities than the ones obtained in initial studies (notably Aschauer (1989) or Munnell (1990)) and, also, with much less variance across countries than is appreciable in the literature. Finally, we do not perceive any supernormal profitability

[19] All our estimations have been carried out using RATS, version 5.

[20] Except in the case of Spain (lags 3rd to 8th), France (lags 3rd to 10th) Japan, USA, United Kingdom and Ireland (lags 3rd to 6th).

[21] Except in Canada (1st and 2nd lags), Denmark, Spain, Ireland and Italy (lags 3rd to 5th), France, United Kingdom, Sweden and USA (lags 3rd to 6th) and Japan (only the 2nd lag of p_{2t}/p_{2t-1}).

[22] Although it is well established in the literature, that the Sargan test also constitutes a specification test, we have checked the robustness of our results to different sets of instruments. Concretely, we have checked that our findings about efficiency are not significantly affected if we use a common set of instruments in all countries in our sample. Also, point estimates of the elasticities remain basically the same in almost every country.

to either public or private capital, nor important differences across countries.

TABLE 2
Estimation Results. Euler equations in [8], σ set at -1.0

Countries	First set of instruments					Second set of instruments				
				Rates of Return					*Rates of Return*	
	ρ_1	ρ_2	Sargan Test	Priv	Public	ρ_1	ρ_2	Sargan Test	Priv	Public
Australia	0.259	0.066	4.534	1.083	1.085	0.259	0.066	6.905	1.083	1.084
	(0.014)	(0.004)	(0.605)			(0.014)	(0.003)	(0.938)		
Austria	0.267	0.081	7.837	1.089	1.094	0.276	0.083	13.963	1.094	1.097
	(0.019)	(0.007)	(0.250)			(0.017)	(0.006)	(0.452)		
Belgium	0.230	0.058	8.576	1.075	1.086	0.226	0.056	13.622	1.072	1.082
	(0.008)	(0.002)	(0.199)			(0.007)	(0.002)	(0.478)		
Canada	0.270	0.044	9.344	1.065	1.077	0.264	0.043	12.742	1.061	1.074
	(0.015)	(0.003)	(0.155)			(0.013)	(0.002)	(0.547)		
Germany	0.233	0.063	11.571	1.084	1.083	0.246	0.068	21.427	1.093	1.095
	(0.012)	(0.004)	(0.072)			(0.010)	(0.004)	(0.091)		
Denmark	0.190	0.061	2.584	1.055	1.053	0.205	0.068	13.359	1.067	1.064
	(0.018)	(0.009)	(0.859)			(0.016)	(0.007)	(0.786)		
Spain	0.231	0.046	20.119	1.088	1.099	0.238	0.048	23.826	1.093	1.107
	(0.012)	(0.003)	(0.065)			(0.009)	(0.002)	(0.472)		
Finland	0.259	0.080	5.397	1.087	1.088	0.274	0.086	12.115	1.096	1.097
	(0.023)	(0.008)	(0.494)			(0.020)	(0.007)	(0.597)		
France	0.204	0.058	24.869	1.082	1.087	0.207	0.060	30.010	1.086	1.091
	(0.006)	(0.002)	(0.072)			(0.005)	(0.002)	(0.568)		
United Kingdom	0.240	0.138	8.309	1.097	1.099	0.237	0.140	25.093	1.094	1.102
	(0.014)	(0.011)	(0.404)			(0.012)	(0.009)	(0.401)		
Ireland	0.226	0.072	4.888	1.092	1.093	0.252	0.084	17.335	1.112	1.115
	(0.028)	(0.010)	(0.769)			(0.019)	(0.008)	(0.834)		
Italy	0.222	0.064	6.530	1.096	1.101	0.224	0.064	18.032	1.097	1.100
	(0.009)	(0.003)	(0.366)			(0.009)	(0.002)	(0.453)		
Japan	0.287	0.119	13.719	1.103	1.103	0.294	0.122	19.867	1.108	1.106
	(0.010)	(0.005)	(0.089)			(0.009)	(0.005)	(0.134)		
Sweden	0.194	0.055	5.832	1.066	1.058	0.184	0.052	23.664	1.058	1.052
	(0.020)	(0.007)	(0.442)			(0.017)	(0.005)	(0.481)		
USA	0.192	0.062	9.582	1.067	1.067	0.194	0.063	13.706	1.070	1.070
	(0.007)	(0.003)	(0.296)			(0.005)	(0.003)	(0.621)		
Average	0.234	0.071		1.082	1.085	0.239	0.074		1.086	1.089

Notes: The sample period goes from 1970:01 to 1994:04 in Austria, from 1970:01 to 1995:04 in Switzerland, Spain, Finland, Greece and Ireland, from 1970:01 to 1996:04 in Belgium, Denmark, Italy and Sweden and from 1970:01 to 1997:02 in Australia, Canada, Germany, France, United Kingdom, Japan and USA.
First set of instruments: constant and lags 3rd to 5th of i_t^r, except Spain (lags 3rd to 8th), France (lags 3rd to 10th) Japan, USA United Kingdom and Ireland (lags 3rd to 6th).
Second set of instruments adds to first set: lags 3rd and 4th of p_{it}/p_{it-1}, except in Canada (1st and 2nd lags), Denmark, Spain, Ireland and Italy (lags 3rd to 5th), France, United Kingdom, Sweden and USA (lags 3rd to 6th) and Japan (only the 2nd lag of p_{2t}/p_{2t-1}).
Standard errors and significance levels for the Sargan test in brackets.

The orthogonality conditions imposed by the Euler equations are not rejected by the data in any country. The results from Sargan's test of the overidentifying restrictions point unambiguously to the non-rejection of the efficiency conditions for capital provision in the fifteen countries. Moreover, we can refer to the results of these tests as outstanding given that only in the cases of Germany and Japan are marginal significance levels less than 30% for the estimations with the second set of instruments. Notice additionally, that the fundamental change between the first and the second set of instruments is the inclusion of relative investment prices in the latter. This generates better results of the test in all countries (with the only exceptions of Denmark and the United Kingdom), giving additional support to the basic argument in OV, that relative investment goods prices play a key role (usually not considered) when evaluating the efficiency of capital provision[23].

Although, as stated in the previous paragraph, we do not reject efficiency conditions, which could reflect a hypothetically incorrect representation of production, we considered, as OV, a more flexible specification of production. Thus, we checked if our results about efficiency were robust to the estimation of a production function with a CES aggregate of the two capital sectors[24]. The conclusion of such an exercise is that efficiency conditions are not affected, given that Sargan tests confirm that orthogonality conditions imposed by the Euler equations are not rejected by the data in any country. However, parameters are estimated much more imprecisely with the CES specification than in the Cobb-Douglas case. This does not allow us to draw any solid conclusion about the degree of substitutability between private and public capital[25]. However, as is the case in OV, these results are suggestive, at least, that the Cobb-Douglas specification may be a more reasonable representation of aggregate production.

To have a better understanding of what is going on with our estimations in Table 2, in Figure 1 we have depicted the time profile of

[23] We also estimated the same model without prices (the benchmark Cobb-Douglas model in OV terminology) finding uniformly worse results, that confirm the important role of relative prices.

[24] Concretely we used the following production function: $Y_t = \left[\mu K_1^{\phi} + (1-\mu) K_2^{\phi}\right]^{\rho/\phi} N^{1-\rho}$. Notice that this specification nests the Cobb-Douglas production function as $\phi \to 0$, while the two capital stocks are perfect substitutes when $\phi = 1$.

[25] For this reason we do not present these results, which are available upon request.

private and public rates of return for the average OECD country[26]. A few things are worth mentioning. First, both rates of return seem to be stationary around a mean of approximately 8.6-8.9% per annum[27].

Second, both rates of return move close to each other over the sample period, and it is quite difficult to appreciate prolonged periods where both returns diverge substantially. This pattern of returns is quite reasonable if we take into account that the Euler equations we are estimating implicitly use the average over the sample period of the intertemporal marginal rate of substitution as the benchmark for the optimal levels of public and private capital. If the overidentifying restrictions are not rejected by data in any country, as is the case, then the average returns to both types of investment have to equal the average discount factor in every country in the sample. This fact is confirmed looking at Figure 2, where we present the differences between the rates of return and the intertemporal marginal rate of substitution implicit in our estimations (which depends on the concrete value given to the restricted parameter σ). Both series are stationary around a zero mean and there is no way to find periods of excess or shortage of either private or public capital.

Summing up, the general picture that emerges from our results in Table 2 is that public and private capital provision have followed efficiency criteria, and that both the estimated output elasticities and the investment returns seem quite reasonable. Nevertheless, there are certain aspects of this story that deserve a more careful scrutiny.

An important aspect of the results in Table 2 is that the point estimates of output elasticities and rates of return depend on the concrete value we are giving to the restricted parameter σ. As emphasized by Poterba (1998) the relative rates of return of both types of capital are crucial to evaluate the adequacy of public investment efforts. Also the output elasticities are important to properly measure the impact of capital accumulation on output. So, it is worth trying to estimate

[26] We prefer to present results for the average economy (the simple average across countries), because it resembles the pattern across countries, with the only caution that the average investment returns for a given country can be higher or lower than for the average OECD economy, as is evident in Table 2. Additionally, this figure corresponds to the results obtained with the second instrument set.

[27] Recall that the rates of return depend on the evolution of the output capital ratios that display some trend behavior in many countries, the depreciation rates that are constant and the investment output relative prices. Obviously, the stationarity of the return series is due to the inclusion of the price series in the model.

σ directly to see which are the values estimated for output elasticities and rates of return compatible with the values obtained for the elasticity of intertemporal substitution.

FIGURE 1
Average Rates of return. (Φ = -1.0)

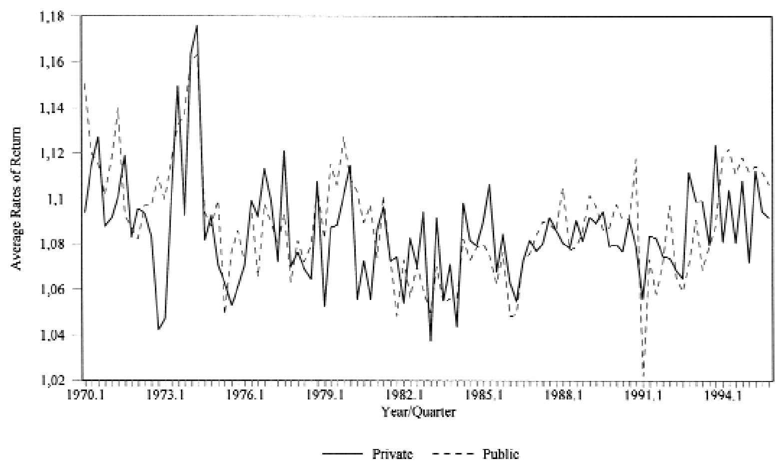
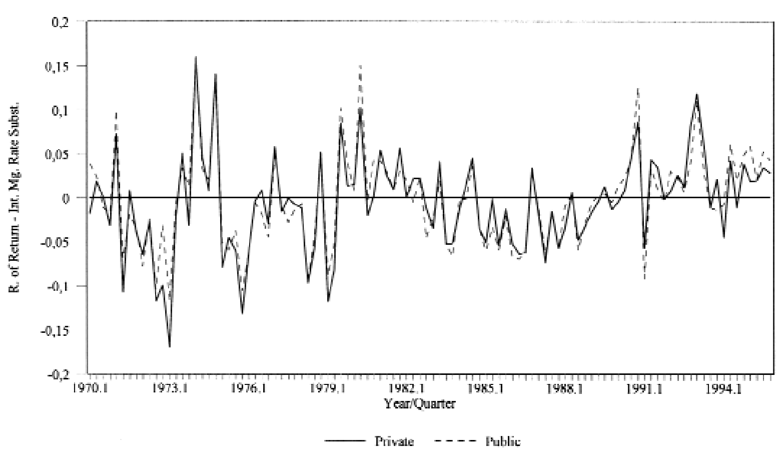


FIGURE 2
Model in Equations (8).
Rate of Return - Intertemporal Marginal Rate of Substitution



As stated in the theoretical section, our first strategy to estimate the parameter related to the intertemporal elasticity of substitution consists in estimating equations [8] again, but leaving free the relevant parameter σ. The results are presented in Table 3, where for the sake of simplicity we only present results with an augmented version of the second set of instruments in Table 2. As is readily apparent the model also fits the data very well in almost every country in the sample. Again, the overidentifying restrictions are not rejected by the data in any country[28], giving additional support to the maintained efficiency hypothesis. Nevertheless, there are two noticeable new results when comparing these estimates with the model estimated in Table 2. Obviously, the first has to do with the estimated values of the coefficient σ. This coefficient is precisely estimated in all countries, displaying an average value of 0.781, far away from the –1.0 set in Table 2. Additionally, only in the case of Germany we get a coefficient greater than 1, not compatible with the theory. Translation of these figures into elasticities of intertemporal substitution implies that for the average OECD economy we obtain an elasticity around 4.6, instead of the 0.5 implied by setting σ at –1.0. Notice that there is no country where we estimate negative values of σ, so that the lower and the upper bounds of the elasticity are approximately 2 and 10. Remarkably, these estimated values are compatible with results in the empirical consumption literature with microeconomic data[29]. Further below we will discuss these figures again.

The second interesting set of results in Table 3 shows up looking at the estimated output elasticities and implied rates of return to both private and public capital. Concretely, now the private output elasticity has settled down to a value of 0.189 for the average economy and the public output elasticity to 0.054. In line with these point estimates the implicit rates of return to both capitals are reduced to annual rates around 5% for both factors (5.0% and 5.2% for private and public capital, respectively). From an economic point of view there are at least two arguments to believe that these results are preferable to the previous results in Table 2.

[28] Comparison of the significance levels of the Sargan's test with Table 2 shows that in approximately 50 per cent of the countries these improve, while in the rest they worsen. Given that we are estimating a new parameter in Table 3, the comparison of significance levels does not allow concluding which model is preferable.

[29] Recently, Márquez de la Cruz (2005) estimates an intertemporal elasticity of substitution for the Spanish case around 2.4, in line with our results. She concludes that the assumption of non separability between durable and non durable consumption in the utility function is the reason why the estimates of this parameter are generally so small in the literature.

First, we are estimating precisely a key parameter related to preferences, finding reasonable point estimates in most of the countries. This parameter is crucial for the estimation of the output elasticities, due to the fact that the concrete value we choose sets the level of the intertemporal marginal rate of substitution that acts as the benchmark for efficient resource allocation.

TABLE 3
Estimation Results. Euler equations in [8], σ estimated

Countries	ρ_1	ρ_2	σ	Sargan Test	*Rates of Return* Priv	Public
Australia	0.199 (0.013)	0.049 (0.003)	0.754 (0.315)	20.021 (0.641)	1.046	1.050
Austria	0.210 (0.008)	0.056 (0.003)	0.894 (0.094)	15.913 (0.775)	1.052	1.051
Belgium	0.193 (0.003)	0.044 (0.001)	0.639 (0.102)	21.089 (0.332)	1.046	1.053
Canada	0.229 (0.009)	0.033 (0.002)	0.906 (0.243)	15.364 (0.699)	1.035	1.043
Germany	0.166 (0.006)	0.040 (0.003)	1.375 (0.174)	15.694 (0.678)	1.035	1.035
Denmark	0.180 (0.005)	0.055 (0.002)	0.927 (0.050)	26.725 (0.772)	1.048	1.044
Spain	0.192 (0.008)	0.032 (0.001)	0.654 (0.196)	30.303 (0.476)	1.058	1.056
Finland	0.195 (0.013)	0.055 (0.006)	0.490 (0.243)	21.529 (0.308)	1.049	1.048
France	0.164 (0.003)	0.044 (0.001)	0.906 (0.088)	24.765 (0.963)	1.046	1.052
United Kingdom	0.192 (0.008)	0.121 (0.006)	0.626 (0.150)	32.040 (0.515)	1.063	1.080
Ireland	0.178 (0.008)	0.051 (0.002)	0.835 (0.097)	28.820 (0.474)	1.056	1.054
Italy	0.176 (0.008)	0.047 (0.002)	0.553 (0.179)	28.721 (0.190)	1.061	1.060
Japan	0.217 (0.010)	0.085 (0.006)	0.743 (0.200)	26.051 (0.074)	1.057	1.059
Sweden	0.177 (0.012)	0.053 (0.003)	0.583 (0.333)	31.539 (0.340)	1.052	1.053
USA	0.166 (0.003)	0.047 (0.001)	0.836 (0.107)	29.500 (0.543)	1.041	1.039
Average	0.189	0.054	0.781		1.050	1.052

Notes: See Table 2.
Sets of instruments in this Table add to the second set in Table 2: lags 3rd to 5th of c_t/c_{t-1} in Belgium, Canada, Germany, Finland and Sweden; lags 3rd to 6th of c_t/c_{t-1} in Austria; lags 3rd to 7th of c_t/c_{t-1} in Australia, Denmark and United Kingdom; lags 3rd to 8th of c_t/c_{t-1} in Spain; lags 3rd to 5th of c_t in Ireland and Italy; lags 3rd to 8th of c_t in the United States; lags 3rd to 4th of Y_t/Y_{t-1} in Japan; lags 3rd to 6th of Y_t/Y_{t-1} in France; $(Y_{t-1}/K_{it-1})/p_{it-2}$ in Ireland and USA; and $(Y_{t-1}/K_{it-1})/p_{it-2}$ in Denmark.

Second, given that the maintained hypothesis of efficient capital provision implies that on average the rate of return to a productive factor has to equal the average stochastic discount factor relevant to investment decisions, it seems surprising that it takes an average value as high as 8.6-8.9%. The reason is that this value should be roughly similar to an equilibrium ex-ante real interest rate in the economy. Looking at results for the rates of return in Table 3, it seems more reasonable to think that an average equilibrium real interest rate in the OECD area (from 1970 to 1995) has taken values around 5-5.5%, instead of the 8.6-8.9% implicit in Table 2.

In any case, one lesson from the results in Tables 2 and 3 is that data from OECD countries support the maintained hypothesis of efficient resource allocation in both cases. This result may appear surprising, at least with respect to the behavior of the public sector. Nevertheless, the reason behind this result is that in those countries where public investment has been reduced along the sample period, suggesting to many researchers the possibility of under-investment in the public sector, the price of public investment goods has risen relative to the price of aggregate output. All along, in these countries the prices of private investment goods have become less expensive relative to output prices. Thus, it is not surprising that in those countries where the cost of public investment goods relative to private goods has risen the result is a decline in the public to private capital intensity. Although this is not necessarily the pattern in all of the countries in our sample, our results suggest that in all of them the relative variation of investment prices seems to account for the movements of the capital intensities.

To finish this section we present the results of estimating the model in equations [9] and [10], i.e. adding to the system of estimated equations the consumption Euler equation. As explained in the theoretical section, the underlying assumption is that the stochastic discount factor relevant for the representative consumer and for firms in both sectors is the same, and equal to an equilibrium ex-ante real interest rate. This means that, as is common practice in the empirical literature of consumption with aggregate data, we need to rely on some real interest rate series to be able to estimate the parameter related to the elasticity of intertemporal substitution, σ. The real interest rates we use are the same we have employed as instruments in the models estimated previously. The results of this exercise are presented in Table 4.

Remarkably, the point estimates of output elasticities and the implied rates of return are almost identical[30] to the ones obtained in Table 3.

TABLE 4
Estimation Results. Euler equations in [9] and [10]

Countries	ρ_1	ρ_2	σ	Sargan Test	*Rates of Return* Priv	Public
Australia	0.204 (0.007)	0.053 (0.002)	0.407 (0.103)	36.641 (0.439)	1.049	1.058
Austria	0.211 (0.005)	0.058 (0.002)	0.883 (0.020)	25.573 (0.819)	1.052	1.054
Belgium	0.199 (0.002)	0.045 (0.001)	0.585 (0.034)	31.828 (0.376)	1.050	1.057
Canada	0.228 (0.003)	0.039 (0.001)	0.216 (0.057)	46.970 (0.963)	1.034	1.063
Germany	0.171 (0.002)	0.040 (0.001)	0.982 (0.030)	34.021 (0.280)	1.038	1.034
Denmark	0.202 (0.004)	0.066 (0.002)	0.549 (0.068)	39.179 (0.814)	1.065	1.061
Spain	0.194 (0.003)	0.033 (0.001)	0.348 (0.052)	39.093 (0.817)	1.059	1.059
Finland	0.217 (0.013)	0.059 (0.006)	0.532 (0.243)	32.645 (0.308)	1.062	1.055
France	0.166 (0.002)	0.045 (0.001)	0.799 (0.026)	41.819 (0.964)	1.047	1.053
United Kingdom	0.187 (0.005)	0.121 (0.004)	0.720 (0.036)	37.593 (0.919)	1.059	1.079
Ireland	0.171 (0.006)	0.052 (0.002)	0.570 (0.072)	40.197 (0.675)	1.051	1.057
Italy	0.188 (0.004)	0.048 (0.001)	0.760 (0.047)	40.313 (0.285)	1.069	1.062
Japan	0.202 (0.003)	0.074 (0.002)	0.890 (0.031)	35.514 (0.126)	1.047	1.044
Sweden	0.170 (0.009)	0.054 (0.003)	0.788 (0.052)	40.644 (0.657)	1.047	1.055
USA	0.163 (0.002)	0.047 (0.001)	0.781 (0.035)	40.630 (0.766)	1.039	1.038
Average	0.192	0.056	0.654		1.051	1.055

Notes: See Tables 2 and 3.
Sets of instruments in this Table are the same as in Table 3, except in Canada (constant, lags 3rd to 9th of i_t^r, lags 1st to 4th of p_{it}/p_{it-1}, and lags 3rd to 9th of c_t/c_{t-1}); Austria where we have replaced lags 3rd to 6th of c_t/c_{t-1} with lags 3rd to 6th of Y_t/Y_{t-1}; Denmark where we have dropped $(Y_{t-1}/K_{1t-1})/p_{1t-2}$; and Spain where we have dropped the 5th lag of p_{it}/p_{it-1}.

[30] For the average economy the private capital output elasticity is 0.192 (0.189) in Table 4 (Table 3), the public output elasticity is 0.056 (0.054), while the rates of return are, respectively, 5.1% (5.0%) and 5.5% (5.2%). Additionally, depicting the analogue Figures 2 and 3 with the results obtained in Tables 3 and 4 gives pretty much the same information. Both return series seem to be stationary around a mean of approximately 5-5.5% per annum and the differences between the rates of return and the intertemporal marginal rate of substitution (Table 3) or the gross real interest rate (Table 4) are stationary around a zero mean.

In fact, according to the standard errors of the estimated coefficients we can be confident that we get similar output elasticities (and rates of return) in both tables, that are at the same time different from the values obtained setting σ at −1.0 in Table 2. This is an important result, because without the results in Table 2 we could think that the difference (approximately 3.5 points) between the rates of return in Tables 2 and 4 might be explained by the poor quality of our constructed measure of the real interest rate. As discussed above it seems rather implausible that the average of the ex-ante real interest rates in the OECD have been 8.6-8.9% in the 1970-95 period. In fact, the average across countries of our estimated interest rate is 5.5% and our method corrects explicitly the negative values that are obtained in the first half of the 1970's when using other techniques.

Summing up, our results in Table 4 confirm the pattern found in Table 3 and the differences found in the latter with respect to the output elasticities and rates of return obtained in Table 2. The model in Table 3 has the advantage of not relying on an "arbitrary" interest rate series, although the results in Table 4 show that our interest rate series may be a reasonable benchmark for investment decisions.

Finally, there are two other important facts from Table 4 that are worth mentioning. First, the overidentifying restrictions are again not rejected by data in any country in the sample, giving support to the maintained efficiency hypothesis. Second, we estimate σ more precisely than in Table 3 (standard errors are lower in all countries, but Denmark) and in all of them it displays values compatible with the theory. The average value is 0.654 implying an average elasticity of intertemporal substitution around 2.9 (ranging between 1.5 and 4.5 in most of the countries).

Our results about the values of the parameter related to the elasticity of intertemporal substitution are encouraging, given that as stated previously, in the empirical consumption literature there is considerable debate about the magnitude of this parameter. This literature has reached a certain consensus on the need of using microeconomic data to control for individual characteristics as the best way of obtaining plausible estimated values for this parameter (see Attanasio and Weber, 1989). The reason is that attempts to estimate it with aggregate data provides very inconclusive and imprecise point estimates (see Campbell and Mankiw, 1991), no matter which country or sample period it is used. These results suggest that, with aggregate data, the Euler equation of consumption alone is not capable of providing reasonable and precise estimates of the elasticity of intertemporal substitution (or, equivalently, of the coefficient of relative risk aversion), at least for non-durable consumption under the usual separability assumptions. In our setting, we incorporate to our econometric exercises more information and more theoretical structure, given that the estimated equations can be considered as intertemporal conditions obtained from a general equilibrium model, where all agents in the economy share a common stochastic discount rate. This may explain why we get reasonable, significant and quite similar estimated parameters in all countries in our sample. In fact, some recent results in the empirical consumption literature with aggregate data point in the same direction. For example, Ogaki and Reinhart (1998a and 1998b) obtain also reasonable values of the elasticity of intertemporal substitution when they relax the assumption of non-separability between durable and non-durable consumption goods[31]. Additionally, it is also remarkable that our results are better than standard results obtained in the CAPM empirical literature. This is especially so if we notice that we are using a simple version of the consumption Euler equation, while more complex and refined versions used in this literature have usually produced very poor results (see Otrok, Ravikumar and Whitaker (2002) and Cogley (2002)). So, our results indicate that the general equilibrium approach we adopt seems fruitful for estimating precisely both the parameters from the production sphere (capital output elasticities and implicit rates of return) and the parameters from the consumption sphere (the elasticity of intertemporal substitution).

5. Conclusions

In this work, we have analyzed the provision of both public and private capital, through the estimation of efficiency conditions derived from processes of optimization. Our empirical exercises cover a sample of fifteen OECD countries over the 1970-95 period. To perform the empirical analysis, it was necessary to elaborate series of public capital for all the countries in our sample and also of private capital for some of them. We applied the perpetual inventory method to our

[31] The fact that our estimate of the intertemporal elasticity of substitution is greater than the values obtained in these papers can be explained by the measure of total private consumption we are considering. Ziliak (1998) has shown that using different measures of consumption can alter considerably the point estimates of relevant parameters.

initial capital stocks estimates, using official OECD investment flows from the Business Sector Database.

Our approach in this paper to the issue of efficiency follows the one pursued by Otto and Voss (1998) that is a natural extension of the consumption-based asset pricing literature on the empirical analysis of Euler equations. In this setting investment returns are modeled using production variables, in a way closely related to Cochrane's (1991) production-based asset pricing model. The efficiency conditions derive from models of intertemporal behavior where the maintained hypothesis is that capital provision (public or private) has been efficient. This approach uses information about the dynamics of the relative prices of private and public investment goods that is usually ignored in the literature. We have extended the work by OV in two directions. First, using a sample of fifteen OECD countries to see if their results and conclusions for Australia are also valid for other advanced countries. Second, estimating the parameter related to the elasticity of intertemporal substitution that these authors restrict, even though they recognize that this is not ideal. In fact, we have shown that it is possible to obtain an economically reasonable (and statistically significant) estimate of this parameter under two different estimation strategies.

As a general conclusion, we can point out that independently of the empirical strategy adopted, we do not find either evidence of excessive returns to public capital, nor systematic or significant differences between private and public rates of return. This finding contrasts with usual results obtained in the literature, fundamentally those based on the estimation of production functions, where it is commonplace to find supernormal returns to public capital. So, we find robust evidence across countries that private capital and, a priori more surprisingly, public capital have followed criteria of efficient resource allocation in OECD countries.

All along we obtain quite plausible values for the parameters of interest in all countries and with little variation across them. The output elasticities of private and public capital display values around 0.19 and 0.055, respectively, implying average rates of return to both factors of approximately 5-5.5%, which are coherent with a reasonable average level of real interest rates in the OECD area along the sample period. The values obtained for the parameter related to the intertemporal elasticity of substitution imply a range of variation of this elasticity across countries between 1.5 and 4.5, which is in line with results obtained in the empirical consumption literature with microeconomic data, and some recent results with macroeconomic data.

In any case, the most important conclusion of this work is that, independently of the approach considered in the analysis, the provision of both types of capital displays high levels of efficiency in a big sample of OECD countries. At the same time, the analysis of capital provision through Euler equations derived from optimization processes in a general equilibrium framework, produces reasonable estimates of rates of return, capital output elasticities and elasticities of intertemporal substitution that display, additionally, less variation across countries than observed using other traditional strategies.

Appendix. Estimation of the capital stocks

As is well known, the basic problem using the *perpetual inventory method* is the need to have an initial stock of capital as reliable as possible, given that as time goes by, and for given depreciation rates, the value of the accumulated stock is more and more realistic. To solve this problem, among the different solutions in the literature, we have chosen Doménech and Taguas (1999) proposal. In fact, under some assumptions, it is possible to estimate an initial stock of capital from the basic accumulation equation. So, this equation can be written as:

$$\gamma_{Ki,t} = \frac{\dot{K}_i}{K_{it}} = \frac{i_{it} Y_t}{K_{it}} - \delta_i, \qquad i = 1, 2 \qquad \text{[A.1]}$$

where δ_i is the depreciation rate (assumed to be 0.048 for public capital and 0.068 for private capital), i_{it} is the investment rate, Y_t is the output level and K_{it} is the stock of capital to be estimated. To obtain an initial stock of capital from this equation, we only need to assume that the growth rate of investment is a good approximation for the growth rate of the capital stock. Nevertheless, and to improve this approximation, given that investment flows are highly volatile, we have filtered the investment series using the Hodrick and Prescott filter, with a smoothing parameter $\lambda = 10$. Because of the problems of this filter in the extremes of the sample, and given that the investment series start at the beginning of the 60's in most of the countries, we have used 1965 as the base year to calculate the initial stocks of capital[32]:

$$K_{i,65} = \frac{\bar{I}_{i,65}}{\delta_i + \gamma_{i,\bar{I}60-70}} \qquad \text{[A.2]}$$

In this expression $\bar{I}_{i,65}$ is trend investment obtained with the Hodrick and Prescott filter and $\gamma_{i,\bar{I}60-70}$ is the trend growth rate in the 60's. Once we have the base year capital stocks, we apply the perpetual inventory method to estimate public and private capital stocks for the remaining years according to:

$$K_{i,65+j} = \sum_{s=1}^{j} (1-\delta_i)^{s-1} I_{i,65+j-s} + (1-\delta_i)^j K_{i,65} \qquad \text{[A.3]}$$

As Doménech and Taguas (1999) argue, this method to generate capital stocks has several advantages with respect to others, because it takes into account that the economy can be out of the steady state. In a different standard approximation (see Coe and Helpman (1996)) the initial stocks are obtained dividing observed investment in the base year (instead of trend investment) by the depreciation rate plus the mean growth rate of observed investment for the whole period (instead of the trend growth rate). Given that growth rates have settled down in many OECD economies, probably because they were out of their steady states at the beginning of the period, and that current investment could be affected by transitory shocks, it seems more appropriate to use the trend growth rate for a shorter period (1960-70, in our case), assigning it to the central year.

To check the validity of our estimated capital stocks, we have done a battery of proves. First, we have checked that in most countries the resulting depreciation series are very similar (almost identical, in many cases) to the series of fixed capital consumption in the National Accounts. Second, we have also checked that the temporal profiles of the ratios of both investments to total investment and of both stocks of capital to the total stock are coherent. Third, we have analyzed the time evolution of the ratio of public to private capital, and we have found that it is coherent with public to private investment ratios. In

[32] In some cases, we have used as the base a different year around 1965, given that it produced better results, attending to the ratios of private to public capital, public to private investment, investment to output and both capitals to output.

Table A.1 we present the means for the capital-output and investment-output ratios. The capital-output ratio average for all the countries is 1.88 (1.32 and 0.56 for public and private capital, respectively), although there are important differences across countries. The same happens with the investment rates, with average values of 14% and 4% for private and public investment, respectively.

In any case, although investment flows are in real terms (assuring their intertemporal comparability), comparisons across countries will require correcting the investment and output series with the different purchasing power parities. Nevertheless, in our case this is not necessary, because we have estimated the efficiency conditions separately for each country.

TABLE A.1
Ratios Capital-Output and Investment-Output. Averages 1970-1995

Countries	K/Y	K_1/Y	K_2/Y	I_1/Y	I_2/Y
Australia	2.25	1.70	0.55	0.16	0.04
Austria	2.12	1.52	0.60	0.17	0.05
Belgium	1.70	1.26	0.44	0.11	0.03
Canada	1.63	1.29	0.34	0.12	0.03
Germany	1.88	1.39	0.49	0.14	0.04
Denmark	2.14	1.43	0.71	0.14	0.04
Spain	1.67	1.33	0.34	0.15	0.03
Finland	2.49	1.79	0.70	0.17	0.04
France	1.59	1.16	0.42	0.14	0.04
U. Kingdom	2.36	1.47	0.88	0.14	0.06
Ireland	1.77	1.15	0.62	0.14	0.05
Italy	1.80	1.34	0.46	0.13	0.04
Japan	2.05	1.29	0.76	0.18	0.09
Sweden	1.50	1.09	0.41	0.11	0.03
USA	1.32	0.84	0.48	0.10	0.04
Average	1.88	1.34	0.55	0.14	0.04

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Resumen

En este trabajo utilizamos una muestra de 15 países de la OCDE para examinar si la provisión de capitales público y privado ha satisfecho condiciones de eficiencia intertemporal entre 1970 y 1995. Obtenemos evidencia robusta de que los capitales público y privado han seguido criterios de asignación eficiente de recursos en todos los países. Las elasticidades-output de los capitales público y privado muestran escasa variación entre países, alcanzando valores promedio de 0.19 y 0.055, respectivamente. Consecuentemente, las tasas medias de rentabilidad de ambos factores son estimadas en el entorno del 5-5.5

Palabras clave: Infraestructuras, capital privado, inversión.

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