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Rates of Return and Alternative Measures of Capital Input: 14 Countries and 10 Branches, 1971-2005

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Abstract

We employ the EU KLEMS database to estimate the real rate of return to capital in 14 countries (11 in the EU, three outside the EU) in 10 branches of the market economy plus the market economy as a whole. Our measure of capital is an aggregate over seven types of asset: three ICT assets (computers, communications equipment, and software) and four non-ICT assets (machinery and equipment, non-residential structures, transport equipment, and other). The real rate of return in the market economy does not vary very much across countries, with the exception of Spain where it is exceptionally high and in Italy where it is exceptionally low. The real rate appears to be trendless in most countries. Within each country however, the rate varies widely across the 10 branches, often being implausibly high or low. We also estimate the growth of capital services by two different methods: ex-post and ex-ante, and the contribution of capital to output growth by three methods: ex-post, ex-ante and hybrid. Our implementation of the ex-ante method uses an estimate of the required rate of return for each country instead of the actual, average rate of return to calculate user costs and also employs the expected growth of asset prices rather than the actual growth. These estimates are derived from exactly the same data as for the ex-post method, ie without any extraneous data being employed. For estimating the contribution of capital to output growth, the ex-ante method uses ex-ante profit as the weight, while both the ex-post and the hybrid method use ex-post profit. We find that the three methods produce very similar results at the market economy level. But differences are much larger at the branch level, particularly between the ex-post and ex-ante methods.

Keywords: Capital, rate of return, ex post, ex ante
JEL Classifications: E22, E23, D24, O47, L6, L7, L8

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1. Introduction

The new EU KLEMS database constitutes a great advance in our ability to analyse trends and developments in the European economy and to compare it with other leading economies on a consistent and comparable basis. Because it is new and in many respects pioneering, it is important to subject the national data underlying it to stress-testing, to see whether its estimates are plausible in the light of economic theory and empirical evidence. This paper deals with two issues. First, is the average rate of return to capital which is implicit in the estimates of capital compensation and capital stocks for each industry and each country in EU KLEMS a plausible one? Second, how sensitive are the measures of capital input and of capital's contribution to output growth to alternative methods of estimation? On the first issue, if the implicit estimates of the rate of return for a particular industry or even for a whole country are very implausible, then the coherence and consistency of the national accounts of that country might be called into question. Even if the estimates of the rate of return seem reasonable, there is more than one way of using them to construct estimates of capital input (the second issue). So there is considerable interest in seeing how sensitive the estimates of capital input and of the contribution of capital to economic growth are to the method employed.

To do growth accounting we need to estimate the contribution of capital to the growth of output. This contribution equals the elasticity of output with respect to capital services multiplied by the growth of capital services. In the real world there are many types of capital so we need to estimate an index of the growth of capital services. For the latter we need estimates of the user cost (rental price) of each asset to employ as weights, on the assumption that user costs measure marginal products. Some of the elements of the user cost, e.g. asset prices, are known ex post but not with certainty ex ante. Another element, the rate of return, is still more problematic. The standard approach (e.g. Jorgenson and Griliches, 1967; Christensen and Jorgenson, 1969; and Jorgenson, Gollop and Fraumeni, 1987; O'Mahony and van Ark, 2003) has been to use an ex-post measure; this is sometimes also called the endogenous approach. In the ex-post approach it is assumed that the rate of return is equalised across assets. Then this unknown rate can be found by using the condition that the sum of the returns across assets (where the return on an asset is the product of its user cost and the flow of capital services that it yields) equals observed, total profit (gross operating surplus in national accounts language). The alternative, ex-ante approach, sometimes also called the exogenous approach, may estimate a rate of return from external information, e.g. from financial market data, or (as here) the rate may be derived from actual rates of return; the approach also uses estimates of expected, rather than actual, asset price inflation.

Many (e.g. Schreyer *et al*, 2003: Schreyer, 2004) have felt uncomfortable with the ex-post approach. After all, investment decisions have to be made in advance of knowing all the relevant facts. Surely agents employ some notion of the required rate of return in deciding how much to invest, and this required rate may differ from the actual, realised rate? Equally, they must base their decisions on expected, not actual, capital gains and losses. Using the ex-post measure would seem to imply either that all expectations are realised (a world of perfect certainty) or that the quantities of capital can be instantaneously adjusted to the desired levels, after all uncertainties have been resolved. Neither assumption seems attractive a priori.[1] This suggests using an ex-ante approach. On the other hand, when doing growth accounting we are interested in what the contribution of capital actually was, not in what it was expected to be, and for this the ex-post approach seems preferable (Berndt and Fuss, 1986; Berndt, 1990). However, Oulton (2007) argues that a hybrid approach, combining elements of both the ex-post and the ex-ante methods, is in fact the one suggested by economic theory. In this paper we estimate the contribution of capital to output growth by all three methods — ex-post, ex-ante and hybrid.

The issues raised here are also quite topical in the light of the forthcoming new version of the System of National Accounts (SNA). The 1993 SNA requires that gross operating surplus be included as a category of income, on all fours with compensation of employees. But though it is widely recognised that gross operating surplus (and probably a part of mixed income too) is the return to non-financial assets, just as compensation of employees is the return to labour, the 1993 SNA does not spell this out. Following the publication of the OECD manuals on productivity and capital measurement (OECD, 2001a and 2001b), there has been an increasing desire on the part of national statistical agencies to produce statistics of capital consumption, capital stocks and capital services that are internally consistent. Now the "Advisory Expert Group for the Update of the System of National Accounts, 1993" has recommended that countries which wish to do so may include a breakdown of gross operating surplus into the returns accruing to different assets; such a breakdown will not be included in the core accounts but may be included in supplementary accounts (Intersecretariat Working Group on National Accounts, 2007). The arguments in favour of this approach are spelled out

[1] The OECD capital and productivity manuals (OECD, 2001a and b) mention the ex post and ex ante alternatives but without substantive discussion as to which is preferable.

in Schreyer *et al*. (2005), who however leave unresolved the issue of the actual method to be employed. The hybrid approach advocated here can contribute to this debate. Not only can it be used to generate estimates of capital services and of capital's contribution to output growth, but it can also be used to estimate the return to each asset and these returns sum to capital compensation as the latter appears in the national accounts.

Plan of the paper

Section 2 estimates the average rate of return (the average rate across seven types of asset) for 10 branches comprising the market economy plus the whole market economy (see the list in Table 1), in 11 EU countries (Austria, Denmark, Finland, France, Germany, Italy, Netherlands, Portugal, Spain, Sweden and the UK) and three non-EU countries (Australia, Japan and the US) over the period 1971-2005 (see Table 2). We look to see whether the variations across branches and countries accord with our intuition. In section 3, we present estimates of the growth of capital services by two methods: ex post and ex ante. Also in section 3, we present estimates of the contribution of capital to output growth by three methods: ex post, ex ante, and hybrid. Section 4 concludes.

2. The average rate of return to capital in the EU KLEMS database

Theory

Our measure of the average nominal rate of return before tax, $\overline{r}_t$, in a particular industry or branch in a particular country in year *t* is:

(1)
$$\overline{r}_t = \frac{CAP_t - \sum_{j=1}^{m} D_{jt} + \sum_{j=1}^{m} CG_{jt}}{\text{Value of capital stocks}_{t\text{-}1}}$$

where CAP_t is capital compensation in year *t* (ie gross operating surplus adjusted for self-employment income),[2] D_{jt} is the depreciation cost on the stock of the *j*-th asset during *t* and CG_{jt} is the corresponding capital gain or loss during *t* ($j = 1,...,m$). That is, the average nominal rate of return is profit minus (true) depreciation costs and minus capital losses (or

[2] This is the EU KLEMS variable *cap* which is gross operating surplus plus the part of mixed income estimated to be a return to capital rather than to labour.

plus capital gains), all as a percentage of the value of assets at the beginning of the year. Here depreciation on asset *j* in year *t* is given by

$$D_{jt} = \delta_j (1 + \pi_{jt}) p_{j,t-1} A_{j,t-1} \tag{2}$$

and capital gain (loss) by

$$CG_{jt} = \pi_{jt} p_{j,t-1} A_{j,t-1} \tag{3}$$

where $A_{j,t-1}$ is the real stock of the *j*-th asset at the end of *t*-1, δ_j is the depreciation rate on the *j*-th asset, p_{jt} is the price of asset *j* in year *t*, and $\pi_{jt} = (p_{jt} - p_{j,t-1}) / p_{j,t-1}$ is the growth rate of the price of the *j*-th asset. The asset stocks are generated by the Perpetual Inventory Method (PIM):

$$A_{jt} = I_{jt} + (1 - \delta_j) A_{j,t-1} \tag{4}$$

where I_{jt} is real gross investment in asset *j* during year *t*.

To give more economic content to the concept of the average rate of return, we can make use of the Hall-Jorgenson cost of capital formula (Hall and Jorgenson, 1967; Jorgenson, 1989; OECD, 2001a; Schreyer, 2008). The true, ex-post user cost (rental price) of the *j*-th asset, q_{jt}^{true}, is:

$$q_{jt}^{true} = T_{jt} [r_{jt} + \delta_j (1 + \pi_{jt}) - \pi_{jt}] p_{j,t-1}, \quad j = 1,...,m \tag{5}$$

where T_{jt} is the tax factor, r_{jt} is the ex post, realised rate of return on the *j*-th asset. We call this the true, ex-post rate of return, to distinguish it from the ex-post rate as commonly estimated by researchers. The difference is that for the *true* rate, we do *not* assume that the nominal rate of return is necessarily the same for all assets: see below for more on this. By definition, since these are true, ex-post rates of return, profit must be the sum of the returns to each asset:

$$CAP_t = \sum_{j=1}^{m} q_{jt}^{true} A_{j,t-1} \tag{6}$$

In other words, the sum over user costs multiplied by the capital stocks adds up to capital compensation (profit). The previous equations then imply that:

$$\bar{r}_t = \frac{\sum_{j=1}^{m} (T_{jt} p_{j,t-1} A_{j,t-1}) r_{jt}}{\sum_{j=1}^{m} T_{jt} p_{j,t-1} A_{j,t-1}} \tag{7}$$

In other words, the average rate of return across all assets is a weighted average of the rates of return on the individual assets, where the weights are asset values (adjusted for tax).

In order to make our estimates of the rate of return comparable over time and also across countries, we examine *real* average rates of return, defined as:

$$\bar{\rho}_t = \bar{r}_t - \pi_t \tag{8}$$

where π_t is a measure of overall inflation; we use the GDP deflator for each country. All the data required to estimate the average rate of return (the right hand side of equation (1)) is available in the EU KLEMS database, with the exception of the tax terms (the T_{jt}).

The real rate of return to capital is a variable of fundamental interest in its own right, quite apart from its usefulness as a check on the coherence and consistency of the national accounts. In a well-functioning market economy we would expect differences between sectors or industries to reflect primarily differences in risk. Temporary differences might arise due to unexpected developments but these should disappear fairly quickly as capital flows towards areas where the return is high and away from areas where it is low. Alternatively, in less well-functioning market economies differences between sectors may reflect monopoly power. But for the EU countries studied here, which are all subject to the Single Market and to European (as well as domestic) competition authorities, this consideration seems likely to be of lesser importance and similarly for the three non-EU countries. Differences in the rate of return across countries may be more long-lasting if countries are initially at very different stages of development: poorer countries would be expected to have higher rates of return, ceteris paribus. But again this consideration seems unlikely to be very important for the countries studied here which are all at similar stages of development, except perhaps Portugal and Spain, particularly at the beginning of the period.

Before presenting the results, it is worth asking what might go wrong with the calculations. Firstly, the measurement of any element of equation (1) might be in error. Consider the elements of the right hand side of equation (1) which can be written out separately as:

$$\bar{r}_t = \frac{CAP_t}{\sum_{j=1}^{m} T_{jt} p_{j,t-1} A_{j,t-1}} - \frac{\sum_{j=1}^{m} T_{jt} p_{j,t-1} A_{j,t-1} \delta_j (1+\pi_{jt})}{\sum_{j=1}^{m} T_{jt} p_{j,t-1} A_{j,t-1}} + \frac{\sum_{j=1}^{m} T_{jt} p_{j,t-1} A_{j,t-1} \pi_{jt}}{\sum_{j=1}^{m} T_{jt} p_{j,t-1} A_{j,t-1}}$$

The first element is the ratio of profit to the (tax-adjusted) value of assets. The second element is an asset-weighted average of depreciation rates and the third is an asset-weighted average of capital gains rates. The second and third elements will be in error if the asset *mix* is incorrect, but will not be affected by an error in the overall *level* of assets. The latter type of error could however affect the first element. *CAP* comes fairly directly from gross operating surplus in the national accounts (though with the addition of the profit income of the self-employed). The asset stocks depend on cumulating real investment, which is nominal investment deflated by a price index. While aggregate real investment by asset might be accurate, there is often less certainty about the allocation of investment to individual industries or sectors and this is often done in a rather mechanical way. The stocks also depend on depreciation rates which are assumed rather than observed. If the depreciation rate is too high, the estimated stock will be too low. The tax factors are not present in the database so in the results reported below we had to set each of them equal to 1.[3]

Secondly, and possible more importantly, equation (1) assumes that we have not omitted any assets. In fact in EU KLEMS all profits are assumed to be generated by fixed reproducible capital: buildings, machinery, vehicles, computers, software and the other intangibles included in the current SNA. Inventories are not counted as part of the EU KLEMS capital stock. Also land and other natural resources are omitted and the importance of these no doubt varies across industries and countries. R&D capital is also omitted since the current SNA does not count expenditure on R&D as investment (though this is likely to change when the new SNA is introduced). And the many other types of intangible assets to which the work of Corrado *et al.* (2006) has drawn our attention are also omitted. Clearly, if assets are wrongly omitted, then the rate of return may be overstated. This will definitely be the case for inventories and land since the return to these is already implicitly included in measured profit (the *cap* variable) and expenditure on these assets is counted as investment. The effect on the rate of return of omitted assets like intangibles is less clear since here profits are understated too (by the amount of gross investment in these assets).

The data

We employed the March 2008 version of the EU KLEMS database to estimate the average real rate of return for 10 branches plus the total, which we call the market economy, for each of 14 countries, using equations (1) and (8). The ten branches are listed and defined in Table 2. They comprise branches A-K, but with industry 70 (real estate) excluded from K. Of the 14 countries, 11 are within the EU — Austria, Denmark, Finland, France, Germany, Italy, Netherlands, Portugal, Spain, Sweden, and the UK — and three are outside the EU —

[3] Erumban (2008) finds that including tax factors makes very little difference to the estimates of the growth rates of capital services and of capital's contribution. This is of course not the same as saying that tax makes no difference to investment decisions.

Australia, Japan and the US: see Table 2. (Data for other EU countries is also available in EU KLEMS, eg for Ireland and some of the recent accession countries, but only from 1995 onwards). We have data on the following eight types of capital (with the EU KLEMS code in brackets):[4]

1. Computing equipment (IT)
2. Communications equipment (CT)
3. Software (Soft)
4. Transport equipment (TraEq)
5. Other machinery and equipment (OMach)
6. Non-residential structures (OCon)
7. Other assets (Other)
8. Residential structures (RStruc)

We exclude residential structures since these assets are very largely owned by households and income generated by them accrues to the omitted industry 70 (real estate). So there are seven asset types to be considered. As mentioned above, we use the EU KLEMS variable *cap* for profit (gross operating surplus *less* the part of mixed income estimated to be labour income) and we set the tax factors (T_{jt}) equal to one. We do this not because we think tax is unimportant but because unfortunately EU KLEMS does not contain any data on tax rates. The depreciation charges are calculated using the EU KLEMS assumptions about depreciation rates and the EU KLEMS asset prices. The capital gains terms are calculated using these same deflators. The inflation rate is the rate of growth of the implicit deflator for GDP.

The data on nominal and real investment, asset prices and depreciation rates come from the capital files of the EU KLEMS database. We estimate capital stocks using the perpetual inventory method of equation (4), which replicates the method used in EU KLEMS. Depreciation rates differ by asset type and industry but not over country and also not over

[4] An important feature of EU KLEMS is that it harmonises the treatment of ICT assets (computers, communications equipment, and software) across countries. Some EU countries, eg France, Germany, Netherlands, Slovenia, Sweden and the UK, already use hedonic methods in their computer price indices. Others, eg Australia, employ the US deflators adjusted for exchange rate movements. For other countries that do not fully adjust for quality in their ICT deflators, EU KLEMS uses the method suggested by Schreyer (2002) to harmonise price indices.

time. They are based on the industry-by-asset-type depreciation rates from the BEA (USA Bureau of Economic Analysis). Other variables such as value added and capital compensation (*cap*) are taken from the EU KLEMS output files.

The current (March 2008) version of EU KLEMS starts in 1970 and finishes in 2005. However, investment data are not available for the whole time span for every country (eg Germany, Portugal and Sweden). Since estimating the real rate of return involves a lagged value, the maximum time span is 1971-2005.

The results

The time path of the real rate of return in the market economy in each country appears in Chart 1.[5] For Portugal and Sweden the time series is too short to draw any conclusions. In the case of Finland, Austria and Australia, eyeballing the data suggests a rise in the real rate since the mid-1990s. In Japan the real rate fell in the 1990s. For all other countries visual inspection suggests that the real rate is stationary. We can formally test for stationarity by fitting an AR model and checking whether the residuals are white noise, using Bartlett's test and the Ljung-Box test. Stationarity cannot be rejected if the residuals of the model are white noise. The results are not entirely in accordance with visual inspection. When an AR(1) model is fitted, then according to the Ljung-Box test at the 5% level, we cannot reject the hypothesis that the residuals are white noise in 12 out of 14 cases; the only exceptions are Austria and France. According to Bartlett's test we cannot reject the hypothesis of white noise for any country. When an AR(2) model is fitted, the results are similar: on Bartlett's test, we cannot reject in any case while on the Ljung-Box test we can reject only in the cases of France and Netherlands. Perhaps rejection in these cases results from the saw tooth character of the series in the earlier years. In other cases where there is an apparent upward or downward trend (Finland, Australia and Japan), the AR model suggests that this is an illusion, ie it could arise purely by chance. All in all, these results give some justification for focussing on the mean real rate of return, at least for the market economy, since there is little evidence of any trend.

The mean real rate of each branch in each country appears in Chart 2. Spain has the highest mean real rate in the market economy as a whole (15.9%), followed by the US at 13.3% and Portugal and Japan close together at 11.6% and 11.5% respectively. Italy has the

[5] The corresponding nominal rates of return are in most cases very close to the EU KLEMS variable *irr* in the capital files.

lowest rate, 2.4%. The others have rates which lie between 7% and 10%. All these rates are all undoubtedly too high, given the omission of land and inventories from the list of assets. But they are not obviously unreasonable. But many of the rates in individual branches seem implausibly high or low. For example, the real rate in Financial intermediation (branch J) is very high in most countries: a real rate of over 30% (when averaged over more than 30 years) is hard to believe. The real rate in Mining (branch C, which includes offshore oil and gas) in the Netherlands (61.0%) is also very implausible.

Is there an economic rationale to the real rates of return? We can do a simple descriptive analysis by taking the annual rates of return for each industry and each country in each year and estimating a dummy variable model. We use T-1 year dummies where T = 35 for most countries, the number of years over 1971-2005, N-1 dummies for the branches, where N = 11 (10 branches plus the whole market economy), and R-1 dummies for the countries, where R = 14. We also include country-branch interaction dummies, in number $(N-1)(R-1)=130$ here. The economic rationale for this can be illustrated by considering the effect of excluding land from the list of assets. This tends to raise the rate of return to the included assets, but it does so by more in land-intensive industries and also in countries where land is scarce and its price is high: an interaction dummy is needed to pick up this type of effect. When only time, country and branch dummies are included the regression "explains" 30.6% of the variance of rates of return. When branch-country interaction dummies are also included, the proportion "explained" rises to 60.4%. In this fuller model, six out of ten branch dummies are significant at the 5% level or better, as are all the country dummies and 68 out of 130 branch-country interaction dummies. Finally, we can also include branch-year and country-year interaction dummies. The former allow for common cross-county effects in particular branches, the latter allow countries to have different time patterns of the rate of return. When these are included, R^2 rises to 0.709.

We would expect that in market economies capital would flow preferentially to areas where the return is higher. We can test this hypothesis by seeing whether the growth rate of capital services is positively correlated with the real rate of return. More specifically, we regress the growth rate of capital services[6] on the real rate of return, and three sets of dummy variables for year, country and branch. The coefficient on the real rate is 0.0262, with standard error of 0.0037 (R^2 =0.41 and the number of observations is 4235). In other words, a

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6 The growth rate of capital services is measured by the ex ante method: see the next section.

rise of 1 percentage point in the real rate of return raises the growth rate of capital services by 0.02 percentage points per annum and this effect is highly significant, in accordance with economic intuition.

Finally, we can ask whether the real rates of return at the market economy level reveal any obvious pattern across countries. If we think of the rate of return as primarily endogenous, then we would expect it to be negatively related to the level of economic development, as measured by GDP per capita at PPP exchange rates. On the other hand, we might think of the rate of return as primarily policy-determined. Then we might expect that GDP would grow faster in countries where the rate of return is higher. These two simple relationships are plotted in Charts 3 and 4. Neither receives much support in our data which admittedly is for only 14 countries.

Although we can explain a reasonably high proportion of the total variation by the dummy variable model, it is not clear how much of even the explained variation can be attributed to genuine economic differences between countries and branches and how much is measurement error. On a generous interpretation, only at most the 29% of the total variance which we have failed to "explain" is measurement error. But some of the "explained" variance may be measurement error too since this may also be country- and branch-specific. As we discussed above, possible sources of measurement error, apart from omitted assets, are (a) incorrect allocation of aggregate investment between branches, leading to estimated capital stocks being systematically too high or too low in some branches; (b) differences in tax rates (since it is after-tax rates, not pre-tax rates, which markets would tend to equalise; and (c) depreciation rates which differ across industries (in EU KLEMS they are largely assumed constant across industries, though differing across assets). In a few countries (eg the Netherlands), there is genuine data about depreciation rates in different industries and this could be applied to test the sensitivity of the rate of return estimates. Further enquiries amongst statistical agencies as to how reliable is the allocation of aggregate investment to industries might also be fruitful. All this however is beyond the scope of the present paper.

It seems likely then that measurement error affects our estimates of the rates of return at the branch level, though probably to a less significant extent at the market economy level. If so, this should not be taken as a criticism of the EU KLEMS database but rather as revealing potential problems in the underlying data supplied by national statistical agencies. Taken in a positive spirit, the analysis above points to areas where there is room for improvement in national data. We speculate that the most likely area for improvement is the allocation of aggregate investment across branches.

3. Alternative measures of capital input growth and capital's contribution

Theory

In this section we intend to test the sensitivity of the capital input estimates to the method employed. Following the analysis in Oulton (2007), we will employ two methods to estimate the growth rate of capital services — ex-post and ex-ante, and three methods to measure the contribution of capital to the growth of output — ex-post, ex-ante, and hybrid. A schematic comparison of the three methods is in Table 3.

The ex-post method is the one that has been most commonly employed by researchers. The ex-post user cost is defined by

(9) $$q_{jt}^{ex\,post} = T_{jt}[r_t + \delta_j(1+\pi_{jt}) - \pi_{jt}]p_{j,t-1}, \quad j = 1,...,m$$

Though it appears similar to equation (5), equation (9) is in fact fundamentally different since it assumes that the nominal rate of return is the same for all assets (r_t appears in (9), not r_{jt}). This common nominal rate can be estimated from the right hand side of equation (1) but now the interpretation is different: the result is interpreted as the common rate of return, not (as in the previous section) as the weighted average rate of return. Also, the growth rates of asset prices in (9) are the actual rates, not the expected ones.

Theory however suggests that firms must take investment decisions in the absence of full information about the outcomes. They are therefore guided by the *required* rate of return and the *expected* growth rates of asset prices, ie they make their investment decisions in the light of ex-ante, not ex-post, user costs. As shown in Oulton (2007), the actual, ex-post rate of return will generally differ across assets even though ex ante firms try to equalise it. The ex-post rates of return will only equal the required rate in full equilibrium, when all expectations about prices and the level of demand are realised. The ex-ante user cost can be written as:

(10) $$q_{jt}^{ex\,ante} = T_{jt}[r_t^* + \delta_j(1+E_{t-1}(\pi_{jt})) - E_{t-1}(\pi_{jt})]p_{j,t-1}, \quad j = 1,...,m$$

Here r_t^* is the required, nominal rate of return and E_{t-1} is the expectation as of time *t*-1. Now writing the required, *real* rate as $\rho_t^* = r_t^* - E_{t-1}(\pi_t)$, equation (10) becomes:

(11) $$q_{jt}^{ex\,ante} = T_{jt}[(\rho_t^* + \delta_j(1+E_{t-1}[\pi_{jt}]) - E_{t-1}(\pi_{jt} - \pi_t)]p_{j,t-1}, \; j = 1,...,m$$

(This assumes that the growth of the relative price of the *j*-th asset, $E_{t-1}(\pi_{jt} - \pi_t)$, is independent of the overall inflation rate). Employing a model of temporary equilibrium, in which investment decisions have to be made in advance of the all facts being known but labour input can be varied after the event, Oulton (2007) shows that in calculating the growth rate of capital services, we should weight the individual asset growth rates by the *true*, ex-post user costs as given by (5), not those given by (9); see also Berndt and Fuss (1986) and Berndt (1990). We cannot directly observe the true, ex-post user costs. But under the assumption that the production function is CES, the ex ante user costs as given by (11) are proportional to the true, ex-post user costs (given by (5)). The ex-ante user costs will not in general be equal to the true, ex post ones, but they will each differ from the latter by a common proportional factor (λ_t).[7] That is to say,

(12) $$q_{jt}^{true} = \lambda_t q_{jt}^{ex\,ante}, \ \lambda_t > 0$$

So we can validly use ex-ante user costs as weights in the capital services index, provided of course that we can find good empirical measures for the expectations and for the required real rate. Since λ is the same for all assets, we can find it as the ratio of ex post, actual profit to ex-ante profit:

(13) $$\frac{CAP_t}{\sum_{j=1}^{m} q_{jt}^{ex\,ante} A_{j,t-1}} = \frac{\sum_{j=1}^{m} q_{jt}^{true} A_{j,t-1}}{\sum_{j=1}^{m} q_{jt}^{ex\,ante} A_{j,t-1}} = \frac{\lambda_t \sum_{j=1}^{m} q_{jt}^{ex\,ante} A_{j,t-1}}{\sum_{j=1}^{m} q_{jt}^{ex\,ante} A_{j,t-1}} = \lambda_t$$

making use of (6) and (12). From the national accounts perspective we can use these last two equations to break down capital compensation into the returns to each asset. For example the return to the *j*-th asset is

(14) $$q_{jt}^{true} A_{j,t-1} = \lambda_t q_{jt}^{ex\,ante} A_{j,t-1} = \left[\frac{CAP_t}{\sum_{j=1}^{m} q_{jt}^{ex\,ante} A_{j,t-1}} \right] q_{jt}^{ex\,ante} A_{j,t-1}$$

and of course the sum of these returns equals actual capital compensation.

To measure the contribution of capital to the growth of output, the ex-post method weights the growth rate of capital services by the actual share of profit in output. The ex-ante method uses the ex ante profit share as the weight, ie the total of the ex ante returns to capital as a share of output. The hybrid method calculates the capital services index using ex-ante user costs but then calculates the contribution of capital using actual (ex-post) profit as the

7 Oulton (2007) suggests that this will remain approximately true when the production function is not CES, eg if it is translog.

weight. The hybrid method was the one recommended by Oulton (2007), on the ground that ex-post profit measures the marginal product of capital.

Ex-post method: results

Before turning to the results, a general comment about measurement error is in order. We have argued above that a likely reason is that the asset stocks are systematically too high or too low in some branches. Even if this is correct, the growth rates of these stocks, which are what we are concerned with in the present section, are much less likely to be affected. Also, provided that the growth paths of the stocks are fairly smooth, the growth rates of the stocks will be insensitive to any errors in the estimated depreciation rates.

We start by checking the number of negative rental prices that are obtained under the ex-post method, since this is an important diagnostic check. We obtain 746, out of a possible total of 27,930 rental prices. So 2.6% of the rental prices are negative.[8] Tables 4 and 5 show the distribution of these negative rental prices by branch, asset and country. They are found disproportionately in service sectors such as Transport and communications and Financial intermediation. As others have found too, negative rental prices are concentrated in the Non-residential construction asset: 414 out of 746. Mathematically this is likely to be the case since the depreciation rate for buildings is low. We can also see that the number of negative rental prices is low in Spain, Sweden, Japan and USA, but particularly high in Finland.

Taken literally, a negative rental price means that the marginal product of the asset was negative in that period. This is impossible with the type of production or cost function commonly assumed (eg translog or CES). More important, it is inconsistent with the underlying theory: why would firms tolerate a negative marginal product when they could reduce their holding of the asset till the marginal product was positive? One answer is that reducing an asset stock cannot be done costlessly within the period. If so, this also indicates a problem with the theory underlying the method which assumes that such adjustments can be made.

The normal response of researchers when they encounter negative rental prices is to smooth them away. This is necessary since negative weights mean that index numbers of capital services like the Törnqvist or Fisher cannot be calculated. This response is understandable, but does not deal with the theoretical problem. We follow the normal

[8] Erumban (2008) reports a similar result.

approach here since otherwise the ex-post method cannot be implemented. But it is important to understand that any comparison between ex-post and ex-ante methods is after negative rental prices have been removed.

Growth rates of capital services: ex-post and ex-ante methods compared

To make the ex-ante method operational, we have to find empirical counterparts for the required rate of return and for the expected growth of prices. Our strategy is to use our estimates of the mean real rate of return as our estimate of the required rate of return (ie the real rate averaged both across assets and over time). The argument here is that in a market economy the realised rate of return will tend to be driven to equality with the required rate by entry and exit of firms. In principle, the required rate of return can vary across industries, due to differences in risk. But as we have just seen the variation of the real rate across branches is implausibly large. We therefore employed the time mean of the average real rate of return in the market economy as a whole as our estimate of the required real rate.[9] So our estimate of the required rate is constant over time but varies across countries. The expected growth rate of the GDP deflator and of relative asset prices were taken from the predictions of AR models of these variables. With this way of implementing the ex-ante method, we found that all rental prices are positive.

Contribution of capital services to output growth: ex-post, ex-ante and hybrid methods compared

The contribution of capital to the growth rate of output is the share of capital multiplied by the growth rate of capital services. Each of these two elements could be measured ex ante or ex post. Oulton (2007) argues that, in the growth rate accounting context, what he called there the hybrid method is the one supported by economic theory: use the ex-ante method to estimate the growth rate of capital services, but use ex-post profit as the weight. Here we see how much difference there is in practice between the three different methods.

[9] An alternative might have been to use the predictions from our AR model of the rate of return as the estimate of the required rate. We judge however that variations in the observed real rate over time reflect a lagged adjustment of the actual to the required rate, rather than changes in the required rate itself.

Estimates of capital's contribution to output growth appear in Table 6. At the market economy level (the bottom right hand panel of the table), the difference between the three methods is fairly small. Once again however the differences at the branch level are much larger, particularly between the ex-post and ex-ante methods. Table 7 (derived from Table 6) shows, for each branch, the number of countries for which the difference between the ex-ante and the ex-post methods on the one hand, and the hybrid and the ex-post methods on the other, exceeds 0.5 percentage points per annum. Out of (11x14 =) 154 possible cases, there are 56 cases where there is such a difference for the ex-ante method, but only 7 cases, all in branch J (Financial intermediation), for the hybrid method. Interestingly, there are no cases in branch D (Manufacturing).[10]

4. Conclusions

We have employed the EU KLEMS database to estimate the real rate of return to capital in 14 countries (11 in the EU, three outside the EU) in 10 branches of the market economy plus the market economy as a whole. Our measure of capital is an aggregate over seven types of asset: three ICT assets and four non-ICT assets. The real rate of return in the market economy (averaged across the seven assets) does not vary very much across countries, although the rate in Spain is exceptionally high and in Italy is exceptionally low. The real rate appears to be trendless in most countries. Within each country, the rate varies widely across the 10 branches, often being implausibly high or low. We have suggested that the most likely reason for this is that asset stocks are systematically too high or too low in some branches. And we suggest (tentatively) that the reason for this is that aggregate investment in each asset has not been correctly allocated across branches by some national statistical agencies.

[10] Erumban (2008) and Inklaar (2008) have also analysed the sensitivity of estimates of capital services growth and of capital's contribution to the method employed. Erumban's data is for four EU countries (France, Germany, Netherlands, and the U.K.) plus the U.S., for 26 industry groups over 1979-2003. Inklaar's data is for 30 industries in the U.S. only over 1977-2005 (this does allow him however to consider the effect of including a wider set of assets, eg land and inventories). Both authors produce estimates for a combination of ex ante and ex post measures of the rate of return, but neither uses econometric methods to estimate ex ante rates as here. Their ex ante measures do not produce measures of the returns to capital which sum to the observed profit total (or *CAP*), unlike the hybrid estimates of the present paper.

We also estimate the growth of capital services by two different methods: ex-post and ex-ante, and the contribution of capital to output growth by three methods: ex-post, ex-ante and hybrid (the latter being the preferred method). Our implementation of the ex-ante method uses an estimate of the *required* rate of return for each country (instead of the actual, average rate of return) to calculate user costs and also employs the *expected* growth of asset prices rather than the *actual* growth. These estimates are derived from exactly the same data as for the ex-post method, ie without any extraneous data being employed. For estimating the contribution of capital to output growth, the ex-ante method uses ex-ante profit as the weight, while both the ex-post and the hybrid method use ex-post profit. The three methods produce very similar results at the market economy level. But differences are much larger at the branch level, particularly between the ex-post and ex-ante methods.

These results suggest that use of the ex-post method (the commonest method in practice) to estimate capital's contribution can be justified at the aggregate level, but may produce somewhat different results from the preferred (hybrid) method at the branch level. The ex ante method should be avoided at the branch level. Finally, more research is needed to pin down the reasons for implausible estimates of the rate of return at the branch level.

Table 1
Branches of the market economy used in the analysis

	Name	*EU KLEMS Code*
1	Agriculture, hunting, forestry & fishing	AtB
2	Mining & quarrying	C
3	Manufacturing	D
4	Electricity, gas & water	E
5	Construction	F
6	Wholesale & retail trade	G
7	Hotels & restaurants	H
8	Transport & storage & communication	I
9	Financial intermediation	J
10	Renting of machinery and equipment and other business activities (exc. industry 70)	K
11	Market economy (sum of above)	MKT

Note The excluded industry 70 is real estate which includes the imputed rental income of owner-occupiers. The other excluded branches are L-Q which relate to activities largely carried out by government or by nonprofit organisations (health, education, social security, defence and public administration, and cultural activities) and are therefore excluded from our definition of the market economy.

Table 2
Countries used in the analysis

	Name	*EU KLEMS code*
EU countries		
1	Austria	AUT
2	Denmark	DNK
3	Finland	FIN
4	France	FRA
5	Germany	GER
6	Italy	ITA
7	Netherlands	NLD
8	Spain	ESP
9	Sweden	SWE
10	Portugal	PRT
11	UK	GBR
Non-EU countries		
12	Australia	AUS
13	Japan	JPN
14	US	USA

Table 3
Comparison of methods of estimating capital services and the contribution of capital

Method	*Rate of return*	*Prices*	*Weights in capital services index*	*Weight for contribution of capital*
Ex post	Ex post, same for all assets; differs across industries. Solved for by assuming that the rate of return is equalised across assets ex post.	Actual	Returns to assets estimated using common, *ex-post* rate of return and actual prices; returns sum to actual, observed CAP.	Observed CAP
Ex ante	The *required* rate of return, same for all assets. Here, taken to be time mean of average rate of return in market sector.	Forecast by ARMA model	Returns to assets estimated using *ex-ante* rate of return and *predicted* prices; returns do *not* sum to observed CAP, but instead to *expected* CAP.	Expected CAP
Hybrid	Same as ex ante.	Forecast by ARMA model	Same as ex ante, except that returns may be grossed up so that they sum to observed CAP.	Observed CAP

Note: see Oulton (2007) for fuller explanation. CAP: EU KLEMS variable, defined as gross operating surplus *plus* the part of mixed income estimated to be a return to capital rather than labour.

Table 4
Number of negative rental prices under the ex-post method, by country and branch

	AtB	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*K*	*TOTAL*
EU											
Austria	0	0	0	0	0	0	0	15	4	0	19
Denmark	0	0	5	26	6	3	4	20	27	0	91
Finland	1	4	7	15	11	20	9	47	66	0	180
France	0	0	3	0	3	0	0	33	18	2	59
Germany	0	0	0	15	10	10	2	26	21	8	92
Italy	0	0	0	8	0	8	5	24	37	11	93
Netherlands	0	0	0	0	0	0	0	17	13	0	30
Spain	0	0	1	0	8	5	0	11	7	0	32
Sweden	0	0	0	2	0	2	1	2	6	2	15
Portugal	3	0	0	1	0	0	0	5	3	0	12
UK	0	4	6	8	4	5	1	19	13	0	60
Non-EU											
Australia	0	3	2	4	7	1	1	24	5	0	47
Japan	0	0	0	0	0	1	1	3	4	2	11
US	0	0	0	1	0	0	0	2	2	0	5
TOTAL	4	11	24	80	49	55	24	248	226	25	746

Table 5
Number of negative rental prices under the ex-post method, by country and asset

	IT	*ISOF*	*CT*	*OMACH*	*TRAEQ*	*OCON*	*OTHER*	*TOTAL*
EU								
Austria	0	0	0	0	0	18	1	19
Denmark	0	1	32	6	5	36	11	91
Finland	1	9	22	24	18	96	10	180
France	0	0	3	3	0	45	8	59
Germany	0	0	15	16	6	40	15	92
Italy	0	0	8	8	5	61	11	93
Netherlands	0	0	0	0	0	26	4	30
Spain	0	0	1	8	5	11	7	32
Sweden	0	0	2	2	1	8	2	15
Portugal	3	0	1	0	0	8	0	12
UK	0	9	10	4	7	30	0	60
Non-EU								
Australia	0	3	6	7	2	26	3	47
Japan	0	0	0	1	1	7	2	11
US	0	0	1	0	0	2	2	5
TOTAL	4	22	101	79	50	414	76	746

Table 6
Mean contribution of capital to the growth of output, by branch and country, 1971-2005: ex-post, ex-ante and hybrid methods compared (percentage points per annum)

Country	*Branch*	*Ex-post*	*Ex-ante*	*Hybrid*	*Branch*	*Ex-post*	*Ex-ante*	*Hybrid*
Austria	AtB	0.07	0.08	0.07	E	0.58	0.77	0.50
Denmark	AtB	0.20	0.25	0.21	E	3.05	3.32	3.05
Finland	AtB	0.31	0.64	0.40	E	2.75	2.68	2.67
France	AtB	0.17	0.96	0.09	E	2.19	3.39	1.86
Germany	AtB	0.23	0.94	0.23	E	0.86	1.41	0.78
Italy	AtB	0.58	0.57	0.57	E	1.93	4.30	1.95
Netherlands	AtB	0.22	0.27	0.23	E	0.94	0.99	0.93
Spain	AtB	0.27	0.62	0.26	E	1.80	1.99	1.89
Sweden	AtB	0.30	0.67	0.24	E	1.00	1.05	0.95
Portugal	AtB	-0.57	0.92	-0.41	E	4.72	3.39	4.73
UK	AtB	0.24	-0.64	0.09	E	1.18	1.64	1.21
Australia	AtB	0.57	0.61	0.53	E	1.70	2.23	1.54
Japan	AtB	0.55	1.99	0.77	E	3.50	6.35	3.59
US	AtB	-0.15	-0.21	-0.16	E	1.53	1.97	1.45
Austria	C	-0.37	-0.53	-0.35	F	0.18	0.13	0.18
Denmark	C	5.81	4.21	5.67	F	0.19	0.29	0.17
Finland	C	1.07	1.19	1.04	F	0.18	0.20	0.20
France	C	0.63	0.30	0.70	F	0.95	0.30	1.08
Germany	C	2.81	0.75	3.13	F	0.36	0.31	0.37
Italy	C	0.37	1.36	0.52	F	1.10	0.65	1.12
Netherlands	C	2.44	2.51	2.68	F	0.46	0.17	0.45
Spain	C	1.50	0.65	1.67	F	1.32	0.44	1.33
Sweden	C	1.28	1.55	1.26	F	0.28	0.64	0.24
Portugal	C	-0.31	-0.45	-0.07	F	0.68	0.53	0.70
UK	C	0.60	-1.90	0.53	F	0.05	-0.06	0.04
Australia	C	3.16	2.25	3.06	F	0.75	0.50	0.85
Japan	C	-0.12	-0.23	-0.12	F	0.42	0.13	0.37
US	C	1.11	1.76	1.04	F	0.41	0.32	0.42
Austria	D	0.58	0.58	0.58	G	1.02	0.62	1.23
Denmark	D	0.89	0.82	0.91	G	1.10	0.95	1.31
Finland	D	1.17	0.97	1.23	G	0.89	0.75	0.94
France	D	0.98	0.80	1.01	G	0.37	0.53	0.40
Germany	D	0.70	0.69	0.69	G	0.77	0.77	0.80
Italy	D	1.19	1.18	1.18	G	2.00	1.63	2.00
Netherlands	D	0.46	0.41	0.44	G	1.55	1.31	1.63
Spain	D	1.15	0.87	1.19	G	0.94	0.50	1.06
Sweden	D	1.94	1.63	1.99	G	1.52	1.59	1.48
Portugal	D	1.17	1.39	1.18	G	2.17	1.31	2.27
UK	D	0.32	0.36	0.32	G	0.59	0.57	0.59
Australia	D	0.95	0.77	1.01	G	1.08	0.86	1.15
Japan	D	1.60	1.21	1.63	G	1.01	0.85	1.02
US	D	0.81	0.72	0.85	G	1.34	1.14	1.41

Table 6, continued

Country	*Branch*	*Ex-post*	*Ex-ante*	*Hybrid*	*Branch*	*Ex-post*	*Ex-ante*	*Hybrid*
Austria	H	0.49	0.63	0.49	K	2.12	2.32	1.97
Denmark	H	1.67	2.00	1.40	K	2.46	2.60	2.20
Finland	H	-0.23	0.44	-0.04	K	0.56	1.18	0.70
France	H	0.20	0.98	0.22	K	1.22	1.20	1.21
Germany	H	0.46	0.53	0.44	K	1.24	1.48	1.12
Italy	H	1.19	0.85	1.23	K	3.18	2.00	3.17
Netherlands	H	1.48	0.98	1.77	K	2.76	2.17	3.23
Spain	H	-0.18	0.63	0.05	K	1.25	2.43	1.04
Sweden	H	0.36	0.59	0.35	K	2.86	2.63	2.84
Portugal	H	2.00	0.85	2.15	K	5.21	3.64	5.63
UK	H	-0.66	0.29	-0.24	K	4.28	2.28	4.60
Australia	H	1.13	1.57	1.12	K	1.89	1.56	1.89
Japan	H	1.59	1.88	1.48	K	4.31	4.51	4.29
US	H	0.87	0.95	0.86	K	2.34	1.69	2.58
Austria	I	1.43	2.29	1.32				
Denmark	I	1.62	2.47	1.46				
Finland	I	1.62	2.02	1.50				
France	I	1.19	1.45	1.14				
Germany	I	1.26	1.86	1.18				
Italy	I	2.63	3.94	2.54				
Netherlands	I	1.25	2.08	0.98				
Spain	I	0.99	1.57	0.94				
Sweden	I	2.78	3.69	2.44				
Portugal	I	2.91	5.02	2.65				
UK	I	1.08	1.65	0.99				
Australia	I	1.65	2.26	1.44				
Japan	I	1.37	3.44	1.32				
US	I	1.75	2.69	1.52				
Austria	J	1.79	1.05	2.25	MKT	0.88	0.88	0.87
Denmark	J	1.56	1.20	2.94	MKT	1.31	1.28	1.28
Finland	J	0.97	1.57	1.74	MKT	1.04	1.03	1.01
France	J	1.59	0.92	2.42	MKT	0.92	0.91	0.92
Germany	J	2.58	1.90	3.10	MKT	1.02	1.02	1.02
Italy	J	2.23	1.57	2.46	MKT	1.53	1.52	1.53
Netherlands	J	2.66	2.06	2.57	MKT	1.13	1.10	1.11
Spain	J	1.50	1.19	1.84	MKT	1.00	0.98	0.98
Sweden	J	2.98	1.46	4.41	MKT	1.83	1.81	1.83
Portugal	J	3.52	1.64	3.38	MKT	1.87	1.86	1.88
UK	J	1.04	0.85	1.21	MKT	0.84	0.84	0.84
Australia	J	2.83	2.02	3.32	MKT	1.30	1.27	1.30
Japan	J	2.17	0.83	2.79	MKT	1.62	1.58	1.61
US	J	4.92	2.90	5.50	MKT	1.31	1.30	1.31

Table 7
Number of countries where the absolute difference between methods in estimates of capital's contribution exceeds 0.5 percentage points per annum, by branch

Branch	*Ex-ante versus ex-post*	*Hybrid versus ex-post*
AtB	5	0
C	7	0
D	0	0
E	6	0
F	2	0
G	1	0
H	5	0
I	12	0
J	11	7
K	7	0
MKT	0	0
Total	56	7

Note: derived from Table 6.

Chart 1
Real rates of return in the market economy

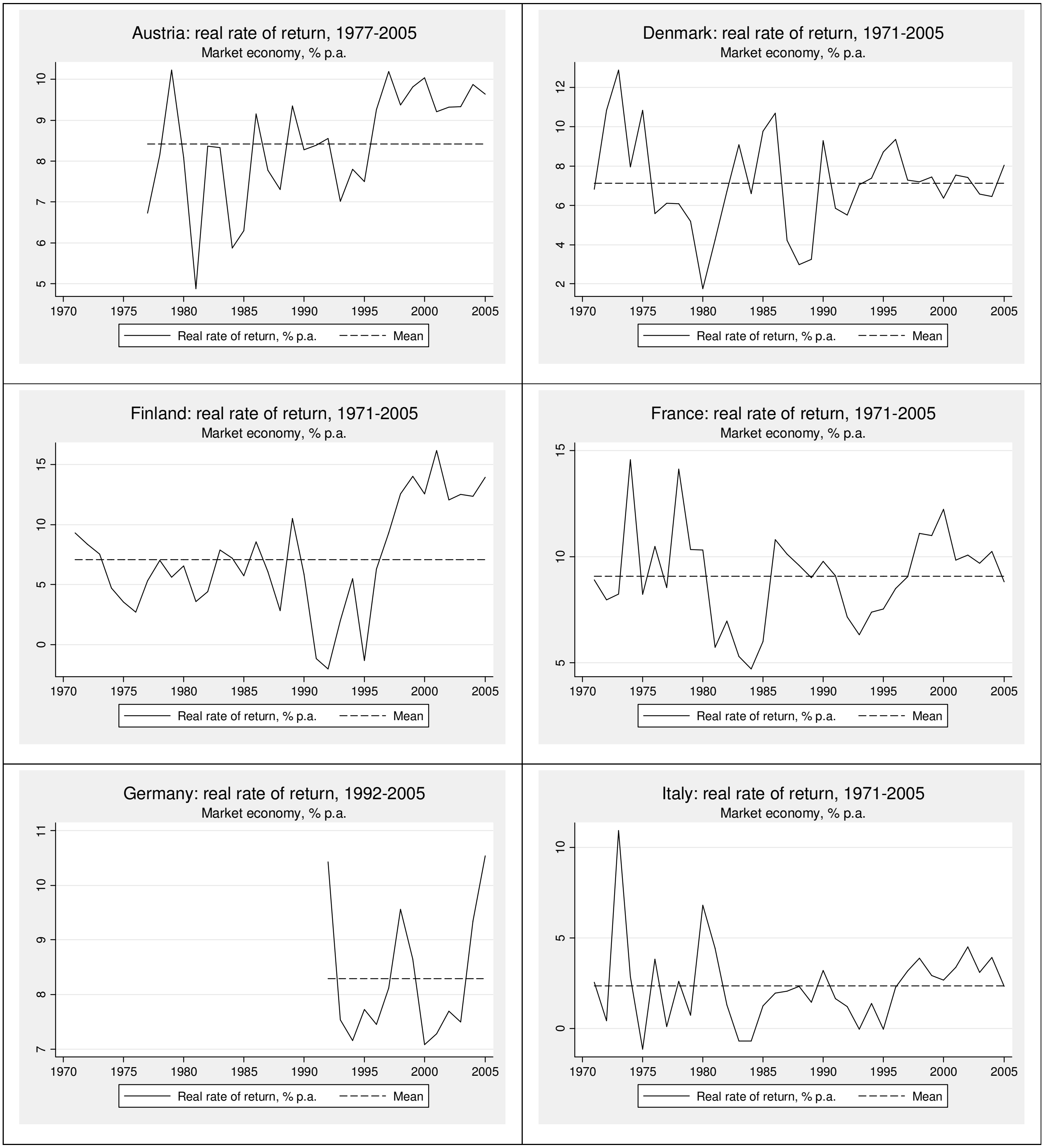


Chart 1, continued

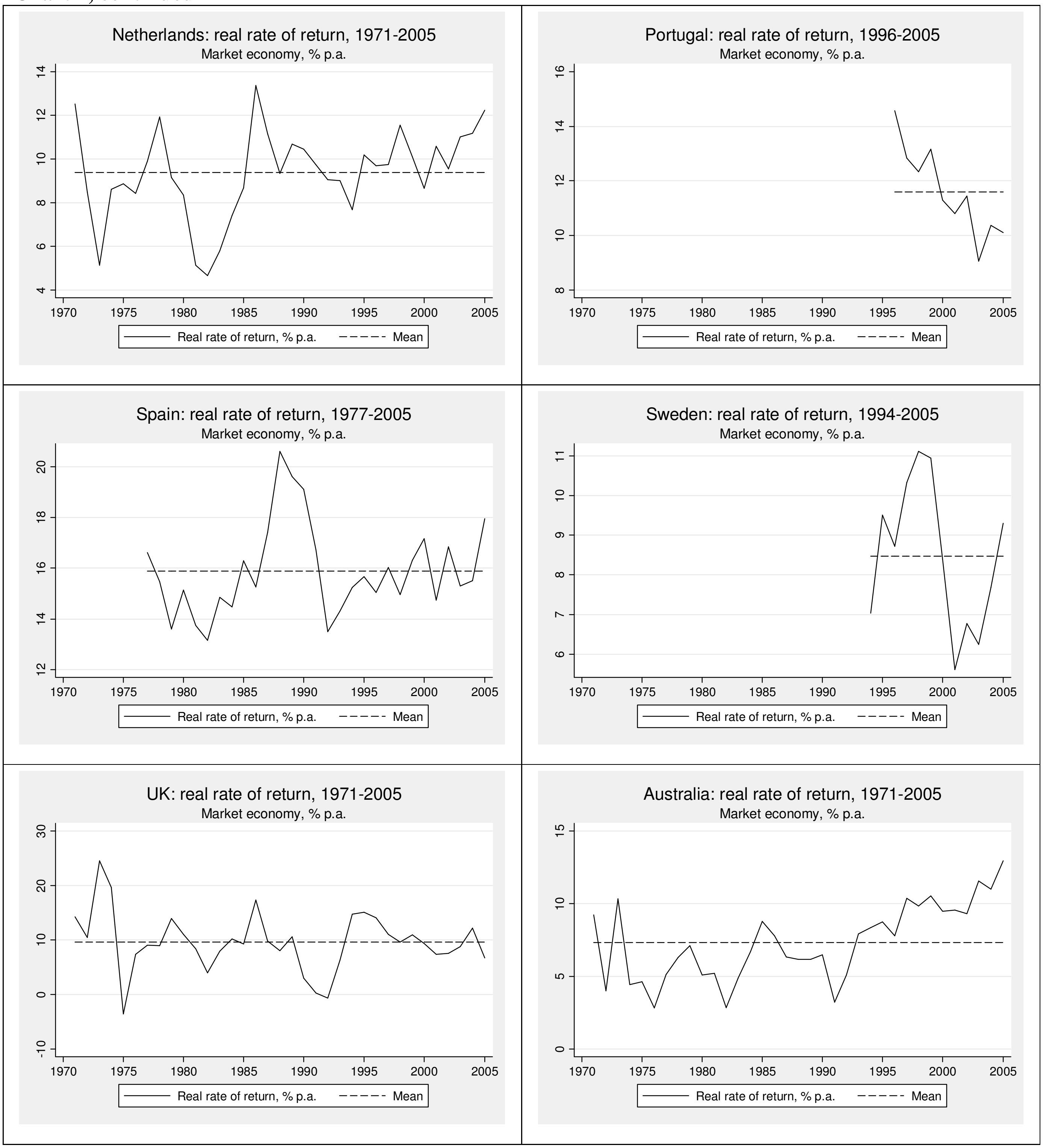
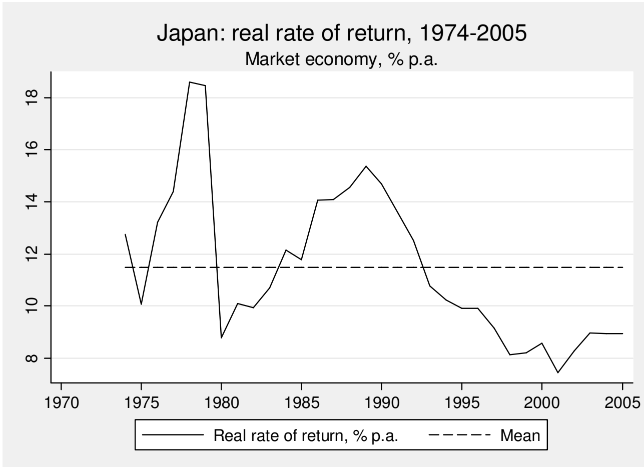


Chart 1, continued



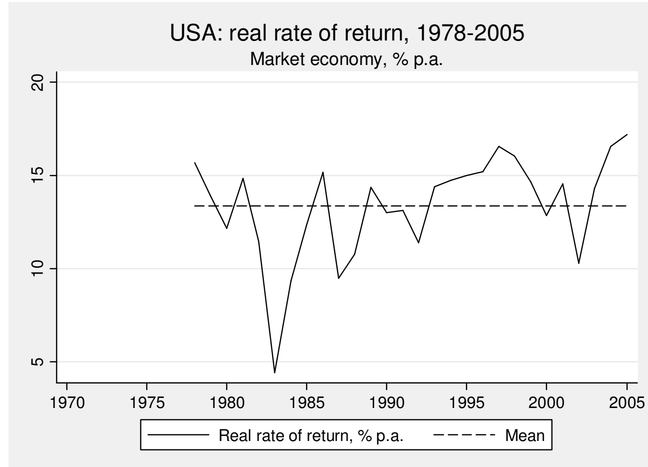


Chart 2 Mean real rates of return, by branch, for 14 countries

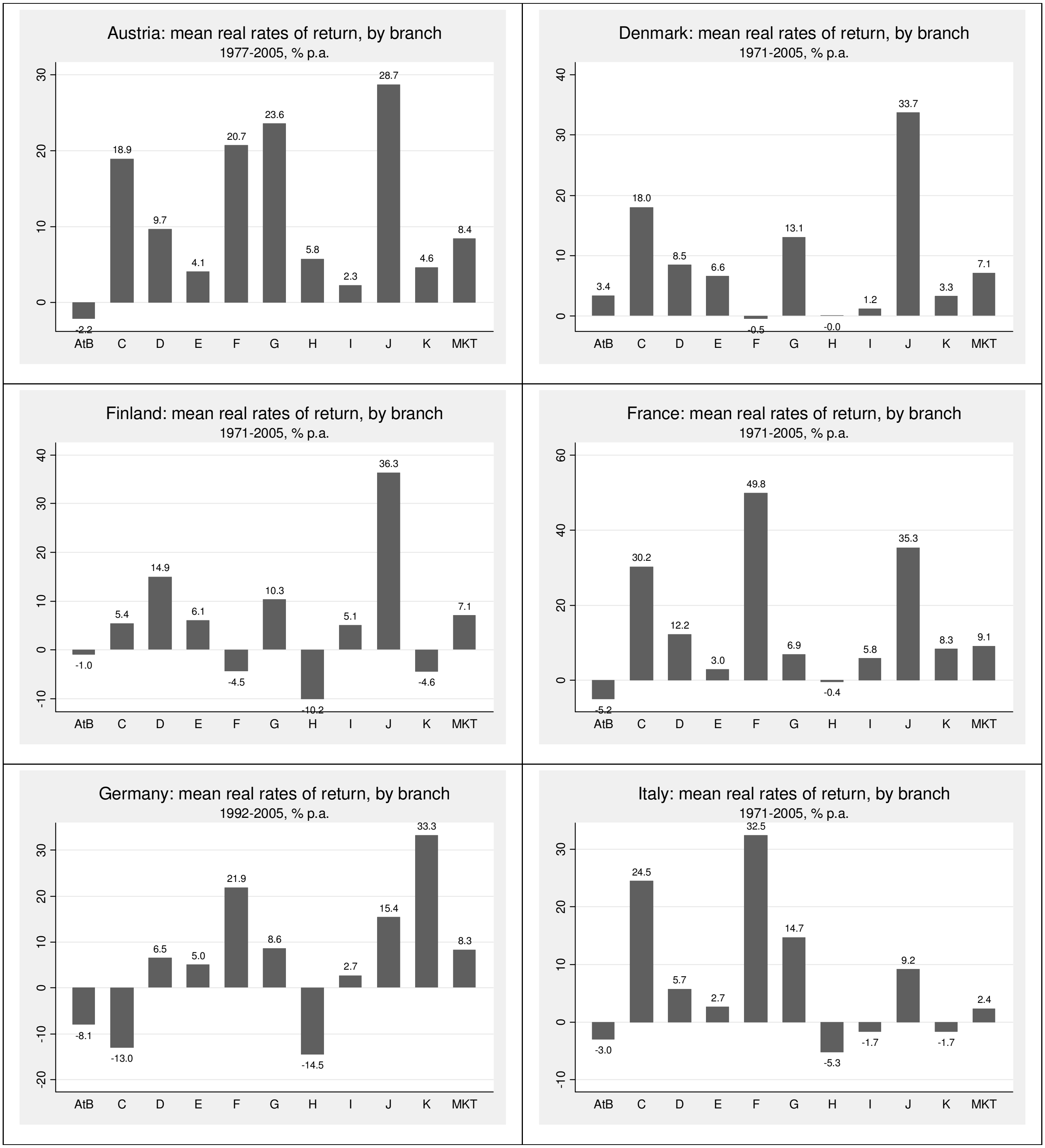


Chart 2, continued

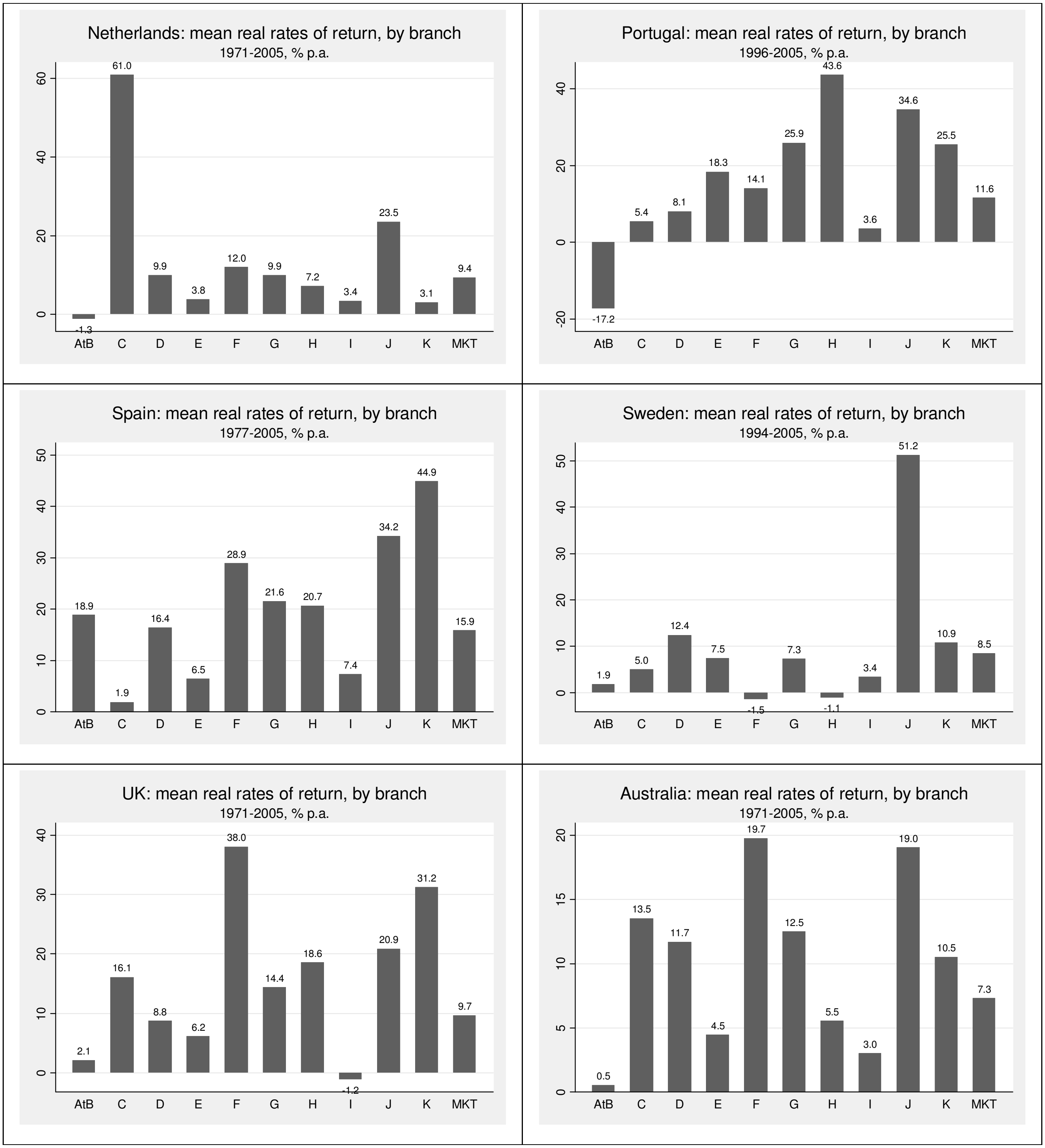
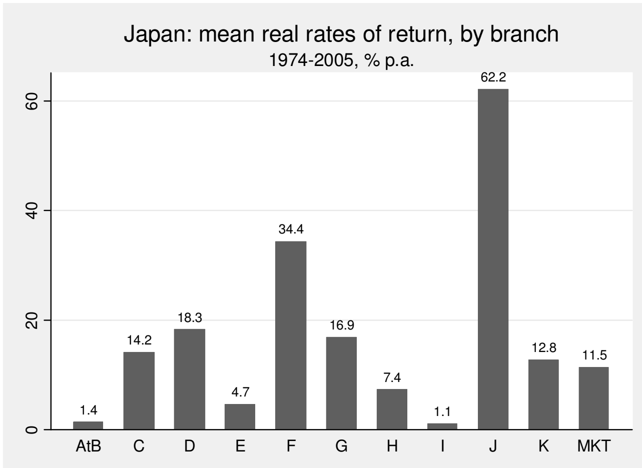


Chart 2, continued



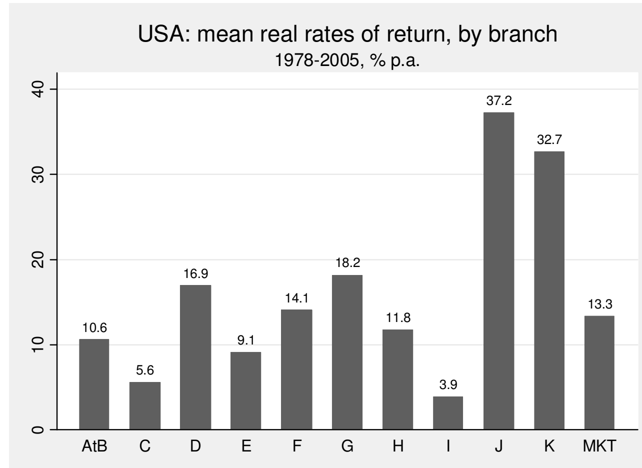
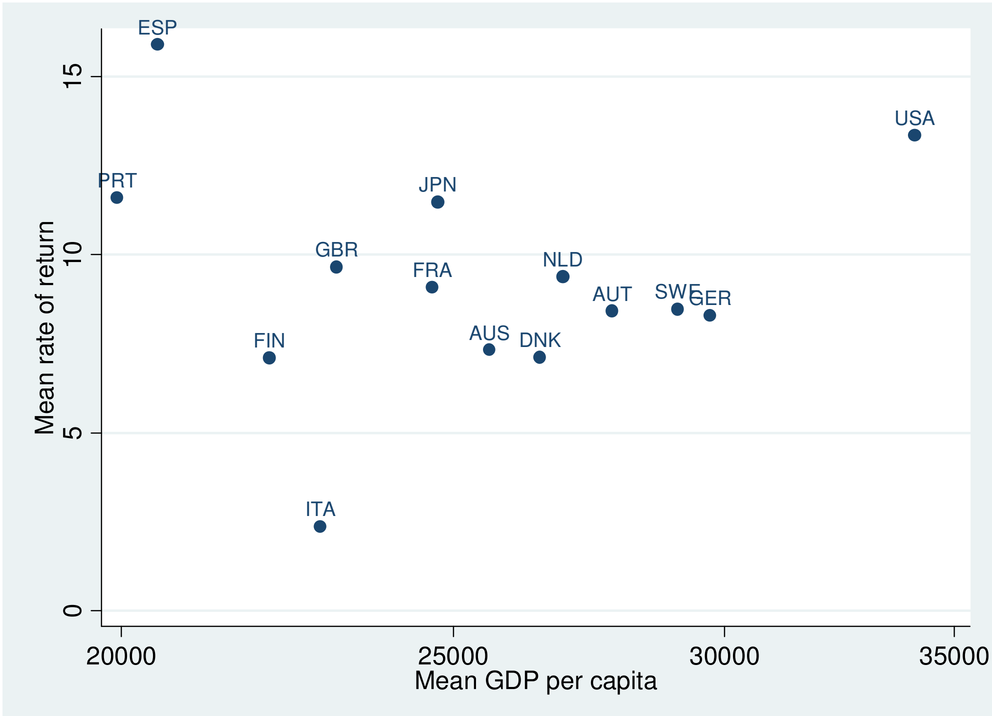


Chart 3
Mean rate of return in the market economy versus mean GDP per capita



Note: correlation is 0.0057 (p-value 0.98). GDP per capita is in PPP levels (2007 EKS$). Source: The Conference Board, Total Economy Database [www.conference-board.org/economics].

Chart 4
Mean growth rate of real GDP versus mean real rate of return in the market economy

Note: correlation is 0.33 (p-value 0.24). Source for real GDP: The Conference Board, Total Economy Database [www.conference-board.org/economics].

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