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Estimating the Capital Stock in Greek Regions: 1980 - 1998

by

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1. Introduction

The analysis of the economic development of the regions of Greece has always been handicapped by the almost unavailability of statistics of regional capital stock. In the absence of time series of capital stock, it is almost impossible to assess fully the contribution of investment activities (private or public) into the growth performance of regional economies.

Actual capital stock data are seldom available and often inadequate, especially at the regional level of analysis. To try to sort this out, relevant studies, estimating the capital stock using data on investment[1]. Following the relevant literature, there are three major methods of obtaining estimates of capital stock series. The first is by employing a '*perpetual inventory*' method, which involves cumulating annual totals of investment at constant prices over assumed lengths of lives of the assets. The second involves the employment of a *surrogate*. In the relevant studies the most frequently used surrogate is the consumption of electricity for industrial purposes. However, such estimates are too far from reality to be useful in practice. The third method refers to the application of the acceleration theory in its 'flexible' version (see Junankar, 1973, Ch. 3). Although this is an indirect' method, nevertheless, allows the researcher to obtain estimates of the annual amount of the capital stock and depreciation independently for each year and each region.

This paper explicitly attempts to confront theory with fact. In particular, reports an attempt to estimate series of the capital stock variable for the regions of Greece, during the 1980-1998 period. The present paper contributes to the existing literature by utilising data on manufacturing

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1. See for example Harris (1983), Hulten and Schwab (1984), Gertler, M. (1986) and Anderson and Rigby (1989).

output and investment in the context of the *accelerator theory*, i.e. the relation between the investment activity and the output.

The remainder of this paper is organised in the following manner. Section 2 outlines the model while section 3 discusses the data used. The estimated time series of the capital stock are shown in section 4. Finally, section 5 concludes.

2. The model

One of the most common methods of estimating capital stock is the so-called *perpetual inventory* method[2]. In essence, this technique requires a time series of deflated values of capital investment as input data. These data are calculated by dividing the current value of investment ($\tilde{I}_t$) in each time period (t) by a capital goods index (P_c). Thus,

$$I_t = \frac{\tilde{I}_t}{P_c} \tag{1.1}$$

where I_t is the deflated value of investment in period t.

The intuition behind equation (1.1) is to adjust for changes in the purchasing power of the monetary value of investment. The measurement of capital in monetary terms is justified in terms of the microeconomic theory. According to this, the price a firm is willing to pay for a capital good is equal to the value of the discounted flow of revenues it is expected to produce. Consequently, the productive capacity, measured in monetary terms, of two capital goods of the same vintage with equal prices must be equal. However, this is not necessarily true, given that it is possible technology and preferences to change through time.

Nevertheless, according to the perpetual inventory method, depreciation is estimated using a single parameter (μ), which is the assumed service lifetime of capital goods (Anderson and Rigby, 1989). A capital good is assumed to be completely withdrawn from the capital stock after μ years. Hence, the simplest assumption governing depreciation is that a capital good

2. For a more detailed description of the perpetual inventory method, see Chenery (1952), Duesenberry (1958), Eisner (1960) and Patterson and Schott (1978).

remains in full service until is withdrawn suddenly at the end of its lifetime service[3]. Under this assumption capital stock at the beginning of period t can be estimated according to the following formula:

$$K_t = \sum_{v=t-\mu}^{t-1} I_v \tag{1.2}$$

An alternative way to estimate capital stock is to assume that following its installation, an equal proportion of the services of capital is withdrawn in each of the m periods (straight line depreciation). Therefore, the capital stock at the start of the period *t* is calculated as follows (Anderson and Rigby, 1989):

$$K_t = \left(1 - \frac{1}{\lambda}\right) K_{t-1} + I_{t-1} \tag{1.3}$$

Equation (1.3) incorporates the fact that capital goods may be removed from production at any time after they installed. In this light the parameter μ reflects the maximum service lifetime. However, several criticisms have been raised against the estimates, which the perpetual inventory method has yielded, because of various empirical problems (For a theoretical critique of this approach see Sraffa (1960), Ch. 10). To be more specific, the most important empirical problem is to estimate the parameter μ. In relevant literature, μ is estimated based on engineering surveys, which assess the average service lifetimes of capital goods. Nevertheless, such studies are not conducted frequently and, moreover, regionally disaggregated studies for Greece are virtually non-existent. The unavailability of appropriate data makes the estimation of capital stock for each region using the perpetual inventory method impossible.

Thus, given the regional data famine it is very useful, indeed, to be able to find a method that fully utilises the existing data across regions. To this aim, the model of the 'flexible' accelerator is deployed. A starting point in this model is provided by the expression for the optimal capital stock, thus

$$K^*_{i,t} = \alpha Y_{i,t} \text{ and } K^*_{i,t-1} = \alpha Y_{i,t-1} \tag{2.1}$$

where α is a parameter and the subscript i refers to each region.

3. Solow in a justly famous article (1962) called this assumption as 'one hoss shay'.

The adjustment function is

$$K_{i,t}-K_{i,t-1}=(1-\lambda)(K^{*}_{i,t}-K_{i,t-1}),\ \text{with}\ 0<\lambda<1 \qquad (2.2)$$

Equally important is to determine an expression for depreciation. The replacement or the depreciation of capital is given by the following equation:

$$D_{i,t}=\delta K_{i,t-1},\ \text{with}\ 0<\delta<1 \qquad (2.3)$$

This view accepts the argument that the capital stock in any period t consists of the existing capital stock plus the new additions by net investment in current period. Thus,

$$K_{i,t}=K_{i,t-1}+I_{i,t}-D_{i,t} \qquad (2.4)$$

where $I_{i,t}$ is the level of gross investment in any region.

The next important step forward is to solve equation (2.2) with respect to $K_{i,t}$. Thus,

$$K_{i,t}=(1-\lambda)K^{*}_{i,t}+\lambda K_{i,t-1} \qquad (2.5)$$

Inserting equation (2.3) into equation (2.4) yields an expression for gross investment. Thus,

$$I_{i,t}=K_{i,t}-(1-\delta)K_{i,t-1} \qquad (2.6)$$

Using the expression given by equation (2.5), equation (2.6) is written as follows:

$$I_{i,t}=(1-\lambda)K^{*}_{i,t}-(1-\lambda-\delta)K_{i,t-1} \qquad (2.7)$$

Lagging equations (2.5), (2.6) by one period yields

$$K_{i,t-1}=(1-\lambda)K^{*}_{i,t-1}+\lambda K_{i,t-2} \qquad (2.5.1)$$

$$K_{i,t-2}=\frac{(K_{i,t-1}-I_{i,t-1})}{(1-\delta)} \qquad (2.5.2)$$

From equations (2.1), (2.5.1), (2.6.1) and (2.7), it follows that

$$I_{i,t} = \alpha(1-\lambda)Y_{i,t} - \alpha(1-\lambda)(1-\delta)Y_{i,t-1} + \lambda I_{i,t-1} \tag{2.8}$$

Moving away from these abstract considerations, so as to get closer to the complications of the real situation, account has to be taken for the econometric specification of the model. In the model of 'flexible accelerator' the expression given by equation (2.8) is of critical importance. Equation (2.8) has the advantage of providing an estimate of the capital stock in each region using data for output and investment. In other words, econometric estimation of the parameters of this equation allows for estimating the capital stock of each region without the need of using data either for the capital stock or the amount of depreciation. Wallis (1973) and Helliwell (1976) used this indirect method of estimating the stock of capital of aggregate economy. Katos (1978) applied a similar approach to estimate the capital stock for the entire Greek economy using data covering the period 1948-1972. A variant of this approach has been developed in this paper for deployment in an entirely different context – the regions of Greece.

Expressing equation (2.8) in terms of a regression equation yields:

$$I_{i,t} = c + b_1 Y_{i,t} + b_2 Y_{i,t-1} + b_3 I_{i,t-1} \tag{2.9}$$

where $b_1 = \alpha(1-\lambda)$, $b_2 = -\alpha(1-\lambda)(1-\delta)$, $b_3 = \lambda$ and *c* is the constant term of the regression.

Quantitatively the most important fact is that the estimated parameters b_1, b_2 and b_3 allow to estimate the values of α and δ. Thus,

$$\alpha = \frac{b_1}{1-b_3} \text{ and } \delta = \frac{b_1 + b_2}{\hat{b}_1} \tag{2.10}$$

With the aid of the parameters α, δ and λ is possible to obtain an estimate for the capital stock for the period t–1. Solving equation (2.7) for $K_{i,t-1}$ and rearranging yields

$$K_{i,t-1} = \frac{(1-\lambda)}{(1-\lambda-\delta)} K^{*}_{i,t} - \frac{1}{(1-\lambda-\delta)} I_{i,t} \tag{2.11}$$

Using equation (2.1), the capital stock of period t–1 can be derived using the following expression[4]:

4. The case $\lambda + \delta = 1$ brings indeterminacy in the model.

$$K_{i,t-1} = \frac{\alpha(1-\lambda)}{(1-\lambda-\delta)} Y_{i,t} - \frac{1}{(1-\lambda-\delta)} I_{i,t} \qquad (2.12)$$

Implementing equations (2.4) and (2.3) and the estimated capital stock in period t-1, capital stock and the amount of depreciation in each period are possible to be determined.

3. The data

The data used for estimation purposes are regionally disaggregated by the National Statistical Agency of Greece and refer to the 13 administrative regions of Greece during the period 1980-1998. Output is measured by the gross value – added at factor cost for the manufacturing sector while the investment variable refers to the total gross asset formation. These data were obtained from various annual surveys from the National Statistical Agency of Greece. The above data were deflated at 1980 current prices using deflators provided by the same official source. Ideally, the data should be deflated using regional price deflators. However, regional price indexes are not available and we simply use national deflators[5].

4. Estimation results

Table 1 presents the results of a set of regression estimations of equation (2.9) for each administrative region.

As it can be seen from table 1, the coefficients are, almost, in all cases statistically significant and have the expected signs, as indicated by equation (2.8) and (2.9). Moreover, the results obtained can be considered as satisfactory in terms of R^2 test. Having obtained the coefficients b_1, b_2 and b_3 it is possible to derive the estimated rates of depreciation for each region. Table 2 gives the obtained depreciation rates.

5. Several authors deflate regional data using indexes reflecting regional differences in cost of living. Nevertheless, such approach serves no purpose in the aims of this paper, given that the primary concern refers to the productive and not the welfare aspect of the regional economies.

Table 1: Estimation results of equation $I_{i,t} = c + b_1 Y_{i,t} + b_2 Y_{i,t-1} + b_3 I_{i,t-1}$

Region	c	b_1	b_2	b_3	R^2	DW
Eastern Macedonia and Thraki	1.638	0.345	-0.325	0.642	0.939	2.142
	(2.142)	(2.193)	(-2.853)	(4.608)		
Central Macedonia	0.115	0.314	-0.284	0.625	0.925	2.002
	(1.385)	(2.883)	(-3.874)	(6.304)		
Western Macedonia	0.656	0.435	-0.421	0.478	0.985	2.156
	(1.884)	(2.636)	(-2.242)	(5.395)		
Hepiros	3.180	0.781	-0.714	0.485	0.902	2.221
	(3.559)	(2.658)	(-2.249)	(2.823)		
Thessaly	1.678	0.619	-0.559	0.487	0.956	2.013
	(2.243)	(2.273)	(-2.041)	(4.008)		
Ionian Islands	4.578	1.936	-1.847	0.638	0.824	1.625
	(3.817)	(3.425)	(-2.788)	(1.762)		
Western Greece	1.722	0.865	-0.854	0.498	0.982	2.034
	(3.422)	(3.044)	(-2.549)	(4.246)		
Sterea Ellada	0.064	0.867	-0.836	0.487	0.996	1.822
	((0.265)	(4.120)	(-3.220)	(7.343)		
Attiki	2.099	0.809	-0.683	0.457	0.897	2.354
	(0.847)	(2.584)	(-3.470)	(2.770)		
Peloponisos	1.920	0.857	-0.779	0.441	0.908	1.298
	(2.968)	(1.691)	(-2.269)	(2.122)		
Northern Aegean	2.563	1.949	-1.833	0.459	0.975	1.574
	(4.203)	(5.299)	(-4.141)	(3.967)		
Southern Aegean	1.188	0.781	-0.716	0.487	0.984	1.529
	(3.969)	(1.762)	(-2.437)	(2.368)		
Crete	3.241	1.034	-0.910	0.404	0.948	1.288
	(4.570)	(4.070)	(-2.740)	(2.920)		

Note: Figures in brackets are t-ratios. DW is the Durbin-Watson statistic and F is the probability associated with an F-test for the overall significance of the regression.

Table 2: Estimated regional depreciation coefficients

Region	δ
Eastern Macedonia and Thraki	0.057971
Central Macedonia	0.095541
Western Macedonia	0.032184
Hepiros	0.085787
Thessaly	0.096931
Ionian Islands	0.045971
Western Greece	0.012717
Sterea Ellada	0.035755
Attiki	0.155748
Peloponisos	0.091015
Northern Aegean	0.059518
Southern Aegean	0.083227
Crete	0.119923

The estimates on table 2 allow for the derivation of the capital stock during the time period t-1, which at the present case is the year 1979. Having an estimate of the capital stock in year 1979, it is possible to construct time series for each region by simply adding the net investment (i.e., gross investment less depreciation) to the capital stock of each year. The derived time series are reported in table 3 while the estimated annual amount of depreciation is given in table 4.

Table 3: Time series estimates of the manufacturing capital stock across the regions of Greece

	Eastern Macedonia & Thraki	Central Macedonia	Western Macedonia	Hepiros	Thessaly	Ionian Islands	Western Macedonia	Sterea Ellada	Attiki	Peloponisos	Northern Aegean	Southern Aegean	Crete
1979	3242724	22319995	865889	1992152	9532759	967019	9197255	11164301	173736970	6899419	2501108	1434477	4533521
1980	5424879	28200742	6506072	2477199	14248537	964423	13183206	23740265	165133368	11635356	2609316	2654211	4550097
1981	8202719	40088897	12009721	3364933	18540192	989029	19464025	45895160	163433876	12152553	2643682	2964826	4607486
1982	12611261	49433750	17080593	3618332	22149416	1006245	24319672	63513475	159017408	14771759	2605265	3017514	4596995
1983	14265245	63159311	23941253	5099878	27352877	1050341	30686702	97459116	158318801	19704182	2763866	2926826	4694298
1984	20994679	70552065	28570378	4991070	30028221	1350019	35338185	122371356	157929458	24639750	2882391	2745772	4894632
1985	25330187	78949658	36615211	4934458	36002659	1471880	43315594	143376280	177131849	26320884	2891806	2632248	5339881
1986	28410621	90303405	43238796	5259989	40220782	1658263	48457580	159625661	210135236	31564410	2891665	2515242	5707596
1987	32160149	107541494	50847869	6918362	45218554	1821952	55372487	180531997	238759163	32707718	2775064	2585698	6226014
1988	38174126	127827630	56158755	7358250	47666480	2530301	64541948	209008926	262729636	34161902	2630122	3415779	6916345
1989	44699153	154161222	64916204	8827263	53489281	2676770	76263185	250249011	290878852	38798867	2615256	3635156	8076298
1990	50474612	177626290	77933253	9540518	63274972	2980422	87795326	303954718	324770478	50266596	2779983	4161749	10522870
1991	56498650	206928759	88726210	11156599	70282551	3479677	100760336	351314085	360260710	61090951	2817187	5095619	12596825
1992	64657150	234128016	104606191	14113310	82028329	3887934	109916117	390328502	415436928	68174835	2889660	5577389	14075352
1993	70788244	260306753	117753411	20455448	90384679	4237290	117655385	427474028	473144420	74827407	3099013	5917972	15032868
1994	91834536	283566061	131375736	23869284	98809187	5001879	126130584	455439765	516443187	82620456	4058597	6193938	17137061
1995	108427939	323644904	142281451	24098164	104118796	5381745	138210041	497179581	578231458	88441042	6307060	6576056	19973466
1996	131014725	360674704	165407763	25855709	121473524	5693959	158415019	535701987	611637728	93685979	6444132	7188094	24593348
1997	160484013	398270348	188593316	26187291	137906282	5825354	183325796	586950597	671023580	102067672	6827853	9275857	28642727
1998	199548089	449291678	218776490	30140389	160449509	6244877	205689830	661220305	783658270	111524282	6818928	10798264	33127797

Table 4: Time series estimates for the depreciation of manufacturing capital stock

	Eastern Macedonia & Thraki	Central Macedonia	Western Macedonia	Hepiros	Thessaly	Ionian Islands	Western Macedonia	Sterea Ellada	Attiki	Peloponisos	Northern Aegean	Southern Aegean	Crete
1980	188074	2117427	28195	172042	952599	44489	121904	398440	27056288	629846	148678	118538	542216
1981	314636	2675315	211848	213930	1423842	44369	174735	847261	15074967	1062187	155111	219330	544199
1982	475747	3803106	391055	290595	1852703	45501	257984	1637941	25451774	1109402	157154	244997	551063
1983	731436	4689623	556171	312478	2213369	46293	322342	2266717	24763991	1348509	154870	249351	549808
1984	827365	5991723	779564	440424	2733346	48322	406733	3478195	24655196	1798788	164298	241857	561445
1985	1217663	6693050	930296	431028	3000690	62109	468386	4367282	24594563	2249354	171344	226896	585406
1986	1469117	7489703	1192248	426139	3597710	67715	574121	5116922	27584977	2402824	171904	217515	638658
1987	1647778	2940419	1407922	454251	4019223	76290	642275	5696842	32724638	2881504	171895	207846	682638
1988	1865246	10202119	1655686	597468	4518646	83821	733928	6442963	37182280	2985876	164964	213668	744641
1989	2214049	12126600	1828616	635457	4763264	116409	855463	7459270	40915234	3118628	156348	282262	827206
1990	2592491	14624785	2113773	762320	5345131	123148	1010821	8931077	45298948	3541935	155464	300390	965938
1991	2927460	16850841	2537628	823917	6323006	137118	1163672	10847767	50576936	4588820	165256	343905	1258552
1992	3276847	19630673	2889063	963481	7023266	160086	1335516	12537964	56103877	5576971	167468	421075	1506600
1993	3750029	22210980	3406140	1218822	8197010	178869	1456870	13930341	64696542	6223656	171776	460886	1683434
1994	4105624	24694473	3834234	1766527	9032052	194941	1559449	15256018	73683407	6830967	184221	489030	1797955
1995	5326281	26901010	4277798	2061345	9873905	230117	1671782	16254081	80426381	7542392	241263	511834	2049620
1996	6288676	30703162	4632905	2081111	10404489	247593	1831888	17743723	90048750	8073751	374923	543410	2388858
1997	7598680	34216061	5385934	2232892	12138729	261957	2099693	19118540	95251153	8552560	383072	593986	2941403
1998	9307859	37782640	6140892	2261528	13780839	268002	2429869	20947539	104499390	9317722	405882	766507	3425716

6. Conclusions

This paper has set out to obtain measures of the capital stock in manufacturing for the regions of Greece over the period 1980-1998. The procedure adopted has been based upon the accelerator theory. While physical capital in manufacturing is a crucial variable in regional economic analysis, little attention has been given to developing accurate methods of estimating time series of regional capital stock.

It should be noted, however, that in order these estimated to be entirely accurate, a measurement, independent of the distribution of income, of the quantity of capital should be available. But according to Robinson (1953) and Sraffa (1960), such measurement is impossible and as a result the estimates in this paper are conditioned based on a series of simplifying assumptions.

Nevertheless, the estimates of capital stock in this paper may to be useful in a variety of regional economic analyses. For example, this data set is appropriate for use in production-function type models in testing macro-economic theories of regional growth. Moreover, using the estimated time series several interesting measures can be obtained, e.g. capital/labour ratios, technical efficiency, capital ages, etc. In addition, the adopted method allows for estimation of the capital stock for future years, using data on output and investment.

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