PRODUCTIVITY AND EQUITY MARKET FUNDAMENTALS: 80 YEARS OF EVIDENCE FOR ELEVEN OECD COUNTRIES

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Abstract. The share market boom in the 1990s is often linked to the acceleration in labour productivity. This paper suggests that labour productivity may be an inaccurate measure of firm's earnings, which underlie equity valuations, and that capital productivity is a better measure of earnings. It employs the Cochrane (1991, 1996) production based asset pricing model to substantiate this point. Using 80 years of data for eleven OECD countries it is shown empirically that the link of capital productivity to share returns is stronger than that of labour productivity and TFP, but generally the link is weaker that is sometimes maintained.

Keywords. Productivity, share returns

JEL classification: G1, G3, O4

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Introduction

The worldwide increase in equity prices in recent years has often been linked to accelerating labour productivity, which has in turn been related to the information technology (IT) revolution (see the discussions in Greenwood and Jovanovic, 1999, Keon, 1998, Hall, 2001, IMF, 2000). It has been argued that the apparent acceleration in labour productivity is an accurate indicator of increases in firms' current and expected real earnings and thus dividends, and its acceleration has thereby contributed to an increase in the value of firms. Campbell and Shiller (2001) also highlight this issue, without advocating labour productivity as a share price determinant.

This paper queries whether labour productivity is the best proxy for firms' earnings. It is argued using the production-based CAPM of Cochrane (1991, 1996) that the more relevant productivity measure for the remuneration of capital, and hence a key element for proxying firms' earnings, is the marginal productivity of capital, which under certain assumptions is equivalent to capital productivity at a macro level (Section 1). Other productivity proxies for firms' cash flow such as labour productivity, potential output and total factor productivity (TFP), may be misleading, as shown in Section 2. In Section 3 we argue informally using a Tobin's Q framework that unexpected increases in capital productivity growth will have their strongest effects on share prices in the short term. This is because higher stock prices will lead via increased investment to a rise in the capital stock and in the presence of diminishing returns, real stock prices are bid down again.

Historical data on share returns, dividends, and productivity over 80 years for 11 countries (G7, Australia, Netherlands, Sweden and Denmark) are presented in Section 4 and the data appendix. Using these data, the relationships between share prices and various measures of productivity are investigated empirically in the light of the theoretical discussion of the appropriate indicator. In Section 5, simple Granger causality tests are first used to examine the bivariate relationship between real share returns and productivity growth. Second, the nexus between real share prices and productivity is investigated using VAR and vector-error-correction frameworks, where other variables than productivity are allowed to influence share returns. Third, we use cointegration techniques in a Vector Error Correction model (VECM) framework.

The empirical results show that capital productivity is indeed the measure which is most closely linked to share returns, although even for this measure, the close share price-productivity relationship asserted by some “new economy” advocates does not seem to be present over a long run of data. Certainly, there is evidence that the strongest effect of shocks to capital productivity growth on stock prices is in the short term, supporting the informal arguments put forward in Section 3.

1 Equity prices and productivity

In the last few years, the popular controversy as to whether equity prices accurately reflect their fundamental values has, to a large extent, centred on the sustainability of the labour-productivity advances in the 1990s. It was argued that unprecedented levels of share prices were justified by an acceleration in labour productivity related to the “new economy” and IT (see, e.g. Keon, 1998). Despite recent falls in share prices and revisions to productivity data, the issue remains relevant at the time of writing, given that valuation measures remain historically high, as well as to analyse the justification of the earlier boom. This section argues that capital productivity is the relevant measure for earnings and hence for share prices.

The production-based CAPM (PCAPM) model of Cochrane (1991, 1996) is used to find the fundamental value of shares. The PCAPM ties stock returns to investment returns (the marginal rate of transformation) in the context of the firm’s dynamic investment problem in the presence of costs of adjustment. As discussed in Arroyo (1996), a production based approach has the logic of permitting firms to influence asset returns through their investment and financing activity, which is rules out by the traditional consumption CAPM (CCAPM) and which we consider essential to a correct assessment of long term trends in asset prices and their link to productivity. (Note that the PCAPM is a “parallel model” to the CCAPM and does not rule out the consumer tangency conditions on which the CCAPM is based.) Consider the firm’s objective function where the rate of depreciation is set to zero for simplicity:

$$\max \Pi = \int_{t=0}^{\infty} e^{-rt} \left[P_t F(K_t, L_t) - W_t L_t - P_t^i I_t - P_t^i C(I_t) \right] dt \quad (1)$$

st.

$$K_{t+1} = I_t + K_t \quad (2)$$

where Π is nominal profits, P is the value-added price-deflator, F is aggregate value-added output, K is capital services, I is net investment, W is the wage rate, L is labour services, r is the required returns to equity, $C(I)$ is the adjustment cost of investment as a positive function of investment, and P^i is the investment deflator.

The current-value Hamiltonian of this problem is given by:

$$H = P_t F(K_t, L_t) - W_t L_t - P_t^i I_t - P_t^i C(I_t) + Q_t [I_t - \Delta K_t] \tag{3}$$

The conditions for an optimum under the assumption of perfect competition in the goods market is

$$MP_K = rQ_t - \dot{Q}_t \tag{4}$$

and the transversality condition

$$\lim_{t \to \infty} e^{-rt} Q_t K_t = 0 . \tag{5}$$

Linking to the capital market, from Equation (4) it follows that the value of shares is given by

$$Q_t = \int_{\tau=t}^{T} e^{-r(\tau-t)} MP_{Kt} d\tau + e^{-r(\tau-t)} Q_t \tag{6}$$

Using the transversality condition, the second right-hand-side term becomes zero. Assuming that the marginal productivity of capital is growing at a constant rate g we get:

$$Q_t = \int_{t=0}^{T} e^{-rt} MP_{Kt} dt = \frac{MP_{Kt}}{r-g} . \tag{7}$$

This equation shows that the value of shares is the discounted value of the marginal productivity of capital minus the rate of depreciation. Under imperfect competition in the goods markets, the real return to capital is given by $MP_K (1 - 1/\eta)$, where $\eta < 0$ is the price elasticity of demand facing the firm.

Note that assuming that all earnings are paid out as dividends Equation (7) would collapse to the well-known Gordon growth model as follows:

$$Q = \frac{D}{r-g} . \tag{8}$$

This is not an essential assumption for our purposes. Nevertheless, it is important to note that the term g cannot longer be interpreted as growth in earnings per unit of capital if the firm retains some of its earnings. If the firm retains some of its earnings the growth in dividends can still be positive even if the earnings per unit of capital is constant (see Copeland and Weston (1992), Ch. 15 for details).

Returning to Cochrane's model, equation (7) suggests that the relevant measure of firms' earnings capacity is the marginal productivity of capital. For empirical implementation of this approach, there is a need for a measure for MP_K at a macro level. For this purpose we employ the well-known Cobb-Douglas production function as follows:

$$Y = AL^{\alpha}K^{1-\alpha} . \tag{9}$$

The Cobb-Douglas production function is appropriate for the current analysis since it assumes an elasticity of substitution between labour and capital of one. This is an appropriate assumption in long-run analysis because it implies that the income shares remain constant in the long run. Under the Cobb-Douglas technology assumption, whereby the average product of capital equals the marginal product of capital, Equation (7) can be written as:

$$Q = \frac{(1-\alpha)(Y/K)}{r-g} . \tag{10}$$

where (1-α) is the output elasticity of capital. To allow for the interaction between share prices and bond yields, the required return to equity is set equal to the real bond yield, r^B, and the equity risk premium, which needs not be constant, ϖ , which inserted into Equation (10) yields:

$$Q = \frac{(1-\alpha)(Y/K)}{r^B + \varpi - g} . \tag{11}$$

This equation forms the basis for the regression analysis in Section 4. The equation shows that equity returns are positively related to capital productivity and the growth therein, and negatively related to the real bond rate and the equity risk premium. The framework assumes fixed income shares. The system could be extended to allow for varying income shares, depreciation rates and leverage, however, this is beyond the scope of this paper.

2 Alternative measures of earnings growth

In the last section it was argued that the relevant measure of productivity for remuneration of capital and hence for determining equity prices is the marginal productivity of capital, which is best proxied by capital productivity and not labour productivity, total factor productivity (TFP) or potential output. The marginal productivity of labour is relevant for the remuneration of labour and TFP is relevant for the remuneration of labour and capital jointly. The relevance of the marginal productivity of capital derives on the one hand from equity finance of fixed capital and on the other from the expected future extra output from the capital investment. Changes in labour productivity will not influence the returns to capital unless they are unexpected, in which case they bring the labour market out of equilibrium and thereby temporarily change earnings per unit of capital. However, since real wages follow labour productivity in the long run the higher returns to capital will only be temporary.

Despite the logic that the marginal productivity of capital is the main component of the relevant measure of firm's earnings potential, the literature has consistently focussed on other productivity measures, especially potential output and labour productivity. In IMF (2000), for example, it is argued that the growth in potential output can be used as a proxy for expected earnings and dividend growth (pp 106-109), and thus may be used in empirical implementations of Gordon's growth model.[1] Kennedy *et al* (1998) of the OECD employ the same method. The argument is that if income shares remain constant, then the growth in earnings will be reflected in output growth. This argument neglects that the fact that the stock of tangible and intangible capital has risen in the growth process and therefore that the returns *per unit of capital* need not have increased.

Elsewhere in IMF (2000), the case is presented that growth in labour productivity can also be the relevant measure of earnings growth (Box 3.1 p 140). Labour productivity growth has also been stressed as the relevant measure for share prices in a series of articles by the *Economist*, for instance Economist (2001) and by Bond (2001) from Barclays Capital.

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[1] Since potential output varies over time, the following version of the Gordon growth model, which is suggested by Barsky and De Long (1993), is used by the IMF:

$$Q_t = \frac{(1+g_t)D_t}{r-g_t}$$

To assess the implications of using labour productivity and TFP as proxies for expected earnings capacity, totally differentiating Equation (9) yields:

$$\Delta \ln Y = (1-\alpha)\Delta \ln K + \alpha\Delta \ln L + \Delta \ln A \qquad (12)$$

which shows that the growth of output is the sum of the share-weighted growth of inputs and growth in TFP.

From Equation (12) it follows that the growth in labour productivity is given by:

$$\Delta \ln(Y/L) = (1-\alpha)\Delta \ln(K/L) + \Delta \ln A, \qquad (13)$$

where the first right-hand-side term shows capital deepening, whereby an increase in capital per worker leads to an increase in workers' productivity and raises labour productivity in proportion to the share of capital. The other term is TFP, which raises labour productivity on a pro rata basis.

The growth in capital productivity is given by:

$$\Delta \ln(Y/K) = \alpha\Delta \ln(L/K) + \Delta \ln A \qquad (14)$$

From this equation it follows that capital deepening lowers capital productivity while TFP adds to it. Comparing Equations (13) and (14) it is transparent that TFP growth enhances both the marginal productivity of capital and labour. Capital deepening, however, increases labour productivity but lowers capital productivity and therefore explains why the real interest rate/return on equity tends towards a constant mean in the long run, while real wages show a continuous rise in the long run. Indeed, subtracting Equation (14) from Equation (13) gives $\Delta\ln(K/L)$. From this it follows that changes in labour productivity are only equivalent to changes in capital productivity to the extent that changes in capital deepening are zero.

Historically, capital deepening has dominated total factor productivity growth. Our calculations suggest that the *K*/*L* ratio has increased by 3.7% per annum in the OECD countries since 1960, whereas TFP has increased by only 1.8%. Over the entire period from 1990 to 1999 labour productivity increased by 18%, whereas capital productivity has remained almost unaltered in the

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where dividend growth is allowed to vary over time. Note, however, that this equation is contrary to the key assumption in the Gordon model of *constant* growth in dividends.

countries considered in this study. Over the 1995-99 period we estimate that US labour productivity grew by over 2.5% per annum on average while capital productivity growth was –1.3%. In this context, for the US Oliner and Sichel (2000) have found that capital deepening accounts for 40% of the rise in labour productivity in the late 1990s and TFP for 60%. These results suggest that growth in labour productivity can be a severely biased proxy of growth in returns to capital. The increase in capital earnings that did take place in the 1980s-1990s was due to increasing capital share in total income (related to factors such as markup) rather than a rise in MP_K per se.

Turning to comparison of potential output as a proxy for dividend growth, the difference between the growth in potential output and capital productivity is growth in the capital stock:

$$\Delta \ln Y - \Delta \ln(Y/K) = \Delta \ln K \,, \qquad (15)$$

ignoring for simplicity cyclical fluctuation in income so that growth in income equals growth in potential output. The difference was 34% over the period from 1980 to 1992 and 18% from 1993 to 1999 for the countries used in this study. This suggests that growth in potential output is also a biased indicator of expected growth in earnings per share.

TFP growth has occasionally been mentioned as a potential measure of the growth in earnings. Using Equation (13), if TFP is used to proxy g instead of the measure based on capital productivity, then the growth in earnings is measured by capital productivity plus workers' income share times the change in the inverse of the capital labour ratio: $\alpha \Delta \ln(K/L)$. This may again be an inaccurate measure of g.

In the light of the above arguments we would contend that it is by no means obvious that the measures typically used to proxy g in the Gordon formula are the best available. This paper has suggested that the correct measure is related to the growth in the marginal productivity of capital provided that all earnings are paid out, which under the Cobb Douglas assumption equals the growth of capital productivity. We have shown that growth in potential output exceeds this aggregate, and for most countries this is also true for labour productivity.

The impact of any bias on estimations of the fundamental value of shares can be seen from the partial differential of Equation (7):

$$\frac{\partial Q/Q}{\partial g} \approx \frac{1}{r-g}. \qquad (15)$$

Suppose that r is 8%, as found below, and that g is 2%. Then the fundamental value of shares is biased upward by around 25% for each percentage upward bias in g. This suggests that valuation models are highly sensitive to the choice of productivity measure.

We acknowledge that the Cobb-Douglas assumption required for an exact correspondence between growth in capital productivity and earnings growth are unlikely to hold precisely. For this reason, it is essential for empirical analysis to be carried out on the relationship of the various productivity measures. Do the actual data support the theoretical arguments presented above? Do they give any guidance on the best proxy for g? In Section 4 we provide empirical analysis using a long run of data to address empirically the arguments above about the appropriate productivity measure to relate to equity returns.

3 Sustainability of share valuations and Tobin's *Q*

As an aside to the basic argument, the debate of whether equity prices are at their fundamental value centres to a large degree on the expected permanent growth rate in real earnings and hence on the term g in the Gordon model. We have argued above that the best productivity proxy for earnings is capital productivity. In this section we argue that under certain assumptions that the long-run capital productivity growth is zero at a macro level, which implies a low level of g. This follows the predictions of Tobin's valuation ratio model (which suggests that the market valuation of firms will in the long run be equal to the replacement cost of the capital stock).

To see this, consider a technology innovation that increases the productivity of capital. The higher marginal productivity of capital drives the valuation ratio in excess of one because future profits per unit of capital is temporarily increased and this triggers investment. The increase in the capital stock will lower the returns to capital due to diminishing returns to capital. The lower cash flow per unit of capital will lower the valuation ratio. Equilibrium – which may take a protracted period - is reached when the valuation ratio is driven back to one. Hence, a one off capital productivity shock should have only temporary effects on the marginal productivity of capital and hence equity returns unless there are constant returns to capital, as assumed in the early literature on endogenous growth (Romer, 1986). However, no empirical studies have given support to the assumption of constant returns to capital, and later models of endogenous growth have relaxed this extreme assumption. Furthermore, in the empirical section we find strong evidence of the bell-shaped response of stock prices to an innovation in capital productivity, which suggests that capital productivity gains have their principal effects on earnings in the short term.

Note the parallel to the neoclassical growth model where changes in the investment ratio (savings rate) have only temporary effects on growth. In these models an increase in savings increases net investment and brings the capital stock up to a higher steady state level. Growth in output is only temporarily higher on the transitional path from the initial equilibrium capital stock to the new equilibrium capital stock.

There are several caveats. Tobin’s valuation ratio is only one under the assumption of perfect competition in the goods market and the absence of adjustment costs and uncertainty. Moreover, if productivity growth is continuous rather than discrete, while investment responds gradually to innovations, the capital stock may never reach the point where the rise in productivity is wholly eliminated by diminishing returns. Both of these effects may have been in operation in the “golden age” referred to by Gordon (2000). We have noted that earnings growth may exceed capital productivity growth owing to factors such as taxes and capital market imperfections, as well as under differing technology than Cobb-Douglas. Nevertheless, the calculation suggests a need for caution in projecting productivity gains. Gordon (2000) indeed argues that IT investments are particularly subject to diminishing returns.

4 Data analysis

Before turning to more formal econometric analysis, this section presents geometric-mean[2] growth rates in various measures of productivity, real share prices, equity returns (capital gain + dividends), real bond returns and other relevant variables in various periods across 11 OECD countries: the US, Germany, Canada, the UK, France, Italy, Japan, Denmark, Sweden, the Netherlands and Australia. Details of data sources are given in the Data Appendix.

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[2] We prefer geometric to arithmetic means since they are a superior means of describing historic time series, although arithmetic means give the best estimate of expected financial returns on financial assets (Bodie *et al* 1999). Arithmetic means are also biased up in volatile series. On the other hand, geometric means may be vulnerable to choice of end points. We have started German real dividends and share returns in 1925 to avoid the distortion caused by the hyperinflation of the early 1920s.

Note that TFP growth is estimated as $100(\Delta \ln Y - \alpha \Delta \ln L - (1-\alpha)\Delta \ln K)$, where α is set to 2/3, which is approximately labour's income share. Volatility is measured as the annual standard deviation of monthly changes in share prices deflated by the CPI.

Some long-term characteristics of the data are illustrated in Table 1. Concerning productivity growth, an immediate stylised fact is that capital productivity growth falls far short of that of labour productivity. The capital stock has in effect risen much more than labour hours, with the latter "capturing" the benefits of productivity in terms of its marginal productivity – reflected in turn in growth in real labour earnings. Total factor productivity growth, reflecting both factor inputs, lies between the two.

Insert Table 1 here

Over the 80-year period considered, capital productivity growth was negative in the UK, Sweden, the Netherlands and Japan, and less than 1% per annum elsewhere. Following the analysis in Sections 2 and 3, there has been marked capital deepening, with capital/labour ratios rising strongly and TFP growth unable to compensate. Labour productivity growth was 1-2% in the US, UK and Australia, 2-3% in the Canada, France, Italy, the Netherlands, Sweden and Denmark, and 3-4% in Germany and Japan. These results suggest that in historical perspective, labour productivity growth has been substantially higher than capital productivity growth due to capital deepening. Real share prices have risen by around 2-4% per annum in most countries, exceptions being Italy Japan and Denmark with lower real increases.

Real equity returns, which of course exceed growth in real share prices as a result of the level and growth of real dividends, are remarkably consistent at around 5-8% annually[3] Real *ex post* bond yields are negative on average in Japan, France and Italy. Elsewhere they are in the range of 2-4%. Hence, the equity premium is 4-6% on average, being the highest in the US and France. In terms of GDP growth, the UK is the weakest performer, with average performance being 2%, and Japan the highest at 4.6%, while elsewhere it lies broadly between 3-4%. In terms of "growth accounting", it can be seen that total factor productivity accounts for a half to two-thirds of this

[3] We started the data for Germany after the hyperinflation of the early 1920s, inclusion of which gives a negative real equity return. The data in war periods were difficult to obtain and sources conflict. This is particularly true for the Japanese consumer prices in the mid 1940s. This is one reason we also give data beginning in 1950.

total, with factor inputs accounting for the remainder. Finally, average inflation has been around 3% in the US, Germany (excluding the early 1920s), the Netherlands, Sweden and Canada, 4% in the UK, Australia and Denmark and well in excess of that figure elsewhere.

Table 2 excludes the earlier years of depression and war, instead focusing on the 50-year period from 1950 to 1999. Patterns of productivity are little changed, although capital productivity growth is on average negative now for all countries except France, Italy and Australia, reflecting capital deepening. Real share price growth is somewhat higher, notably for Japan, while growth for Australia is lower. Real equity returns are again in most cases higher than over the entire period 1920 to 1999, and considerably so for France, Germany and Japan, reflecting post-war recovery and reconstruction. Real bond yields are consistently positive, while equity premia rise to 6% or more in the US, Germany, France, Japan, the Netherlands and Sweden. Economic growth is again highest in Japan, but is also close to 4% in France, Canada, Germany and Australia. The final line shows the well-known higher inflation in most countries in the post-war period.

Insert Table 2 here

5 Empirical estimates

In Section 1 it was shown that equity prices[4] reflect the discounted present value of expected earnings, which in turn should depend largely on the expected marginal productivity of capital. We would expect equity prices in an efficient market to be able to predict the marginal productivity of capital, as reflected in expected productivity increases.

In this section we test the causal relationship between real equity prices and productivity to shed light on whether equity markets base share valuations on the marginal productivity of capital, and not other productivity measures. The main focus is on whether capital productivities are predicted by real equity prices, which is what would be anticipated given gestation lags in investment and advance availability of information on technological changes and investment intentions. We also include some assessment of causality from productivity to real equity prices, while noting that this would imply market inefficiency (markets should have information on productivity before the investment comes on stream). The long and eventful data period covered lends additional weight to estimation results. Preliminary Granger causality tests are undertaken in the first subsection, VAR models are estimated in the second subsection, while VECM cointegration analyses are shown in the third.

A preliminary to estimation is testing for unit roots, since variables entering a Granger causality or VAR system should normally be stationary, while trend stationary variables are relevant for cointegration. The results of Dickey-Fuller tests are shown in Table 3. They indicate that the first difference of the log of productivity growth, the log of CPI and real share price growth are stationary. Share market volatility (the standard deviation of changes in monthly share prices, deflated by the CPI) the real long-term interest rate and real equity returns are stationary in levels. The deviation of GDP from a Hodrick-Prescott filtered trend, justification for which is discussed below, is also stationary in levels (by construction).

Insert Table 3 here

5.1 Granger causality tests

A straightforward way to address the direct relation between productivity growth and share prices is to undertake Granger causality tests.[5] Productivity is measured as log first difference of labour productivity, capital productivity and TFP in the tests and share prices as the log first difference of real share returns. The Granger causality test assesses whether there is a consistent pattern of shifts in one variable preceding the other. Such tests do not give any proof on causality, but nevertheless where causal mechanisms based e.g. on expectations can be suggested, as outlined above and in Section 1, then a positive result gives grounds for further investigation.

Granger causality can only be a starting point in empirical investigation for at least two reasons. First, there are a number of additional influences on real equity prices, as outlined above, so a multivariate regression approach needs to be adopted before reaching any conclusions. In addition, the absence of a short-term relationship may not preclude a long run link in a cointegrating framework. On the other hand, VAR analysis has some disadvantages (such as the problem of recursive ordering etc) that are not present in the Granger analysis and it is therefore an invaluable supplement to the VAR analysis.

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[4] Note that the model of Section 2 relates to share prices and not returns – for this reason we use real share prices and not real equity returns in our estimation.

[5] As noted, productivity and share prices both tend to be integrated of order 1. Hence we need to log-difference to obtain consistent results.

To run the Granger causality test, the following equations are estimated for each country:

$$X_t = \alpha_0 + \alpha_1 X_{t-1} + \alpha_2 X_{t-2} + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \varepsilon_t \qquad (17)$$

where X is either log productivity growth or log real equity price increases and *Y* is the other variable in question, and ε is a disturbance term. If there is Granger causality from *Y* to *X*, then some of the *ß*-coefficients should be non-zero; if not then all of the *ß* coefficients should be zero. Testing whether the coefficients on the lagged indicator variables are zero can be readily performed using standard *F*- or *t*-tests.

The results of the Granger causality analysis are shown in Table 4, based on using two lags of each variable. Data are for 1920-1999. The results show that growth in real share prices most frequently Granger-causes capital productivity growth (in the US, Canada, the UK, Italy, Japan, Australia and Sweden), while Germany and France show Granger-causality from capital productivity to real share prices. Results for labour productivity and total factor productivity show much less Granger causality, with a link from TFP to real share prices in Japan and Australia and from labour productivity to real share prices in Japan and Denmark. France shows causality from real share prices to labour productivity.

Insert Table 4 here

In sum, the tests for Granger causality between share returns and productivity growth tend to suggest that share returns are often a leading indicator of productivity growth, but that productivity growth is very rarely a predictor of share prices. This is consistent with the forward-looking nature of equity returns. There are strong contrasts between the types of productivity, with capital productivity much more strongly related to real share prices than the other measure, consistent with the overall argument of this paper and an interesting contrast to the focus of US analysts on labour productivity.[6]

5.2 VAR systems

[6] Similar tests – not reported in detail - were run using the dividend yield, following the intuition that this may be a more forward looking measure of equity market sentiment than the total return (as argued inter alia by Campbell and Shiller 2001). The outcome shows a more tenuous link from dividend yields to

A key problem associated with the estimation of predictive links between variables, is that they are almost always conditioned on the other variables incorporated in the related equation (Davis and Fagan, 1997). A criticism of Granger causality tests is naturally that only two variables and their interrelations are assessed, while as shown in Equation (11) these should only be a subset of the set of variables which combine to determine real share prices. Accordingly, we proceeded to wider estimation using multiple variables.

We estimate a standard VAR system, which is the reduced form of a linear dynamic simultaneous equation model in which all variables are treated as endogenous. Each variable is regressed on lagged values of itself and on lagged values of all other variables in the information set. In the light of the discussion of equity price determination in Section 1 and summarised in Equation (11), we sought to assess the relation between the log difference of real equity prices, the log difference of productivity, the real long bond rate, and real equity price volatility as a proxy for the equity risk premium. These proxy the variables entering the valuation formula. We added to these variables the difference between the log of GDP and a Hodrick-Prescott filter to allow for cyclical and "real business cycle" effects and the log difference of the CPI to allow for potential non-homogeneity of equity prices to inflation.

We estimated VARs separately for the log-difference of TFP, labour productivity and capital productivity using the 1920-99 dataset[7]. The aim is to provide some quantitative estimates of the relationship between productivity, equity prices and related variables. To do this we need to orthogonalise the estimated VAR model - which is in reduced form - to identify the effect of shocks to the innovations of the variables in the VAR. The problems of identifying impulse responses in VAR models now arise. We have treated this by adopting a standard approach, using a Choleski decomposition. Identification then uses the Sims's triangular ordering.

A well-known problem with the Sims triangular ordering is that it is arbitrary, and requires a justification for the ordering chosen. The presence of common shocks and co-movements among the variables makes the decision on ordering a crucial one. We decided, in line with Canova and De Nicolo (1995) and Nasseh and Strauss (2000) to assume that exogenous shocks are largely

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productivity growth than was the case for real share prices. There are very few cases where dividend yields help to predict productivity growth, and virtually none where productivity helps to predict the yield.

technology driven and hence affect productivity and output. Stock returns, in line with the present value model, respond according to the effect of these shocks on future cash flow. Stock prices may also respond to changes in inflation, long term real rates (discount factor) and volatility (risk premium), which may all also be affected by technological factors and other shocks. Hence, we order the variables with productivity first, followed by output deviation from the HP filtered trend, inflation, long rates and real equity price volatility before real equity prices themselves. Real equity prices are thus constrained to only feed back on the other variables with a lag. Note that this need not exclude a marked leading indicator property of share prices, if the data suggest it.

Following the Schwarz Bayesian Information Criterion, two lags were chosen for all countries except Denmark, the Netherlands and Australia, where one lag was appropriate. The block exogeneity tests shown in Table 5 reveal that the inclusion of equations for productivity, and lags of productivity in the other equations, is always justified. Meanwhile, Table 6 shows in the individual VAR equations capital productivity and equity prices are most frequently related (in all countries but the UK, Denmark, Australia and the Netherlands), in effect generalising the Granger causality test to the presence of other variables. TFP and labour productivity show up more frequently than in Granger causality, however.

Insert Tables 5 and 6 here

The key output of a VAR for the purposes of our current exercise is the variance decomposition and impulse responses. There may be effects in the whole system which are hidden from individual equations. With a model of this sort there is a large amount of output generated by this exercise: six equations, subject to six different shocks gives 36 solutions. Therefore, we have selected a few representative and key results for presentation. Given the focus of the work on real equity prices and productivity, we report only the variance decomposition of real equity prices to shocks in the innovations to variables in the VAR, and of productivity to real share prices, together with selected impulse responses.

The results for variance decompositions in the VARs are shown in Tables 7-9. These show the degree to which the variance of the “independent variables” explain the forecast variance of the

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[7] For some countries the estimation starts later than 1920 owing to data shortages – generally in dividend yields, while for Germany we began estimation in 1925 to remove the influence of the 1921 hyperinflation on real share prices.

"target" variable in the VAR system, in the light of which one may interpret the response of the system to shocks. In most countries, errors in equity returns help largely to explain forecast errors in the same variable. The strongest explanatory effect otherwise is from price inflation and the real long rate.

Insert Tables 7-9 here

The variance of productivity has little explanatory power for the forecast variance of equity prices in the Anglo Saxon countries such as the US, Canada, the UK and Australia as well as Denmark and the Netherlands, in line with market efficiency. A polar opposite result is in Japan and Germany, where a substantial part of the forecast variance of real share prices is explained by variance of lagged capital productivity and (to a lesser extent) TFP and labour productivity. This may of course relate to the lesser development of equity markets (only responding in the wake of actual real developments, rather than in line with expectations), as well as the strong post war growth in productivity highlighted in Section 4. Italy and Sweden, as well as France, also have an impact of capital productivity on real share price variance, not present for labour productivity – albeit smaller than for Germany and Japan.

In the US and Canada there is a strong feedback effect of real equity prices on capital productivity, explaining 25% of the forecast variance after 4 years[8], suggesting forward looking behaviour by equity holders in response to expected increases in productivity. This is absent for TFP and labour productivity. Italy and Australia and to a lesser extent Sweden also have this effect. In contrast, in neither Germany nor Japan is there strong feedback in terms of forecasts of variance from real share prices to productivity, suggesting that there are limited forward looking signals from financial asset prices to real activity. In the other countries, there is little relation detected in the VAR between real share prices and productivity.

Table 10 shows the impulse responses to certain shocks, which are highlighted by the variance decomposition analysis. First we show effects of shocks in capital productivity on equity returns in Germany, Japan, Sweden and France. Except for Sweden, they generate a significant rise in equity returns, which comes in years 2-3 for Japan and Germany and years 4-5 in France. The overall effect after 6 years is however much lower than the peak, and in some cases it is negative.

[8] This result was also broadly unchanged when we changed the ordering (implausibly) to have capital productivity after real share prices

Insert Table 10 here

A remarkable result emerges for effects of shocks to share prices on capital productivity in the US, Canada, Australia and Sweden in that a rise in real equity prices tends to raise capital productivity in year 2 but then depress it markedly in succeeding years. Although this could be seen as just a cyclical pattern, we suggest that it is consistent with a valuation ratio effect as highlighted in Section 3, whereby high equity returns in response to a technical innovation prompt increased investment, which given diminishing marginal productivity of capital leads to lower capital productivity. The figure below shows the pattern for the US. The pattern in Italy is not consistent with the other countries, with a fall in productivity followed by a rise in the wake of a shock to equity prices.

Insert Figure 1 here

Table 11 shows some variants on the basic VAR, focusing on the variance decomposition results for capital productivity and share prices. The basic aim is to gauge whether the results presented above are purely an artefact of the precise VAR specification chosen. The variants were: (i) to include the first difference of GDP, i.e. a pure cyclical pattern, instead of the deviation from the HP filtered trend; (ii) to have the level of real equity returns (as an $I(0)$ variable) instead of the difference of real share prices, (as noted, we prefer the share price as the correct output from the Gordon model); (iii) to allow for foreign influences by including the log difference of the US equity price as an exogenous variable (except for the US where we included the UK price); (iv) starting the estimation in 1950, to assess stability. The stylised facts highlighted above come through in virtually all cases, notably a strong explanation of variation in capital productivity by share prices/equity returns in the US and Canada and the reverse in Germany and Japan.

Insert Table 11 here

5.3 Cointegration analysis

In a final empirical section, we sought to estimate the properties of relationships between the $I(1)$ variables in the dataset. The variables concerned are the measures of productivity, the real share price and the CPI. Whereas the CPI is already incorporated in the real share price, its separate inclusion permits non-homogeneity of share prices in the long run. The estimates were carried out using the Johansen procedure, after which the estimates were incorporated in Vector Error Correction Models (VECM). Ultimately, our interest is in whether the results for a productivity-equity price link carry over when long run relationships are allowed for.

The results of estimation normalised on share prices are shown in Tables 12-14. Note that the Johansen procedure indicated that in no case could cointegration be detected for France, Italy and the Netherlands, while this is also the case for capital productivity in the UK and Canada and in Canada for TFP.

Insert Tables 12-14 here

As regards the results for capital productivity (Table 12), the estimates of the long run elasticity varies plausibly from around 0.5 to 1.5, albeit with an extreme result for Denmark (3.3). In other words, real share prices move broadly in line with capital productivity in the long term. (Note that a negative sign in the table indicates a positive elasticity.) The price terms indicate a lack of long run price homogeneity, although only for Sweden is the estimate implausibly beyond 1.

In the VAR, the cointegrating equation (CE) residuals are significant for real share prices in all cases, indicating a strong error-correction effect, and significant in all cases but Australia for the CPI, while the residuals are significant for capital productivity only for Germany and Sweden. The results for the variance decomposition are wholly consistent with those in the dynamic VARs, with a strong explanation of levels of capital productivity by levels of real share prices in the system in the US, Denmark, Australia and Sweden, and a strong explanation of share prices by capital productivity in Germany and Japan.

Results for labour productivity are shown in Table 13. Elasticities range from 0.3 to 4.6, while the price effects are generally smaller. Again, the cointegrating vector residuals are frequently significant for share prices and CPI in the VAR, while the decompositions tend to show a much smaller explanatory power over forecast variance than for capital productivity for most countries (Japan is an exception). Finally for TFP (Table 14) elasticities and CPI effects are comparable to labour productivity, while the explanation in the variance decomposition is again lower than for capital productivity. These results reinforce the conclusion above, that TFP and labour productivity are poor measures of firms' earning capacity.

6 Conclusions

The share market boom in the 1990s is often linked to the accelerating labour productivity over the same period. Following the logic of the production based CAPM, we have suggested that labour productivity may be a misleading measure of corporate earnings, and capital productivity is more relevant. This is supported by evidence from 80 years of data for 11 countries.

Among the empirical findings are that the overall performance of the major OECD countries since the 1920s is broadly similar in terms of both productivity and equity returns. Of the three measures of productivity, equity prices seem to be most strongly related to capital productivity. Variance decompositions show strong linkages from share prices to capital productivity in countries such as the US, Canada and Australia. There is less evidence that shocks to productivity consistently help to explain equity prices in these countries. For Germany and Japan there is evidence of an opposite effect, with productivity shocks helping explain the forecast variance of equity returns.

Meanwhile, impulse responses suggest that there may be effects of equity price shocks on productivity in the US, Australia, Sweden and Canada, whereby an initial boost to prices in response to news of a technological improvement is followed by a fall. This may link to the effects of higher returns on investment, and as a corollary supports the suggestion that rises in share prices which are justified by news about capital productivity may overshoot.

In opposing the view that labour productivity is an appropriate measure of equity-market fundamentals, our results are consistent with the findings of Campbell and Shiller (2001), who sought to assess the argument that the high stock market value is often justified by expectations of a continuation of the high labour productivity growth in the 1990s, with an underlying premise that labour productivity is the relevant productivity measure of earnings. In fact, finding that price-smoothed-earnings ratio cannot predict future labour productivity for the US, they concluded that the high share prices at the time of writing could not be due to a rational forecast of labour productivity growth[9].

[99] Meanwhile, our data suggest that innovations in productivity in the 1990s had little effect on outturns for capital productivity, the key component of a more correct measure of earnings (which was flat from 1995-7 then fell sharply). If the levels of share prices seen in the late 1990s were not justified by such long run fundamentals, one is left with largely one-off or temporary factors to explain them. These include a decrease in the risk premium, higher international liquidity, baby boomers, the disinflation, a fall in the

relative price of capital goods, a rise in the capital share of GDP and increased leverage (IMF, 2000), or even irrational exuberance (Shiller, 2000).

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DATA APPENDIX

HISTORICAL DATA (prior to 1959).

Capital stock of equipment and non-residential structures. The perpetual inventory method is used with the following depreciation rates; 17.6% for Machinery and equipment, and 3% for non-residential buildings and structures. The stock of capital is set equal to the average investment over the first 6 years initially and multiplied by 5.68 for machinery and equipment and 33.6 for non-residential structures and construction, reflecting depreciating rates of 17.6% and 3% respectively.

Investment in equipment and non-residential structures between 1870 (or before) and 1949. Canada. 1870-1900: Both types of investment are assumed to follow total non-residential investment at current prices deflated by the CPI. 1901-1925: 5-year average disaggregated into 1-year intervals using total non-residential investment deflated by CPI. Source: F. H. Leacy (ed.), 1983, *Historical Statistics of Canada*, Statistics Canada: Ottawa. United States. 1870-1900: Department of Commerce, 1975, *Historical Statistics of the United States: Colonial Times to 1970*, Bureau of the Census: Washington DC. Only 10-year averages are available in the two decades 1870-1878 and 1879-1888. The data are uniformly distributed within the 10-year intervals. 1901-1949. T. Liesner, *One Hundred Years of Economic Statistics*, The Economist: Oxford. Japan: 1885-1949: K. Ohkawa, M. Shinchara and L. Meissner, 1979, *Patterns of Japanese Economic Development: A Quantitative Appraisal*, Yale University Press: New Haven. Total non-residential investment is used for the period 1940-1949. 1860-1885. Investment in equipment and non-residential buildings, respectively, for Sweden (see source below), using the average over the period 1885-1890 as scaling factor. Australia: 1863-1902: C. Clark, 1970, "Net Capital Stock," *Economic Record*, pp. 449-466. 1903-1950: M. W. Butlin, 1977, *A Preliminary Annual Database 1900/01 to 1973/74*, Research Discussion Paper 7701, Reserve Bank of Australia: Sydney. Denmark: 1870-1950: K. Bjerke and Nils Ussing, 1958, *Studier Over Danmarks Nationalprodukt 1870-1950*, G. E. C. Gads Forlag: København. France. 1856-1895. Total investment deflated by industry prices. E. Chadeau, 1989, *l'Economie Nationale Aux XIX et XX Siecles*, Paris: Presses de l'Ecole normale Superieure. 1896-1914 and 1921-1938. J-J Carre P. Dubois and E. Malinvaud, 1975, *French Economic Growth*, Stanford: Stanford University Press. 1914-1921 and 1939-1949. Crude steel production adjusted. Liesner *op. cit.* Germany: W. Kirner, 1968, *Zeitreihen fur das Anlagevermogen der Wirtschaftsbereiche in der Bundesrepublik Deutschland*, Deutsches Institut fuer Wirtschaftsforschung, Duncker & Humbolt: Berlin. The data are adjusted for war damage in the source. Non-residential buildings and structures 1850-1949: The following categories are added together: Land und Forstwirtschaft, Energiewirtschaft, Bergbau, Grundstoff- und Productiongueter-industrie, Investeringsguterindustrie, Verbrauchengueterindustrie, Nahrungs- und Genuessmittel-industrie, Industrie Kleinbetr. und Handwerk, Baugewerbe, Handel, Eisenbahnen, Schifffahrt, Ubringer Verkehr, Nachr. ubermittlg, Kreditintitutionen und Vers. gew., Wohnungsvermietung, Sonst. Dienstleist., Strassen und Brucken, Wasser strassen und Hafen, and Ubrige staatl. Bereiche. Machinery and equipment 1926-1949. The same categories are added together as for investment in non-residential buildings and structures. 1870-1925: Scaled investment in machinery and equipment for Denmark, using the average over the period 1926-1930 as scaling factor. Italy. Istituto Centrale di Statistica, 1976, *Statistiche Storiche Dell'Italia 1861-1975*. Residential building investment is included in investment in buildings. Only 10-year averages are available before 1945. The data are uniformly distributed within the 10-year intervals. Netherlands: C A van Bochove and T A Huitker, 1987, *Main National Accounting Series, 1900-1986*, Central Bureau of Statistics, the Netherlands. Sweden. 1861-1949. O. Krantz and C. A. Nilsson, 1975, *Swedish National Product 1861-1970*, C. W. K. Gleerup. Investment in buildings include residential investment. UK. 1856-1900: B. R. Mitchell, 1962, *Abstract of British Historical Statistics*, Cambridge University Press: Cambridge. The data are measured in nominal terms. The data are deflated by the general investment price deflator. 1901-1949: T. Liesner, *One Hundred Years of Economic Statistics*, The Economist: Oxford.

Total employment. The algorithm which is suggested by V. Gomez and A. Maravall, 1994, "Estimation Prediction and Interpolation for Nonstationary Series with the Kalman Filter," *Journal of the American Statistical Association*, 89, 611-624, is used to interpolate between the benchmark years as indicated for the individual countries. Canada. 1921-1959. F. H. Leacy (ed.), 1983, *op. cit.* 1870, 1890, and 1913, and A.

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Average hours worked per employee. C. Clark, 1957, *The Conditions of Economic Progress*, Macmillan: London. The algorithm which is suggested by V. Gomez and A. Maravall, 1994, *op. cit.*, is used to interpolate between the benchmark years as indicated for the individual countries. Canada. Data available for the years, 1870, 1880, 1890, 1900, 1910, 1920, and 1926-1949. The US. 1868 ,1973, 1878, 1883, 1888, 1993, 1898, 1903, 1908, and 1913-1949. Japan. 1901, 1913, and 1919-1949. The weekly hours worked are assumed to be 72.5 before 1901. Australia. 1891, 1901, and 1919-1949. The weekly hours worked are assumed to be 45 before 1891. Denmark. 1870, and 1903-1949. Germany. 1900-1914, 1926-1949, and 1947-1950. The weekly hours worked are assumed to be 50 before 1900. Italy. 1901-1949. Daily hours worked are assumed to be 13 before 1901. Sweden. The data are available for all years except for the years 1940-1944, where ILO, *Yearbook* is used to interpolate. The UK. The data are available for all years.

Real GDP. A. Maddison, 1995, *Monitoring the World Economy 1820-1992*, Development Centre, OECD. Japan. 1870-1885. Interpolated using the algorithm which is suggested by V. Gomez and A. Maravall *Op. Cit.*

Annual consumer prices: B. R. Mitchell, 1983, *International Historical Statistics: Americas and Australasia*, Macmillan: London, B. R. Mitchell, 1975, *European Historical Statistics 1750-1975*, Macmillan: London, and B. R. Mitchell, 1982, *International Historical Statistics: Asia and Africa*, Macmillan: London, Mitchell, 1983.

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Total employment. ILO, *Yearbook (YB).*
Average hours worked. Weekly hours of work in the non-agricultural sector, *YB*. Weekly hours worked in manufacturing used for all countries except for the US, Japan and the UK from 1950-1960. Weekly hours worked in manufacturing are used in the whole period for Finland.
Real GDP. *NA*.
Consumer Prices. IMF, *International Financial Statistics (IFS).*
Equity prices. *IFS.*
Interest rates. *IFS.*

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Figure 1: Impulse response of capital productivity to equity prices, United States

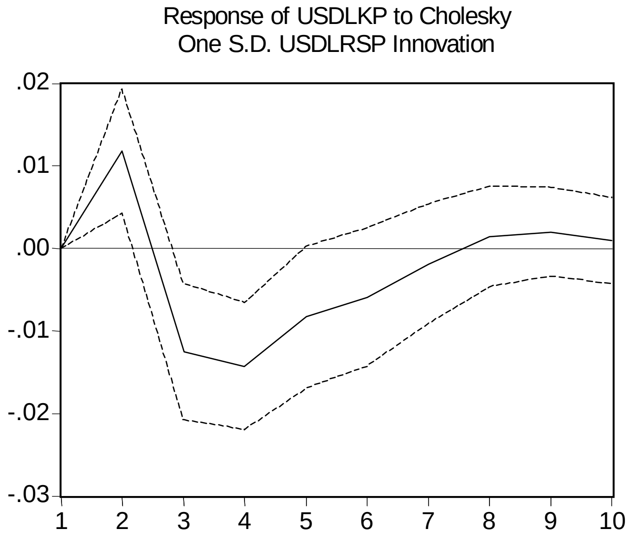

Table 1: Long term geometric averages for annual productivity growth and increases in real equity prices (1920-99)

	US	DE	CA	UK	FR	IT	JP	DK	AU	NL	SE
Labour productivity	1.61	3.14	2.14	1.97	2.98	2.32	3.78	2.00	1.81	2.04	2.47
Capital productivity	0.70	0.32	0.05	-0.64	0.57	0.22	-0.84	0.05	0.40	-1.01	-0.10
Total factor productivity	1.58	1.45	1.53	1.04	2.12	1.69	1.86	1.37	1.38	0.89	1.63
Real share prices	4.15	4.79	2.75	2.50	1.94	-0.37	0.77	0.79	2.20	2.26	4.42
Memo items:											
Real equity returns	8.50	7.65	6.16	6.85	5.63	2.43	4.88	5.64	7.90	7.22	8.44
Real bond yields	2.30	3.85	3.25	2.63	-3.83	-4.23	-1.65	3.57	2.30	2.37	2.28
Growth	3.03	3.26	3.76	2.18	2.92	2.94	4.31	2.84	3.49	3.10	2.89
Inflation	2.68	2.34	2.66	3.70	8.13	9.42	7.69	3.56	4.08	2.78	3.42

Key: US=United States, DE=Germany, CA=Canada, UK=United Kingdom, FR=France, IT=Italy, JP=Japan, DK=Denmark, AU=Australia, NL=Netherlands, SE=Sweden

Table 2: Post-war geometric averages for annual productivity growth and increases in real equity prices (1950-99)

	US	DE	CA	UK	FR	IT	JP	DK	AU	NL	SE
Labour productivity	1.63	3.90	1.93	2.28	3.25	3.28	5.09	2.47	1.91	2.55	2.22
Capital productivity	-0.23	-0.50	-0.43	-0.93	0.42	0.43	-0.90	-0.36	0.19	-0.65	-0.33
Total factor productivity	1.26	2.37	1.36	1.12	2.38	2.27	3.09	1.60	1.47	1.52	1.43
Real share prices	4.79	4.10	2.63	3.28	4.96	1.52	6.44	2.42	0.97	4.79	5.89
Memo items:											
Real equity returns	8.35	9.71	6.04	8.22	9.01	4.90	9.28	6.53	6.39	9.57	9.22
Real bond yields	2.43	4.03	3.26	2.56	2.08	2.27	1.80	3.78	2.07	2.54	2.01
Growth	3.06	3.77	3.92	2.43	3.52	3.64	5.84	2.92	3.85	3.50	2.59
Inflation	3.95	2.49	4.10	5.65	5.42	6.71	4.30	5.25	5.69	3.79	5.50

Key: see Table 1

Table 3: Unit root (DF) tests (* indicates stationarity at the 95% level), 1920-99

	US	DE	CA	UK	FR	IT	JP	DK	AU	NE	SE
RLR	-4.8*	-5.0*	-3.9*	-4.2*	-2.6	-2.7*	-4.2*	-4.6*	-2.9*	-3.7*	-3.3*
VOL	-3.1*	-4.3*	-3.8*	-4.0*	-3.7*	-4.4*	-3.9*	-3.3*	-4.0*	-5.2*	-3.9*
EQR	-5.0*	-5.0*	-5.6*	-6.7*	-6.8*	-4.5*	-4.8*	-5.1*	-5.3*	-4.9*	-4.9*
LRSP	-0.2	-1.1	-1.6	-1.1	-1.6	-2.4	-2.1	-2.2	-2.3	-0.2	0.7
DLRSP	-4.9*	-13.1*	-5.6	-6.1*	-6.2*	-5.0*	-4.6*	-5.2*	-5.4*	-4.7*	-4.9*
LCPI	1.5	1.3	0.7	0.2	-1.1	-1.2	-1.2	0.9	0.2	0.2	1.5
DLCPI	-4.4*	-7.1*	-3.6*	-3.0*	-2.5	-2.8*	-3.9*	-3.9*	-2.8*	-3.8*	-4.8*
LYD	-5.7*	-4.7*	-5.4*	-6.8*	-5.3*	-5.3*	-4.9*	-4.6*	-6.0*	-5.2*	-4.8*
LKP	-2.1	-2.8*	-2.5	-0.8	-1.9	-1.7	-1.3	-1.7	-1.6	-2.0	-1.2
DLKP	-5.1*	-5.6*	-4.3*	-5.7*	-4.3*	-5.6*	-5.1*	-4.8*	-5.5*	-6.1*	-5.0*
LLP	-1.6	-0.5	-0.6	-0.1	-0.6	0.1	0.1	0.2	0.2	-0.5	-2.2
DLLP	-5.3*	-5.7*	-3.7*	-6.7*	-4.3*	-4.4*	-4.0*	-4.0*	-6.2*	-5.0*	-6.3*
LTFP	-1.4	-1.7	-1.1	0.0	-0.7	-0.3	-0.6	0.3	1.0	-0.9	-0.9
DLTFP	-4.8*	-5.2*	-4.0*	-5.1*	-4.1*	-4.7*	-5.0*	-5.1*	-6.1*	-5.0*	-4.6*

Key: RLR=real long rate, EQR=real total return on equity, RSP=share price index, CPI=consumer price index, VOL=real share price volatility, TFP=total factor productivity, KP=capital productivity, LP=labour productivity, YD=deviation of GDP from Hodrick-Prescott filter. A “D” before the variable name indicates first difference, an “L” stands for log. For country codes see Table 1

Table 4: Granger causality tests for real share prices and productivity, estimated over 1920-99

* indicates Granger causality at the 95% level, * at 90% level

	Capital Productivity		Total factor productivity		Labour productivity	
Dependent variable	DKP	DRSP	DTFP	DRSP	DLP	DRSP
Independent Variable	DRSP	DKP	DRSP	DTFP	DRSP	DLP
US	**					
Germany		**				
Canada	**					
UK	**					
France		*				**
Italy	*					
Japan	**		**		**	
Denmark					**	
Australia	**		*			
Nether-lands						
Sweden	**					

Key: See Tables 1 and 3

Table 5: Block exogeneity tests for productivity from the VAR system, estimated over 1920-99

(Likelihood ratio tests for 22 restrictions where $\chi 2$ (22)=34)

	LR(kp)	LR(lp)	LR(tfp)
US	576	336	418
Germany	586	268	278
Canada	522	454	406
UK	574	564	446
France	596	434	324
Italy	622	362	250
Japan	548	484	394
Denmark	474	452	362
Australia	596	388	510
Nether-lands	418	368	344
Sweden	544	432	372

Table 6: Significant lags in the VAR system, estimated over 1920-99
(** significant at 95%, *significant at 90%)

VAR system	Capital Productivity		Total factor productivity		Labour productivity	
Equation	DLKP	DLRSP	DLTFP	DLRSP	DLLP	DLRSP
Variable	DLRSP	DLKP	DLRSP	DLTFP	DLRSP	DLLP
US	**		**			
Germany		**		**		*
Canada	**					
UK						*
France		**			**	
Italy	**	**	**	*	**	
Japan		*		**		
Denmark						**
Australia						
Netherlands						
Sweden	**	**				

Key: See Tables 1 and 3

Table 7: Variance decompositions for real share prices, using capital productivity (percent of forecast variance accounted for by variance in each variable)

Variable	Years	US	DE	CA	UK	FR	IT	JP	DK	AU	NL	SE
DLKP	1	0	2	0	0	2	12	2	1	0	0	0
	4	1	36	3	2	7	12	29	2	2	3	13
LYD	1	3	1	0	0	3	1	1	0	2	1	1
	4	2	0	1	2	5	4	1	1	5	1	5
DLCPI	1	13	0	2	10	0	1	23	0	7	1	1
	4	12	3	5	10	1	6	17	6	17	3	1
RLR	1	3	13	5	37	14	1	5	20	4	23	9
	4	3	9	4	34	15	1	3	24	3	22	9
VOL	1	8	2	5	9	0	0	0	0	7	1	7
	4	8	3	4	14	1	7	2	1	5	1	7
DLRSP	1	74	82	88	44	80	84	69	75	80	73	80
	4	73	48	83	37	71	70	47	66	68	69	66
Memo:												
DLRSP on DLKP	4	23	3	25	3	3	8	0	3	6	1	4

Key: See Tables 1 and 3

Table 8: Variance decompositions for real share prices, using labour productivity (percent of forecast variance accounted for by variance in each variable)

Variable	Years	US	DE	CA	UK	FR	IT	JP	DK	AU	NL	SE
DLLP	1	2	2	1	1	0	3	1	0	3	0	0
	4	4	22	5	2	2	4	19	7	4	2	4
LYD	1	0	13	1	3	5	10	0	1	5	2	1
	4	1	15	3	6	10	11	9	1	6	2	8
DLCPI	1	10	0	4	5	1	2	29	1	6	0	2
	4	9	1	6	7	2	8	21	7	16	2	2
RLR	1	3	13	6	34	17	2	5	26	4	23	7
	4	4	10	34	9	17	2	5	25	3	22	7
VOL	1	9	4	10	11	0	2	0	0	3	1	12
	4	8	5	15	11	2	5	0	1	2	1	12
DLRSP	1	76	68	42	73	78	80	65	72	79	73	78
	4	74	45	36	67	68	70	46	59	69	71	67
Memo:												
DLRSP on DLLP	4	2	1	0	4	7	8	0	1	1	0	1

Key: See Tables 1 and 3

Table 9: Variance decompositions for real share prices, using total factor productivity (percent of forecast variance accounted for by variance in each variable)

Variable	Years	US	DE	CA	UK	FR	IT	JP	DK	AU	NL	SE
DLTFP	1	0	2	1	1	0	1	2	0	1	0	0
	4	2	22	5	2	4	6	38	2	3	2	5
LYD	1	0	8	1	1	9	5	2	0	4	0	0
	4	1	18	2	2	11	7	4	2	3	0	6
DLCPI	1	9	0	1	5	1	0	10	0	2	0	2
	4	9	2	4	5	2	7	8	2	12	1	2
RLR	1	4	14	5	41	15	1	2	26	7	24	7
	4	4	9	5	38	16	1	3	26	6	23	7
VOL	1	8	3	4	9	0	2	7	0	7	1	12
	4	7	3	4	15	2	7	9	1	6	1	12
DLRSP	1	79	73	86	43	74	84	77	74	78	74	78
	4	76	46	80	38	65	70	38	67	69	72	67
Memo:												
DLRSP on DLTFP	4	5	0	6	1	1	11	0	1	7	0	1

Key: See Tables 1 and 3

Table 10: Impulse response functions for selected variables (responses to 1 standard deviation shocks in other variables) (* significant at 95%)

Year	1	2	3	4	5	6
DLKP on DLRSP						
JP	0.04	0.15*	-0.05	-0.1*	-0.07*	-0.06*
DE	0.04	-0.09*	0.16*	-0.01	-0.05	-0.06*
FR	0.04	-0.04	-0.02	0.04*	0.04*	0.02
SE	0.02	-0.01	-0.05*	-0.04*	-0.02	0.0
DLRSP on DLKP						
US	0	0.012*	-0.013*	-0.015*	-0.008*	-0.006
CA	0	0.011*	-0.012*	-0.014*	-0.01*	-0.007
AU	0	0.002	-0.008*	-0.005*	-0.002	-0.001
SE	0	0.004*	-0.001	-0.002	-0.002	-0.001
IT	0	-0.009*	-0.003	0.011*	0.0	0.0

Key: See Tables 1 and 3

Table 11: Variants on the basic VAR – variance decompositions for capital productivity

	Years	US	DE	CA	UK	FR	IT	JP	DK	AU	NL	SE
(1) DLGDP instead of LDY												
DLKP on DLRSP	1	0	3	0	0	0	20	7	6	3	0	9
	4	2	34	1	1	7	18	46	13	4	4	12
DLRSP on DLKP	4	17	1	17	5	3	11	1	1	6	2	12
(2) EQR instead of DLRSP												
DLKP on EQR	1	0	1	0	0	1	14	0	0	0	0	0
	4	1	23	1	4	9	13	58	5	2	3	10
EQR on DLKP	4	20	3	15	2	2	10	0	3	5	1	8
(3) Including DLUSRSP as exogenous (DLUKRSP for US)												
DLKP on DLRSP	1	0	0	0	0	1	11	1	0	0	0	1
	4	1	13	4	2	6	10	27	3	2	3	11
DLRSP on DLKP	4	20	5	23	1	3	8	1	1	7	2	3
(4) Estimate over 1950-99												
DLKP on DLRSP	1	0	0	0	3	2	0	8	0	0	0	0
	4	6	5	5	13	9	5	12	3	17	5	3
DLRSP on DLKP	4	28	1	23	1	5	11	9	2	8	11	3

Key: See Tables 1 and 3

Table 12: Vector error correction estimation using capital productivity, 1920-99
Based on Johansen procedure

Vector normalised on LRSP, maximum eigenvalues

	US	DE	JP	DK	AU	SE
LKP	-1.2**	-0.6**	-0.3	-3.3**	-1.6	-0.6
	(0.4)	(0.03)	(0.5)	(0.8)	(1.1)	(2.6)
LCPI	-0.5**	-1.1**	0.6**	-1.0**	-0.2*	-1.6**
	(0.1)	(0.05)	(0.1)	(0.1)	(0.1)	(0.2)
Intercept in CE	Y	N	Y	N	N	Y
Trend in CE	N	N	Y	N	N	N
CE Significant in VAR equations						
DLRSP	**	**	**	**	**	**
DLKP		**				**
DLCPI	**	**	**	**		**
Variance decomposition (after 10 years)						
LKP explained by LRSP	12	1	4	10	17	53
LRSP explained by LKP	1	28	59	1	3	4

Key: See Tables 1 and 3. CE=cointegrating equation.

Note: trace test showed no cointegration for CA, UK, FR, IT and NL

Table 13: Vector error correction estimation using labour productivity, 1920-99
Based on Johansen procedure

Vector normalised on LRSP, maximum eigenvalues

	US	DE	CA	UK	JP	DK	AU	SE
LLP	-1.6**	-0.3**	-1.1**	-4.6**	-1.1**	-0.6	-1.9*	-2.8**
	(0.5)	(0.02)	(0.2)	(0.8)	(0.2)	(0.5)	(1.0)	(0.7)
LCPI	0.06	-0.6**	0.2	1.5**	0.4**	0.007	0.4	0.6
	(0.2)	(0.04)	(0.16)	(0.3)	(0.06)	(0.2)	(0.4)	(0.4)
Intercept in CE	Y	N	Y	Y	Y	Y	Y	Y
Trend in CE	N	N	N	N	N	N	N	N
CE Significant in VAR equations								
DLRSP	**	**	**		**	**	**	**
DLLP								
DLCPI	**	**	**	**		**		**
Variance decomposition (after 10 years)								
LLP explained by LRSP	3	1	8	3	10	2	5	3
LRSP explained by LLP	10	24	2	1	72	10	1	1

Key: See Tables 1 and 3.CE=cointegrating equation.

Note: trace test showed no cointegration for FR, IT and NL

Table 14: Vector error correction estimation using TFP, 1920-99
Based on Johansen procedure
Vector normalised on LRSP, maximum eigenvalues

	US	DE	UK	JP	DK	AU	SE
LTFP	-1.7**	-0.24	-0.38**	-1.04**	-0.66**	-0.57**	-2.7**
	(0.5)	(0.5)	(0.05)	(0.03)	(0.03)	(0.06)	(0.9)
LCPI	0.04	-0.012	-0.3**	0.2**	-0.06	-0.12	0.06
	(0.2)	(0.1)	(0.08)	(0.05)	(0.06)	(0.11)	(0.3)
Intercept in CE	Y	Y	N	N	N	N	Y
Trend in CE	N	Y	N	N	N	N	N
CE Significant in VAR equations							
DLRSP	**	**	**	**	**	**	
DLTFP					**		
DLCPI	**	**	**		**		**
Variance decomposition (after 10 years)							
LTFP explained by LRSP	6	3	7	4	2	1	18
LRSP explained by LTFP	2	13	3	66	6	11	1

Key: See Tables 1 and 3 CE=cointegrating equation.

Note: trace test showed no cointegration for CA, FR, IT and NL