



BANK OF ENGLAND

# Speech

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## **Monetary Policy and the Supply Side**

Speech given by

John Vickers, Chief Economist, Bank of England

At the Society of Business Economists

15 March 2000

# **MONETARY POLICY AND THE SUPPLY SIDE\***

**John Vickers**  
**Chief Economist**  
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## **Introduction**

To come from the Bank of England to speak to the Society of Business Economists is to be a nominal economist among real economists. Businesses like yours and those who work in them are the real economy—the supply side—the workings of which ultimately determine the paths of real economic variables such as output growth, employment and productivity. The Bank's paramount monetary policy objective of price stability, on the other hand, concerns (the rate of inflation of) a nominal variable—the general price level or, inversely, the purchasing power of money. The MPC pursues that objective by determining the terms of supply for money itself.

Interactions between the real and nominal sides of the economy are my subject this evening. I want to discuss some possible implications for inflation—and hence for monetary policy—of some current developments on the supply side, in particular the ongoing revolution in information and communications technology.

Views on the relationship between inflation and the real economy have shifted substantially over the years. Long ago, in the age of the Paleo Paradigm, it was believed that there was a trade-off such that higher real activity could be sustained at the expense of higher inflation. That view having collapsed under the weight of both theory and facts—a rare and thus devastating combination—the current conventional (and correct)

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wisdom is that higher inflation cannot increase real activity sustainably. So the best that monetary policy can do for the real economy is to secure and maintain actual and expected price stability.

Recently, moreover, a view has gained ground that special supply-side developments can ease the task of monetary policy—in particular, that current technological and competitive developments are helping, or will very soon help, to suppress inflation. Then the prospect would be higher growth together with *lower* inflation. (And indeed in the Necro Paradigm inflation is dead.)

Assessing this view involves answering two questions:

1. What are the implications for growth of current and prospective supply-side developments?
2. What do these developments mean for inflation, and hence for monetary policy that targets inflation?

### **Information technology and economic growth**

Twenty years ago I worked for IBM on a competition law case. The question was whether IBM possessed, and was abusing, a dominant position in the computer hardware industry. A similar antitrust case had been brought against IBM by the US Government long before—when President Johnson’s term of office was drawing to its close in January 1969. The fact that the computer industry was large enough to see major antitrust litigation more than thirty years ago shows that the large-scale commercial exploitation of information technology (IT) is far from new.

Since then the costs of computing power have gone on falling dramatically, the personal computer has become pervasive in home as well as office, the accessibility and capability of IT have been enormously enhanced by ever-improving user-friendly software, and, spurred by falling telecommunications costs, computer networking has exploded. And now there is the Internet.

These developments—the Internet above all—are self-evidently amazing. They hold out the prospect of substantial productivity gains in the years to come, just as IT has for many years past. Developments in IT might also help to sharpen competition, as new forms of business organisation challenge older ones, and by improving price transparency generally. But what does all this add up to in macroeconomic terms?

Ironically, just as the IT revolution was getting under-way, measured productivity growth in the United States and elsewhere slowed down. The table shows Jorgenson and Stiroh's (1999) analysis of US economic growth from 1948 to 1996. In the golden age from 1948 to 1973, estimated annual output growth was 4%, and labour productivity growth—the growth of output per unit of labour—was 3%. Total factor productivity (TFP) growth—ie allowing also for capital and consumer durable inputs, which grew strongly over the period—was, on these estimates, a little under 1½%. In the 1973-1996 period, by contrast, output growth slowed to about 2¾% despite a rise in labour input growth, productivity growth fell to around 1½% (less in the early 1990s), and TFP growth was less than ½%.

This slowdown, which forms the background to the late-1990s US growth spurt, is the Solow productivity paradox. Robert Solow quipped in 1987 that 'you can see the computer age everywhere but in the productivity statistics'. Various explanations have been put forward for the paradox of a productivity slowdown in the age of IT.

The first possibility is measurement problems (see Griliches (1994)). The balance of economic activity in developed economies has increasingly shifted towards service sectors whose output is hard to measure. If the under-recording of 'true' output has increased since the early 1970s—which is something we ultimately have to guess at—then the slowdown in productivity growth will have been overstated by the official figures. (Relatedly, inflation in the 'true' cost of living may have been overstated by available price indices. But inflation targets for monetary policy can be based only on available indices.)

Second, since it is only recently that computers have become a large part of the capital stock, perhaps one should not have expected a major IT contribution to growth much before now. On Jorgenson and Stiroh's estimates in the table, computer outputs

accounted for about 0.4% of annual US growth in 1990-96, and computer inputs contributed less than 0.2% to growth. Computers by then accounted for as much as a fifth of the contribution to growth of capital services, reflecting the vast shift towards IT investment prompted by the sharp declines in IT equipment prices that reflect the dramatic technological advances made by the computer industry. But the gains to IT investment have, on these figures, accrued to computer producers and their customers, rather than generating externalities in the form of TFP growth.

Third, it could be that an IT-based acceleration in productivity has just got under-way in the US and is just around the corner in other countries such as the UK. Ten years ago Paul David (1990) suggested, on the basis of the historical experience of electrification in the US, that it was too soon to be disappointed that the computer revolution had not yet led to a discernible acceleration of economy-wide productivity. Commercial electricity generation began in the 1880s but did not have a substantial measurable impact on US productivity until the 1920s.

The diffusion of general-purpose technologies such as electricity and IT can take a long time and be arduous processes insofar as scarce resources are absorbed in the associated processes of economic restructuring. As David (2000) puts it:

‘For these changes to be set in place typically requires decades, rather than years. Moreover, while they are underway there is no guarantee that their dominant effects upon macroeconomic performance will be positive ones’.

And he notes the limits to historical analogy. While history may teach that an instant productivity payoff is not to be expected and that its absence is not inconsistent with a large eventual payoff, it cannot foretell the time path of such gains. That said, David is cautiously optimistic that, relative to the experience of the past two decades, the future may well bring a resurgence of TFP growth resulting from the exploitation of IT.

Is that what we are seeing in the US right now? Charts 1 and 2 show the level and growth rate of US non-farm business labour productivity since 1970. Since 1996, annual productivity growth has averaged about 2½%, 1 percentage point higher than over the 1973-96 period. This is undoubtedly impressive, but is it evidence at last of a substantial broad-based productivity impact of IT across the economy as a whole?

Robert Gordon (1999) is doubtful. His decomposition of the US productivity growth recovery accounts for all of it in terms of three factors:

- (i) The normal cyclical rise in productivity that typically occurs in economic upswings;
- (ii) large productivity gains in the computer industry itself; and
- (iii) improvements in inflation measures that have had the effect of increasing measured productivity growth.

This is not to deny the good productivity news. Rather, it is to locate it, as far as (ii) is concerned, in the computer-producing sector of the US economy, and not generally across the economy.

Oliner and Sichel (2000), however, reach a somewhat different view from their analysis of the recent data. Unlike Gordon, they do not attempt to distinguish between cyclical and trend movements in productivity. Of the 1% rise in US labour productivity growth between the first and the second half of the 1990s, Oliner and Sichel attribute  $\frac{1}{2}\%$  to the increasing use of IT capital throughout the non-farm business sector, and another  $\frac{1}{4}\%$  to advances in the technology for producing computers. On this view, IT is most of the story behind the recent acceleration in US productivity.

So far I have dwelt on the US evidence because it has been so extensively debated, because productivity there has recently picked up so sharply, and because the US is the country that has been at the leading edge of the IT revolution since its commercial inception. (But let us not forget the intellectual forefathers of IT such as Charles Babbage and Alan Turing.) What are the implications for us in the UK?

Annual labour productivity growth over the past 40 years in the UK has been about 2% on average—see Chart 3. Since 1996, however, just as productivity growth in the US picked up, it has been not much above 1% in the UK. It would be pessimistic to have as one's central expectation a persistence of 1% or so productivity growth in the period

ahead, though uncertainty and volatility in the data mean that 1%, like 3%, is an entirely possible outcome. In good part because of the strength of business investment in the late 1990s (see Chart 4)—probably a growing share of which has been in IT—a more likely outcome would seem to be a rise in productivity growth, perhaps to around its longer-run trend rate of about 2%. (Together with annual labour force growth of near ½%, this would imply a central expectation for output growth of around 2½%.) Anyhow, that is what all the MPC members have assumed as the central case in recent projections. (We have also assumed a further decline in the stock/output ratio, which business-to-business e-commerce may help to bring about.)

Higher productivity growth than that is entirely possible—as is less—but 2% is not far short of the 2½% productivity growth that the US has experienced in the remarkable recent years. And although it is growing rapidly in the UK, the IT sector, which appears to have experienced especially sharp productivity gains, is a larger part of the US economy.

Is 2% annual productivity growth large or small in broader historical terms? From a long-run perspective it is quite large. No historical knowledge is needed to show this. If it had grown at that rate since 1066, output per head would then have been one hundred millionth of its current level. Even with 1% annual productivity growth, output per head would have been an impossible ten thousand times smaller than now.

Estimates of the trend rate of growth of output in the British industrial revolution show a slow but steady rise from about 1% in the second half of the 18th century to around 2% in the early 19th century, then a peak of perhaps 2½% mid-century, before a significant slowing of growth (see Crafts (1998)). Allowing for labour force growth, productivity growth was much smaller than these figures, and, according to Crafts, ‘total factor productivity growth was apparently very modest during the Industrial Revolution and was less than 1% per year throughout the 19th century’. This despite inventions such as the steam engine, railways, steel and the telegraph—the ‘Victorian Internet’ discussed in Wadhvani (2000).

But what about the more recent experiences of the post-war golden age of growth in Western Europe, and of the East Asian economies which at times grew at rates close to 10%? In the latter case, a good deal of the spectacular growth performance can be accounted for by demographics, fast capital accumulation, and the seizing of huge technological catch-up opportunities—see Young (1995). Some of those factors are also relevant to the experience of post-war Europe, which shows that high labour productivity growth over an extended period is by no means unprecedented, especially in the presence of strong capital investment. But it is historically rather unusual.

It is nevertheless quite possible that the IT revolution could at some point bring a period of historically unusual productivity growth. For example, it is plausible that the diffusion of Internet technology is and will be much faster than that of previous innovations. But some caveats must be kept in mind.

First, productivity growth does not happen by magic. Without continual innovation, growth would slow, and the main engine of innovation at present is IT. So while IT will no doubt add to productivity growth in the sense that it would be lower without IT, productivity growth without IT might have been lower than average past rates.

Second, other things being equal, the level of innovation must keep rising for productivity growth not to slow down. (The reference to ‘other things being equal’ is because innovation is by no means the only source of productivity growth. Others include exploitation of scale economies, gains from structural adjustment, and human capital investment.) Loosely speaking, steady growth requires innovation to grow as fast as output. So if the feeling is correct that there is more innovation now than there used to be, it does not necessarily follow that productivity growth will be higher than in the past, because ‘a greater number of new things is not necessarily a greater rate of new things’ (Triplett (1999)).

Third, strong capital accumulation is generally a prerequisite for high labour productivity growth. Gains from IT depend on investment in physical capital and in intangible, but nonetheless important, knowledge capital and human capital. Investment is one way in which the prospect of supply-side improvement may stimulate demand. This is a suitable point to turn to the monetary policy implications of IT.



## Implications for monetary policy

Now let us *assume* that the IT revolution has created an unusual opportunity for a period of substantially higher productivity growth, and perhaps also for a structural intensification of competition. What then are the implications for inflation, and hence for monetary policy?

At first sight this might seem obvious. If costs are falling because of greater productivity, and if prices are if anything decreasing in relation to costs, then the pressure on prices would surely seem to be downwards.

But that is to confuse real and nominal (ie money-denominated) variables. Higher productivity means that more output can be produced from given inputs, so the price of output will tend to decrease relative to the prices of inputs. In particular, if competition does not weaken, output prices will fall relative to input prices such as wages. That is to say, wages will rise relative to prices—the real wage will increase. But this, by itself, says nothing about the effect on the level or rate of change of prices, or of nominal wages, or of nominal unit labour costs.

To put the point starkly, one could infer nothing about the path of inflation—movement in the value of money—from knowledge that oranges were getting cheaper in relation to lemons.

Shifts in productivity and competition can certainly affect inflation, but—as Willem Buiter (2000) has emphasised with his customary clarity—the links are by no means straightforward. The simple argument above that rising productivity means downward pressure on prices is at best seriously incomplete.

A full argument must involve monetary variables. Inflation is after all a monetary phenomenon. In that spirit, suppose for a moment that monetary policy involved setting a path for the growth of some monetary aggregate  $M$ . Holding that path fixed, higher productivity growth would mean lower inflation if velocity—the ratio of nominal

demand to  $M$ —did not shift. Inflation would then have to fall to keep the path of nominal demand the same.

But why would velocity stay the same? Velocity is notoriously variable, at least for most UK monetary aggregates. And it seems quite plausible that IT developments such as e-commerce should increase velocity, at least for narrower monetary aggregates, by facilitating economies in holdings of transactions balances. (Indeed, there has been some speculative discussion recently of a prospect of the ultimate demise of money, though it is interesting that the 1990s were the first decade since at least the 1940s that narrow money velocity *fell* in the UK, perhaps partly because of lower nominal interest rates.) If developments in IT increased both productivity growth and velocity in the thought experiment with a fixed money growth path, then the implications for inflation would be mixed.

However, although monetary quantities are valuable indicator variables, monetary policy in practice involves choosing the (inter-temporal) *price* of money—the short-term nominal interest rate—with the explicit aim in the UK of achieving the inflation target. The question then arises of whether, for a given nominal interest rate path, the arrival of a productivity-boosting supply-side opportunity will tend to increase or decrease inflation. And of whether, by implication, interest rates need to be increased or decreased to keep inflation on target.

In a range of simple macroeconomic models, the dynamics of inflation depend, among other things, on the output gap—actual output minus potential output. (See, for example, Clarida, Gali and Gertler (1999), McCallum and Nelson (1997), and Woodford (1999).) A positive output gap tends to go with rising inflation—as demand presses on capacity—and an increasing output gap tends to mean accelerating inflation. Conversely for negative and falling output gaps.

This sort of framework, which can be built up from microeconomic foundations, offers a simplified but coherent account of how supply-side developments can affect the paths of nominal variables. For example, a positive supply shock—such as unexpectedly higher (total factor) productivity growth, or a fall in the unemployment rate consistent

with steady inflation—reduces the output gap and so lowers the path of inflation for a given path of nominal interest rates.

At first sight this might seem to justify the view that the IT revolution, as a positive supply shock, will moderate inflation. After all, we are assuming here that it will raise productivity growth unusually. (Moreover, as Sushil Wadhvani (2000) has stressed, it might also reduce the NAIRU via effects on product market competition and by improving the efficiency of matching people to jobs in the labour market.)

But supply ‘shocks’ are so called for a reason—they are *unexpected* changes in supply capacity. If the Internet, say, improves productivity (relative to a world without the Internet), that will now hardly be a surprise. An innovation such as the Internet is perhaps better described, when it arrives, as a shock to future productive potential. Once an improvement to the supply-side has come to be anticipated—whether or not it has yet been realised—demand too may be boosted. Then the innovation imparts a demand shock as well as a supply shock. So depending on the links between the supply side and demand, a relevant question is whether the productivity improvement turns out to be more or less than expected. And timing is important, for an anticipated supply-side improvement could boost demand by more than supply in the short term.

Two kinds of demand channel matter. The first, mentioned above, is direct investment demand, without which the supply-side improvement is unlikely to be realised. New technological opportunity creates a high marginal return on investment in new technology and so leads to a surge of investment in capital embodying it. Insofar as the new technology allows extra economies in inventory investment or reduces the marginal return on investment in ‘old’ technologies, there may be some offset to the expansion in investment demand, but the likely direction of the overall effect seems clear.

Moreover, new technological opportunity may encourage various other forms of investment in the broad economic sense, including training and restructuring of organisations and employment. Investment of this kind may temporarily reduce supply—for example because employees investing in training are not full-time in production activities—rather than being part of investment demand.

The second channel is via increases in consumer demand in anticipation of future income gains. The most prominent aspect of this mechanism concerns stock market wealth. Stock markets generally rose strongly in the last decade—see Chart 5. Especially striking over the past year or so has been the extraordinary rise of IT sector stock prices—see Chart 6. (Some stellar performers have yet to make profits, suggesting that the hallmark of exceptional stock market valuation is no longer a very high price/earnings ratio, but an appropriately negative one.) As well as stimulating consumption, high stock market values may also further boost investment by lowering the cost of capital.

Stock market wealth gains related to IT have been very large in the US. They have been large, but not as large, in the UK because the IT sector is proportionately smaller here—see the Box on page 10 of the Bank’s February *Inflation Report*. But of course rises in the US and other overseas stock markets affect demand in the UK via external demand and wealth effects for domestic holders of international stocks.

Current market valuations of IT stocks, if interpreted as reasonable expectations of future dividend flows, imply enormous future profits for IT companies. This accords with the hypothesis that IT is about to bring substantial increases in productivity growth (a good part of which the IT companies will capture). But the general level of current stock prices, relative to the past, sits less easily with the proposition that competition in the economy as a whole, as distinct from particular sectors, is about to be greater than in the past.

Stock market wealth is the most visible but not the only source of demand stimulus in anticipation of productivity gains. Unusually high productivity growth would certainly be positive for real labour income growth—and hence for human capital wealth—especially if accompanied by a structural increase in competition. (In overall demand terms, a partial offset to the gain to labour income from greater competition would be the corresponding loss to profit income, but share prices should already reflect this in the case of quoted companies.) Once these labour income gains were expected, they would be a stimulus to consumer demand whether or not the expected gains had yet started to come through.

This does not presume that households spend freely out of expected ‘permanent income’. Many households are near the limit of borrowing constraints, but many (including savers) are not, especially in an environment of financial liberalisation. And attitudes to risk and uncertainty may limit the spending even of the unconstrained. The point remains, however, that expectations of greater productivity growth and competition, if shared by households, could significantly increase consumer demand through effects on non-financial, as well as financial, wealth.

One way of drawing together these points is by reference to the concept of the *natural rate of interest*, which is defined as the short-term real rate of interest that would prevail in an economy with fully flexible prices (and hence always a zero output gap).

If a new technological opportunity appears unexpectedly, it would be normal in a wide and far-from-perverse range of circumstances for the natural rate of interest to *increase* for a period. The new opportunity increases the marginal return on investment—specifically, on investment to exploit the new technology. The marginal reward for saving—ie, postponing consumption—must rise correspondingly in order to keep demand in line with potential supply (and the output gap equal to zero).

A standard economic relationship, which is derived from the inter-temporal optimisation behaviour of (unconstrained) consumers, links the real rate of interest positively to the growth rate of consumption. The real rate of interest is higher when consumption growth is higher because the richer I expect to be in the future than now, the more reward I will need to defer some consumption from now to the future. The arrival of a new technological opportunity seems likely to be doubly positive for consumption growth. If exploited it will raise output growth, and, in order to be exploited, it will require substantial investment, and hence saving, in the near term. In that event, in order to bring demand and supply into balance, the natural rate of interest will be higher than if the technological opportunity had not arisen.

This account has for simplicity glossed over open-economy aspects. If the new technological opportunity were country-specific and the country small in relation to the world economy, then the effect on the relevant natural rate of interest might be negligible. The happy country could consume ahead of the full realisation of the supply-

side improvement, run a trade deficit, and finance itself by borrowing from abroad. The technological opportunities offered by IT are not country-specific, though the rates of diffusion of their benefits are likely to vary, perhaps unpredictably, from place to place.

It is not just a theoretical or perverse possibility that the arrival of a new technological opportunity might, on unchanged real interest rates, increase demand by more than supply in the short term. In his Humphrey-Hawkins testimony to Congress last month, Federal Reserve Board Chairman Alan Greenspan (2000) stated that:

‘Accelerating productivity growth entails a matching acceleration in the potential output of goods and services and a corresponding rise in the real incomes available to purchase the new output. The problem is that the pickup in productivity tends to create even greater increases in aggregate demand than in potential aggregate supply.’

The prospect of demand increasing by more than supply in the short term is also a feature of some recent analysis of business-to-business (B2B) e-commerce by Brookes and Wahhaj (2000). They estimate that annual growth could be higher by ¼% over the next decade on account of B2B. However, imparting a ‘B2B shock’ in simulations of the IMF’s Multimod model of the world economy causes higher inflation and interest rates in a range of industrialised countries in the short term, but not in the long run. Demand boosts from anticipatory rises in equity markets are particularly emphasised by Brookes and Wahhaj, and they judge the US to be the country most susceptible to this effect.

Suppose, then, that prospective productivity gains do tend to cause demand to increase by more than supply in the short term on unchanged real interest rates. Does it follow that actual real interest rates—and therefore nominal interest rates—need to be higher, in step with the higher natural interest rate, in order to keep inflation on target? This requires examination of how the sources of the productivity gains might also shift the relationship between the output gap and inflation.

This question is hard. A full attempt at it, which would involve analysis of the microeconomics of price-setting, is well beyond my scope. But here are some general comments.

First, if short-term nominal inertia is greater for costs than for prices, which I think is plausible in the case of wage costs, then a reduction in price-cost margins would tend temporarily to lower price inflation (for a given output gap path). But the quantitative importance of this point is hard to gauge. The existence, size and phasing of a prospective structural compression of price-cost margins on account of IT are unclear. And just as firms exploiting new technologies compete with others to win customers, so they compete—very evidently—for resources such as skilled employees and investment capital, and in the process put some upward pressure on costs generally.

Second, if the long-run consequence of e-commerce were ever more widespread real-time pricing, then the importance of nominal price stickiness would diminish over time. My bet is that the convenient underpinning institution of central bank money would still survive, but monetary policy would have ever less traction on the real economy. The job for monetary policy would be to set the nominal interest rate equal to the natural rate of interest plus the inflation target. Monetary policy errors would have less effect on the real economy, but with less price stickiness might lead to rather volatile inflation. I am unsure whether monetary policy would be more or less boring in these circumstances.

## **Conclusion**

On the first question posed—the impact on economic growth potential of current and prospective technological advances—I am a cautious optimist. Prospects seem good for a sustained recovery in UK productivity growth from its subdued level of recent years. It is possible that there will be a leap to a historically high productivity growth rate over the next couple of years—the horizon that matters most in setting monetary policy—but that would be rash to presume. Past growth has stemmed from the exploitation of past innovations, which were no doubt spectacular in their day, just as computers were yesterday and the Internet is today. And history teaches that the lags from innovation to growth tend to be long and variable—more so than for monetary policy. Hence the caution with the optimism. We can but wait and see, so neither an ostrich nor a lemming be.

The second question concerned the implications for inflation. If IT is bringing a supply-side revolution, cannot monetary policy be eased for a while? That simply

does not follow. Indeed, the arrival of an unusual supply-side opportunity could easily expand demand by more than supply initially, so that the natural real rate of interest goes up, not down, in the short term. That does not lead me to presume that the IT revolution has upward implications for inflation and nominal interest rates, because other, possibly offsetting, effects could also be at work, for example involving competition. But, equally, I see no strong grounds to presume that the overall effect on inflation is downward. This conclusion might seem like a classic case of 'on the one hand, on the other hand' economics. It is, and that should be no surprise. The supply side cannot be expected to take care of the value of money.

That is the task for monetary policy, and the reason why monetary policy is aimed at price stability, not a growth target. No one knows how the supply-side potential of the economy will grow, or the trajectory of demand in relation to supply. Inflation targeting—especially with a symmetric target—is a framework for a flexible and forward-looking response from monetary policy to these and other uncertainties in the light of unfolding data. Whatever the supply side may have in store, delivering low and stable inflation—and being expected to do so—is how monetary policy can give sustainable growth its best chance.



## REFERENCES

- Brookes, M, and Wahhaj, Z (2000), 'The Shocking Economic Effects of B2B', Goldman Sachs Global Economics Paper no 37.
- Buiter, W (2000), 'The New Economy and Old Monetary Economics', unpublished paper, Bank of England.
- Clarida, R, Gali, J, and Gertler, M (1999), 'The Science of Monetary Policy: A New Keynesian Perspective', *Journal of Economic Literature*, 37, 1661-1707.
- Crafts, N (1998), 'Forging Ahead and Falling Behind: The Rise and Relative Decline of the First Industrial Nation', *Journal of Economic Perspectives*, 12, 193-210.
- David, P (1990), 'The Dynamo and the Computer: An Historical Perspective on the Productivity Paradox', *American Economic Review Papers and Proceedings*, 80, 355-61.
- David, P (2000), 'Understanding Digital Technology's Evolution and the Path of Measured Productivity Growth: Present and Future in the Mirror of the Past', forthcoming in Brynolfson, E, and Kahin, B, eds, *Understanding the Digital Economy*, MIT Press.
- Gordon, R (1999), 'Has the "New Economy" Rendered the Productivity Slowdown Obsolete?', working paper, Northwestern University.
- Greenspan, A (2000), Testimony before the U.S. House of Representatives Committee on Banking and Financial Services, 17 February.
- Griliches, Z (1994), 'Productivity, R&D, and the Data Constraint', *American Economic Review*, 84, 1-23.
- Jorgenson, D, and Stiroh, K (1999), 'Information Technology and Growth', *American Economic Review Papers and Proceedings*, 89, 109-122.
- McCallum, B, and Nelson, E (1997), 'An Optimizing IS-LM Specification for Monetary Policy and Business Cycle Analysis', NBER working paper 5875.
- Oliner, S, and Sichel, D (2000), 'The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?', paper given at the conference on Structural Change and Monetary Policy at the Federal Reserve Bank of San Francisco, 3-4 March.
- Triplett, J (1999), 'Economic Statistics, the New Economy, and the Productivity Slowdown', *Business Economics*, 34, 13-17.
- Wadhvani, S (2000), 'The Impact of the Internet on UK Inflation', speech delivered at the London School of Economics, 23 February.

Woodford, M (1999), 'Optimal Monetary Policy Inertia', *Manchester School Supplement*, 1-35.

Young, A (1995), 'The Tyranny of Numbers: Confronting the Statistical Realities of the East Asian Growth Experience', *Quarterly Journal of Economics*, 110, 641-680.

## Table A

### Sources of US Economic Growth 1948-1996

	1948-1973	Growth rate 1973-1990	1990-1996
<b>Outputs</b>			
Total output	4.020	2.857	2.363
Non-computer	3.978	2.650	1.980
Computer outputs	0.042	0.207	0.384
<b>Inputs:</b>			
Capital services	1.073	0.954	0.632
Non-computers	1.049	0.845	0.510
Computers	0.025	0.109	0.123
Consumers' durables	0.550	0.426	0.282
Non-computers	0.550	0.414	0.242
Computers	0.000	0.012	0.040
Labour input	1.006	1.145	1.219
Aggregate total factor	1.391	0.335	0.231

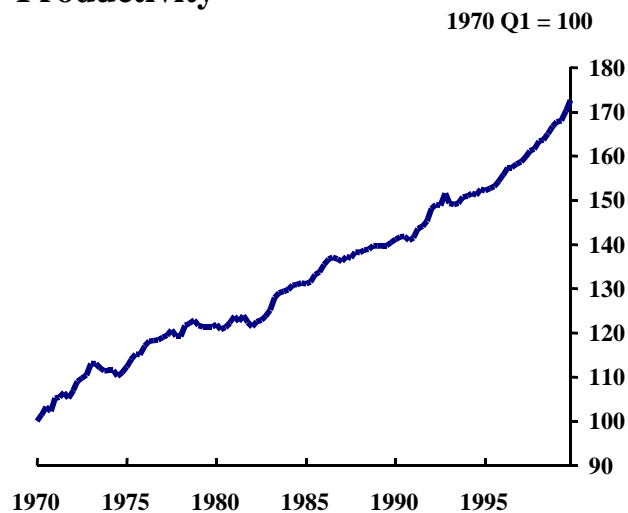
Notes: Contribution of inputs and outputs are real growth rates weighted by average, nominal shares. All average annual

Source: Jorgenson and Stiroh,

[This analysis is based on data available prior to the comprehensive National Accounts revisions of October

## Chart 1

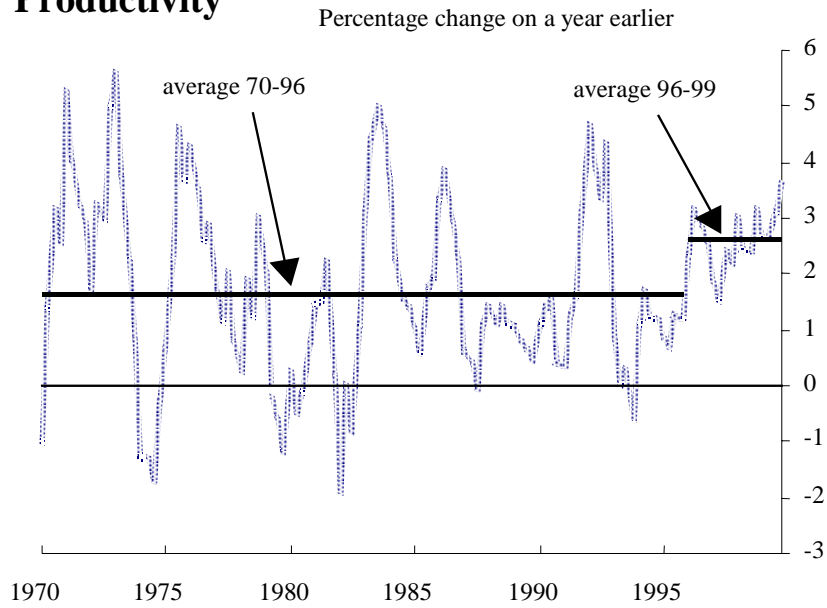
### US Non-Farm Business Sector Labour Productivity



Source: Primark Datastream

## Chart 2

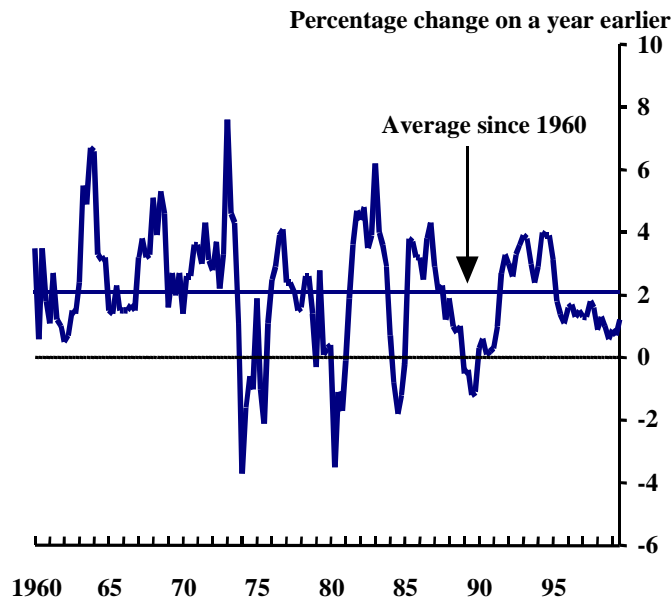
### US Non-Farm Business Sector Labour Productivity



Source: Primark Datastream

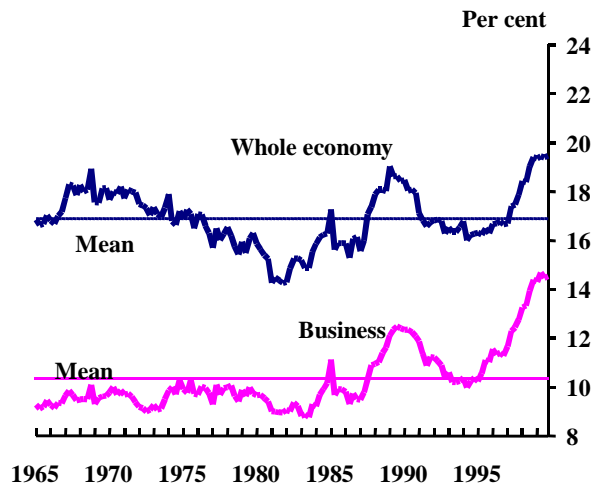
## Chart 3

### UK Labour Productivity GDP Per Person Employed



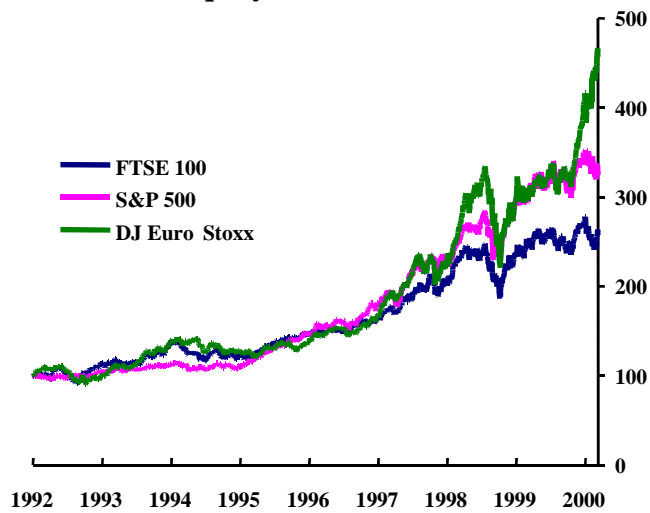
Sources: ONS and Bank of England

**Chart 4**  
**Investment as a Share of GDP**



Note: At constant prices.  
 Sources: ONS and Bank of England

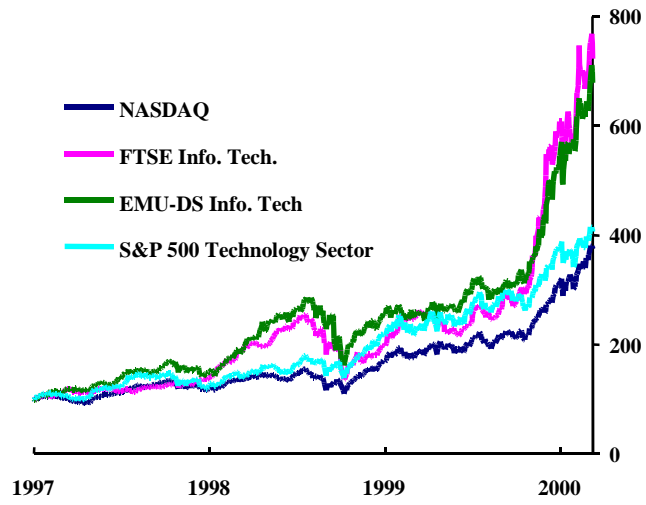
**Chart 5**  
**Worldwide Equity Indices <sup>(a)</sup>**



(a) Measured in local currency (1/1/92 = 100)  
 Source: Datastream

## Chart 6

### Worldwide Technology Indices <sup>(a)</sup>



(a) Measured in local currency (1/1/97 = 100)

Source: Datastream