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Macroeconomic Vulnerabilities in the Twenty-first Century Economy: A Preliminary Taxonomy

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Abstract

Our current information technological revolution is, by crude metrics, two to three times the relative size of previous industrial revolutions which transformed the economy and the world. However, at the moment, it is anyone's guess what changes in macroeconomic vulnerabilities and opportunities our current industrial revolution will bring. It seems highly likely that it will bring a better-performing labour market. It also seems highly likely that it will bring larger swings in asset prices and investment demand, which will call for more aggressive counter-cyclical monetary policy. It is possible that it will bring a reduction in the size of the inventory-driven component of the business cycle, and that it will add to the difficulties of financial regulation as complexity increases the government's task while euphoria diminishes its competence.

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I. Introduction

The twentieth century saw industrial economies quake along at least five different macroeconomic fault lines:

1 Economies fell into recessions and depressions as a result of large confidence shocks that reduced the volume of investment spending.
2 Economies fell into recessions and depressions as a result of contractionary monetary policies – either overly contractionary and mistaken policies, or policies undertaken because of a perceived need to reduce inflation and stabilize prices.
3 Economies fell into recessions and depressions not as a result of large contractionary macroeconomic shocks, but because of small contractionary shocks combined with a self-reinforcing debt-deflation mechanism as detailed either by large declines in internal prices, or large declines in the value of domestic currency coupled with large-scale external harder-currency-denominated debt which turned out to amplify adverse-selection problems in financial markets and thus depressed investment spending.
4 Economies could spiral into hyper- or near hyper-inflation if their central banks lost their reputations for being deeply committed to maintaining price stability and acquired, instead, reputations for seeking to push unemployment permanently below its natural rate.
5 High inflation could be caused by the interaction of persistent government deficits on the one hand with a politically driven need for the central bank to be the government's deficit financer of last resort.

One would have to be very optimistic to conclude that any of these five fault lines have been repaired and will pose no threat in the twenty-first century. There has been no effective fundamental reform to keep government finance from becoming feckless. The interaction of slack demand with price level declines, debt denominated in local currencies and bankruptcy will continue to be dangerous. Businesses' investment committees' animal spirits will continue to be volatile; and central banks will continue to make mistakes – both on the deflationary and on the inflationary side.

One can ask, though, which of these fault lines will become less active, which will become more active, and what new fault lines will emerge in the twenty-first century. Industrial economies have ridden waves of structural change since the mid-nineteenth century. So far, there is no sign that structural change is slowing down; and it is natural to ask how structural change affects macroeconomic vulnerability. What should policy makers and academics watch out for in the next generation that is not just a repeat of the past one? How will the fault lines of macroeconomic vulnerability change as the structure of the economy shifts from industrial to post-industrial under the impact of the ongoing technological revolutions in data processing, data communications and whatever other leading growth sectors in turn follow them? How should public policy react to maximize the opportunities and to minimize the risks?

These are very large questions. I cannot answer them.

First of all, macroeconomists' track record at prospective, rather than retrospective, identification of macroeconomic vulnerabilities is not good. It is difficult to find analyses that highlight the macroeconomic dangers of large-scale downward price flexibility like that seen during the 1929–33 American Great Contraction before Fisher (1933). (Earlier writers like Keynes (1924) had stressed the contractionary effects of anticipated deflation, but not the financial market failures caused by recent past deflation.) Few before Friedman (1968) and Phelps (1967) understood the medium-term consequences for US inflation of macroeconomic policy that attempted to fix the average unemployment rate at a level below the NAIRU; and, as Krugman (2001) lamented, few in the early 1990s had any inkling that, in that decade, developing-country exchange-rate crises would arise not from governments' pursuing fiscal policies that were unsustainable in the long run, but from how the interaction of large-scale harder-currency-denominated debt with financial-sector adverse selection and moral hazard created the possibility for an economy to suddenly jump from a 'good' high-currency-value equilibrium to a 'bad' low-currency-value equilibrium. I see no reason to think that our collective expertise will be better at prospective analysis in the future than it has been in the past.

The most I can do, at this moment, is to make preliminary (but informed) guesses as to how structural changes in the economy are transforming the fault lines of macroeconomic vulnerability. To shift metaphors drastically, I can at most be a Linnaeus – sorting creatures into a preliminary classification without providing many deep insights – as opposed to a Darwin, let alone a Crick, Russell or Watson.

So, let me begin to guess.

First of all, it seems highly likely that two opposed forces will influence the size of macroeconomic shocks affecting industrial economies over the next generation. The first of these two opposed forces is that the 'new economy' of the technological revolutions in data processing and data communications is real. We can expect the secular acceleration in productivity growth back to near pre-1973 levels as was noticed in the late 1990s to continue for some time to come. Faster productivity growth means that a greater share of the present value flowing from today's investment projects will take place further in the future, for output in the distant future will loom larger in magnitude relative to output today. Thus, the duration of equities is likely to increase. Moreover, a leading sector-driven boom adds to uncertainty about the pace and direction of technological development. Thus, it is likely that the magnitude of asset market shocks will increase, both as the greater-than-usual amounts of uncertainty are resolved and because longer-duration assets exhibit wider price fluctuations than shorter-duration ones would. Waves of euphoria and the reaction when it turns out that the profits flowing from technological advance have been overestimated will drive asset price fluctuations. Such fluctuations will, in a simple IS-LM model, shake the location in the IS curve by amounts greater than those we have become used to.

However, if information technologies really are information technologies, then the inventory-driven component of the business cycle should be smaller in the future than in the past. To the extent that a large share of past business cycles have been caused by 'mistakes' in inventory accumulation and decumulation because of a lack of rapid information transmission from final demand to the factory floor, information technologies *should* reduce this problem.

So far, however, there are no signs that better information technologies have brought better inventory control with them. By contrast, there is powerful evidence that asset price movements have become larger than in the past. Unless one wishes to honour at full face value the theoretical claim that errors in inventory build-up and drawdown should be substantially reduced as a result of modern information technologies, one must conclude that it is likely that industrial economies in the future will face private sector-driven shocks to asset prices and the position of the IS curve larger than we have grown used to over the past several generations.

Second, it seems very clear that our current structural changes are bringing faster aggregate productivity growth. Faster productivity growth is very good in itself, but if one takes a narrow, business cycle-centred view it is good not just in itself but also because it is likely to improve the functioning of the labour market significantly. Bruno and Sachs (1985) and Blanchard (2000) both attribute a very large share of western Europe's macroeconomic problems over the past generation to the interaction of the productivity slowdown of the 1970s with labour market structures that cannot adjust to slower warranted real wage growth without extraordinarily large rises in and extraordinarily persistent unemployment that has been extremely damaging for western European economic and social welfare. In the USA, Ball and Mankiw (2002) see a strong (although much smaller) connection between productivity growth and the level of the natural rate of unemployment. If slower productivity growth is bad for structural unemployment, it is highly likely that more rapid productivity growth will generate a much more high-pressure labour market with concomitant benefits.

Last, our current ongoing structural changes are likely to bring changes in the *responsiveness of policy* to macroeconomic shocks as well. Lawrence Summers has argued that periods of rapid growth and euphoria are very likely to degrade the government's ability to carry out successful macroeconomic management. The end of a period of high euphoria and extravagant boom inevitably brings a reduction in investment. Managing the resulting necessary expenditure-switching from investment to consumption and exports is a delicate task. It is made more delicate if, as Summers argues, a euphoric boom is a period during which people stop thinking as intensely about problems of macroeconomic management. Moreover, our increasingly advanced information technologies are adding to the complexity of our financial system. The difficulties of financial-market regulation and surveillance rise with increasing financial market complexity. To the extent that a principal goal of economic policy is to keep chains of large-scale bankruptcies from disrupting the financial sector, it is essential for government regulators to understand the capital structure and the portfolio risk profile of financial services firms. This may be becoming more and more difficult.

Thus we have three potential seismic changes driven by ongoing structural change: a likely rise in the magnitude of private-sector financial market-driven IS shocks (perhaps offset by improved inventory control), a much-to-be-welcomed improvement in labour market performance, and increasing difficulties of macroeconomic management as periods of euphoria degrade governmental regulatory and managerial competence in the face of additional financial complexity which may raise the difficulties of financial market regulation.

It is important, however, not to overstress how large these changes are likely to be. In all probability, they will be visible at the margin of macroeconomics and macroeconomic policy, but they are unlikely to grab the daily headlines. The past 150 years have seen immense structural changes in leading economies. They have seen technological revolutions, as one leading sector after another has taken the lead in productivity acceleration. They have seen the rise of systems of credit that allow households to smooth their spending. They have seen the modern social insurance state become a sea-anchor for the economy by virtue of the large relative size of its spending programmes. They have seen the government take on responsibility for managing the macroeconomy.

Yet, in spite of all this, the business cycle today is – or certainly until very recently was – remarkably like the cycle of a century ago. This does not mean that today's business cycle is identical to that of 1872. For example, Blanchard and Simon (2001) have identified a post-1982 reduction in US output volatility that Romer (1999) traces to improved institutional competence on the part of the Federal Reserve. The striking thing when one looks at the past, though, is how much continuity there is in the shape of the business cycle. I would have expected the shift from the agro-manufacturing economy of the 1880s to the industrial-paperwork economy of the 1970s to have produced major changes in the shape of the business cycle; however, Romer (1986) concluded that any such changes were relatively small.

II. Background: Technological Revolution

To begin with, consider the scope and magnitude of our ongoing technological revolutions in data processing and data communications. Compare our use of information technology today with that of our predecessors half a century ago. The decade of the 1950s saw electronic computers largely replace mechanical and electromechanical calculators and sorters as the world's automated calculating devices. By the end of the 1950s, there were roughly 2000 installed computers in the world: machines like Remington Rand UNIVACs, IBM 702s or DEC PDP-1s. The processing power of these machines averaged perhaps 10,000 clock cycles per second. Today? There are perhaps half a billion processors installed and working across the world, with clock speeds of a billion cycles per second. Computing power is not quite clock speed times installed base, and appropriately valued real output is not computing power, but still the net increase is awesome.

The 50 years after the invention of electricity, 1880–1930, saw an increase in horsepower applied to US industry of a hundredfold: an annual increase in applied horsepower of 9% per year. The 100 years from 1750 to 1850 saw British textile output multiply 30-fold. In the middle of the eighteenth century, it took hand-spinning workers 500 hours to spin a pound of cotton but, by the early nineteenth century, it took machine-spinning workers only three hours to perform the same task – a rate of technological progress of 10% per year sustained across half a century.[1] These earlier transformations were true 'industrial revolutions'.

These earlier transformations created true 'new economies'. The original industrial revolution in Britain triggered sustained increases in median standards of living for the first time: for the first time in human history, the median worker was not one downward shock away from malnutrition. It triggered a shift to a manufacturing- and then to a services-heavy economic structure. It changed what people's jobs were, how they did them and how they lived more completely than any previous economic shifts save the invention of agriculture and the discovery of fire. The economic transformations of the second industrial revolution driven by electrification and other late

[1]See Freeman and Louca (2001) and Devine (1983). Paul David (1989) argues that, in the long run, the increase in the possible flexibility of factory organization resulting from the coming of the electric motor played as large a role in raising productivity as did the decrease in the raw cost of applied energy from the shift from steam and shafts to electrons and wires.

nineteenth-century general-purpose technologies were almost as far reaching: mass production, the large industrial enterprise, the continent- and then world-wide market in staple manufactured goods, the industrial labour union, the social insurance state, even more rapid sustained increases in median living standards, and the middle-class society. From the perspective of human welfare or economic structure, these industrial revolutions were extraordinarily important events.

Our available quantitative metrics suggest that our current ongoing transformation looks to be even larger than the first and second industrial revolutions outlined above. William Nordhaus (2002) estimates that the cost of 'computation' has fallen a trillionfold since 1940 – a rate of productivity increase of 46% per year (compounded continuously – 58% per year compounded annually). This is not all: there are also ongoing closely related – but conceptually separate – technological revolutions in storage technology and in communications bandwidth. The 5–7% of American gross output that is information technology equipment and software today is, when compared to the estimates of Crafts (2002), approximately 2–3 times as large a share of GDP as was invested in the 'high tech' capital of steam, iron and factory during the heyday of the British Industrial Revolution, and approximately twice as large a share of GDP as was invested in the 'high tech' capital of electricity, chemicals, steel and mass production during the heyday of America's late-nineteenth-century Second Industrial Revolution.

Crafts concludes that steam engines and railroads' effect on *measured* economic growth during its peak years in the first industrial revolution was of the order of a quarter of a percentage point per year, and that electricity and electrical machinery's effect on *measured* economic growth during the first generation of the twentieth century was of the order of half a percentage point per year. As Crafts points out, the computer contribution was of the order of half a percentage point per year even back when Robert Solow was asking why we didn't see computers in the aggregate productivity statistics. Today, the information technology contribution to growth is significantly greater.

Moreover, the information technology contribution to growth is not going to vanish tomorrow. There is every reason to believe that the pace of productivity growth in today's leading sectors will continue. More than a generation ago, Intel Corporation co-founder Gordon Moore noticed what has become Moore's Law – that improvements in semiconductor fabrication allow manufacturers to double the density of transistors on a chip every eighteen months. The scale of investment needed to make Moore's Law hold has grown exponentially along with the density of transistors and circuits, but Moore's Law has continued to hold, and engineers see no immediate barriers that will bring the process of improvement to a halt anytime soon.

The computers, switches, cables and programs that are the products of today's leading sectors appear to be what Bresnahan and Trajtenberg (1995) call 'general-purpose' technologies, hence demand for them is extremely elastic. Rapidly falling prices and elastic demand imply rapidly growing expenditure shares. Plus, the economic salience of a leading sector – its contribution to productivity growth – is the product of the rate at which the cost of its output declines and the share of the products it makes in total demand.

The most powerful reason to believe in the long-run economic salience of today's ongoing technological revolutions comes from the underlying growth accounting of the impact of the information technology revolution. Back in the 1980s, information technology capital accounted for 3.3% of income earned in the economy; today, according to Oliner and Sichel (2000), it accounts for 7.0% of income earned. Back in the 1980s, the economy's stock of information technology capital was growing at 14% per year; today, according to Oliner and Sichel (2002), it is growing at 20% per year. Multiply these two sets of numbers together to find that the increase in the economy's information technology capital stock was responsible for 0.5% per year of economic growth in the late 1980s, and for 1.4% per year of economic growth today.[2] All these factors are highly persistent: the growth accounting thus implies that they will remain salient – and perhaps increase in salience as prices continue to fall, if elasticities of demand remain greater than one, as DeLong and Summers (2002) argued that they are.

III. A Standard Framework for Thinking About the Business Cycle

When we teach undergraduates about the determinants of business cycles, we usually present them with a simple framework that has five components:

- An IS curve that details the short-run relationship between interest rates and output levels

[2]Oliner and Sichel's conclusions are very similar to those of Jorgenson and Stiroh (2000), and not inconsistent with Nordhaus (2000a, 2000b, 2001). Before 1995, critics of visionaries who saw the computer as transforming the world pointed to slow and anaemic growth in aggregate labour productivity. As Nobel Prize-winning MIT economist Robert Solow posed the question, if the computer is so important 'how come we see the computer revolution everywhere but in the [aggregate] productivity statistics?' However, as Oliner and Sichel (1994) pointed out in the early 1990s, the then-failure to see the computer revolution in the aggregate productivity statistics should not have come as a surprise. In the 1970s and 1980s, the computer industry was simply too small a share of the economy and its output was not growing fast enough for it to have a large impact on aggregate productivity.

- Macroeconomic shocks that push this IS curve left or right
- A central bank that sets an interest rate in an attempt to choose a particular level of the interest rate that, when combined with the IS curve, produces a level of output equal to potential output – with neither excess unemployment nor excess demand and rising inflation
- An Okun's law-like relationship that determines the 'set point' of the economy is: how close the economy can be to full utilization of labour and capacity before inflation begins to accelerate
- Lags – both 'inside' lags within the government (recognition lags, implementation lags) and 'outside' lags (long and variable) that limit the central bank's ability to shift the interest rate in response to shocks before a considerable period of time has elapsed.

In this framework, the causes of macroeconomic instability are straightforward. It is the job of the central bank to vary interest rates to offset shifts in the location of the IS curve, understood as the relationship between the short-run interest rates that the central bank controls and the level of output. Any of a large number of shocks – to the term structure, to consumption demand, to invest, as a result of government policy, and so on – will change the location of the IS curve. The central bank tries to determine where the IS curve will be, for its interest-rate policies take effect only with long and variable lags. Given the central bank's guesses about the location of the IS curve, it chooses the interest rate so as to set aggregate demand equal to potential output.

Thus, the central bank offsets those shocks to the IS curve that it foresees, and fails to offset those that take it by surprise, either because of the lags inherent in the system or because of central bank misjudgements. When central bank misjudgements are large enough, it then finds itself having to play catch-up. If its misjudgements have been long enough and prolonged enough on the inflationary side, it must find a way to reduce inflationary expectations and to change not just the bias of its policies but what outsiders perceive the inflationary bias of its policies to be. This may turn out to be a remarkably difficult task. Many of the structural changes that produce the formerly missing inflation-fighting credibility create other macroeconomic vulnerabilities in place of those that were produced by lack of confidence in the central bank's desire to control inflation. Consider, for example, the recent crisis in Argentina, triggered by the incompatibility of persistent – although not overwhelmingly large – fiscal deficits with the hard exchange rate peg of the currency board that Argentina had adopted a decade ago to control inflation (Mussa 2002).

If the central bank's monetary-policy misjudgements have been long enough and prolonged enough on the deflationary side, the central bank may need considerable fiscal policy or regulatory policy help to assist it in returning autonomous spending to a level consistent with full employment. In a situation in which large components of either the banking system or of operating corporations are or are feared to be underwater, properly measured risk and default premiums are likely to remain very high. Thus, even extraordinarily stimulative monetary policies may have limited ability to undo a persistent deflation. Regulatory policy – mandatory capital and ownership restructuring of banks and operating companies – may be essential to reduce risk and default premiums. This is one interpretation of the current macroeconomic troubles of Japan (Kuttner and Posen 2001).

Fiscal policy – direct government spending to boost aggregate demand – may also have a role in stabilization policy, but the balance of opinion today is that, as far as the USA is concerned at least, fiscal policy institutions are unsuited for such a role. Taylor (2000) is convincing in his argument that – at least as long as the US government retains its current political-bureaucratic structure – the US government is so thumb-fingered and hamstrung that fiscal policy is essentially useless as a stabilization policy tool.

From the perspective of this framework, ongoing structural changes can have three sets of effects on the likelihood of macroeconomic distress:

- They can change the magnitude of the shocks to the IS curve.
- They can change the 'set point' of the economy: they can shift the natural rate of unemployment and thus change the average level of utilization.
- They can affect the ability of the central bank and the rest of the government to offset such shocks – either through making it more difficult for governments to find out what is going on, or through making it more difficult for governments to respond to problems and crises as they arise.

IV. Shocks to Asset Prices and Their Real Effects

The *Economist Global Agenda* (2002) quotes Barsky and DeLong (1993) as authorities for the somewhat platitudinous point that asset prices are likely to be the most volatile – hence private sector-driven shocks to the location of the IS curve are likely to be the largest – whenever the future is most uncertain. The unknowns created by a leading sector-driven economic boom are the very essence of uncertainty about the future. New and untried technologies are, by definition, new and untried. Either substantial sectors or the aggregate market as a whole are more likely to find themselves substantially mispriced when technological change is relatively rapid and uncertain.[3] Asset price changes

[3]For a model in which small changes in technology-driven expectations of future growth rates produce large swings in asset prices and in desired investment spending, see DeLong (1990).

can be the result of waves of euphoria produced by excitement about the prospects of new technologies on the part of some and the reluctance to bear-speculate against the enthusiastic by rational agents aware of the risk that new technologies sometimes do turn out to be miraculous (Shleifer 2000; Kindleberger 1978). Asset price overshooting on the downside can result from a reaction to previous manias, when it turns out that profits from technological advance are less than anticipated.

A series of large upward shocks in asset prices from favourable news about technology are also likely to transform the ecology of the stock market. In a world with agents possessing constant relative risk aversion, the stock market is a voting mechanism for deciding on Tobin's Q, with each agent weighted by his or her wealth. A period of good news increases the stock market weight of those far-sighted enough to have anticipated the news, yes. However, it also increases the stock market weight of the chronically overoptimistic and – to the extent that asset price news turns out to be serially-correlated *ex post* – of trend-chasers who buy when prices rise and who sell when prices fall.

There is reason to fear that the run up in asset prices in the 1990s may have reduced the US asset markets' effectiveness as part of a rational social capital allocation mechanism. If we look far back in history at the long bull runs of the US stock market – 1890–1910, or 1920–30, or 1950–70 – we see that, for each 10% that the real value of dividends rose over a 20-year period, the real value of stock prices tended to rise by half again as much – by 15% (Barsky and DeLong 1993). The run up in stock prices during the 1920s was extraordinary but, in real terms, the increase in dividends paid out in the 1920s, and the increase in corporate profitability, was more than half of the increase in real stock market values. The run up in stock prices during the 1950s and 1960s was extraordinary too but, in real terms, increases in dividends and in earnings were two-thirds as large as the increase in real values.

The most recent bull market, as measured by the S&P composite index, is the largest: a more than seven-fold increase in real values from trough to peak in less than two decades. Yet real dividends paid on a pro-rata share of the S&P composite index rose by less than 30% between the early 1980s and the peak; and earnings on a pro-rata share increased by less than 50%. During this most recent long bull market, a market-wide rise in dividends of 10% produced not a 15%, but a 26% increase in stock prices. Even after two years of declining nominal values, the US stock market as of the fall of 2002 remained extremely high by standard dividend-ratio or earnings-ratio yardsticks (Figure 1).

It is certainly possible (albeit unlikely, from this observer's perspective at least) that it is the yardsticks and not the equity values that are out-of-whack. It has long been a mystery why firms in the past paid out as much in dividends as they did, given their unfavourable tax treatment: perhaps firms have learned better, or perhaps investors have learned to judge firms on the basis of

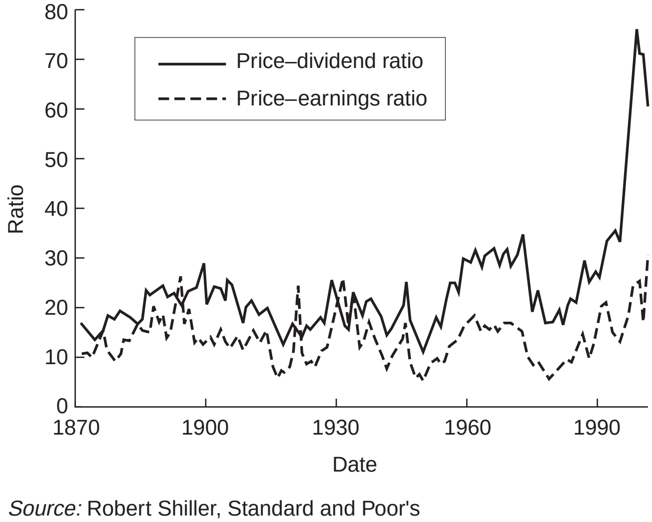


Figure 1: US stock market price–earnings and price–dividend ratios

other, less-dissipative signals than dividends. Average price–earnings ratios in the US stock market have long seemed ludicrously high from the perspective of any diversified portfolio chosen by an agent with a reasonable degree of risk aversion (Mehra and Prescott 1985). Perhaps investors have finally recognized the true risk-return trade-offs.[4] It seems more probable, though, that large components of recent asset price fluctuations represent shifts in 'animal spirits' that narrow-eyed sober calculating believers in fundamentals have been unwilling to speculate against on a sufficiently large scale – for 'the market can remain irrational longer than you can remain solvent'.[5]

Odean and Barber (2001) have pointed out that experimental economists have defined conditions under which markets are most vulnerable to prolonged mispricing and to speculative bubbles, and that our current stock market as it has been fuelled by the growth of online trading and online information appears to meet all of them. To larger asset price swings driven by increases in fundamental uncertainty must be added larger asset price swings driven by additional asset-price noise.

[4]Another possibility – although one that looks less likely with every passing day – is that GAAP greatly understate the magnitude of firms' investments in organizational capital associated with the ongoing technological revolutions, and thus greatly understate true corporate earnings by classifying a large component of the firm's Haig–Simons investment as an operating cost. See Hall (2000).

[5]Lowenstein (2000) attributes this quotation to John Maynard Keynes. I have not been able to verify it.

It would be surprising if a period of rapid leading sector-driven technological change was not the cause of large asset price shocks. It would be surprising if these large asset price shocks were not, in their turn, the cause of large swings in investment spending, which will, in their turn, generate large shifts in the location of the IS curve. Thus, stabilization policy becomes more difficult and the central bank has to be prepared for larger than usual fluctuations in interest rates to counter these unusually large shifts in animal spirits,[6] at least as long as the technological revolution continues.

How large in magnitude will these effects of amplified asset prices shocks be? Reflect that the 911-driven and the NASDAQ bubble collapse-driven reductions in demand have already required that the Federal Reserve reduce short-term safe interest rates remarkably close to the zero nominal interest rate bound, and that neither shock was as large in its effects on demand as could easily have been envisioned. The answer to the question, 'How large?' may well be, 'Too large for conventional monetary policy to handle', at least in an environment of near price stability.

V. The Inventory Component of the Business Cycle

Perhaps offsetting the additional potential macroeconomic vulnerability generated by the potential interaction of technological uncertainty with asset prices and investment spending, the ongoing technological revolutions promise to reduce the magnitude of macroeconomic shocks by reducing the likelihood and magnitude of large-scale shocks to inventory accumulation. So far, however, there is little evidence that such forces are at work in the economy. This hope for a reduction in the inventory cycle is still a theoretical promissory note, that it would be optimistic to take at face value.

To the extent that information technologies really are *information* technologies, they should make it easier for firms to gather, transmit and use information. One prime piece of information that firms need to know is the state of the goods and services moving through its value chain: its inventory, in all stages from goods piling up (or running bare) on store shelves to the likelihood that its suppliers will successfully make their just-in-time deliveries. To the extent that, in the past, macroeconomic instability has been driven by mistakes in inventory accumulation and decumulation, themselves the result of a lack of rapid information transmission from final demand to the factory

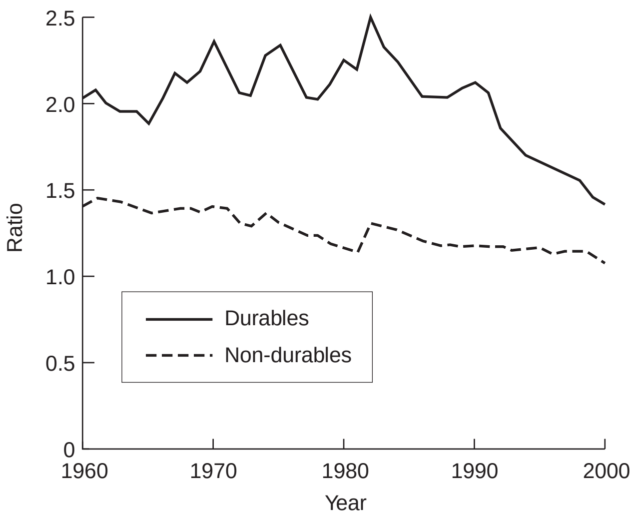
[6]The fact that such interest-rate offsets will presumably have to operate both upward and downward raises doubts about the wisdom of too-aggressive central bank pursuit of price stability in the context of a large ongoing technological revolution (DeLong and Summers 1993).

floor, the ongoing revolution in information technology should reduce their magnitude.

American inventory-to-sales ratios have been declining for nearly a generation. Today, manufacturers of durable goods hold only two-thirds as much inventory relative to their sales as they held in the 1970s (Figure 2). Manufacturers of non-durable goods hold 80% as much inventory in proportion to sales as they did in the 1970s. Inventories have also been less volatile.[7]

However, much of this reduction in inventory-to-sales ratios is *not* due to information technology, at least not directly. Before there was a new economy, after all, there was a 'Japanese challenge': American firms scrambled to develop and implement 'lean production' systems that economized on inventories and achieved much greater control over materials flow and quality (Womack et al. 1991).

Managers do claim that one of the principal benefits of new computer-and-communications technologies is better inventory control. We will need at least a decade, if not more, of additional observations, though, before we will be



Source: US Department of Commerce

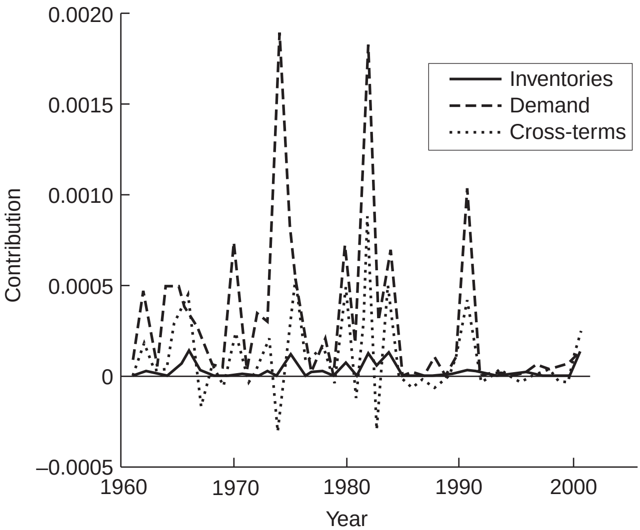
Figure 2: US inventory-to-shipments ratios in manufacturing

[7]It is, however, hard to tell whether this reduction in volatility in the years since 1984 is cause or effect of overall macroeconomic stability. More interesting is Blanchard and Simon's (2001) finding that the covariance between inventory changes and other shifts in the business cycle may be changing.

able to see to see whether and what macroeconomic benefits in terms of reduced business cycle amplitude will follow from the plausible role of better information technology in generating a leaner inventory pipeline.[8]

So far, the empirical news is not encouraging for this inventory channel. Figure 3 shows, year by year, the contributions of the variances of demand and inventories and the covariance terms to the overall calculated variance of annual growth in real output. The dashed line shows the (dominant) contributions of variability in demand growth. The solid line shows the (relatively small) contributions of variability in the change in inventories; and the dotted line shows the covariance terms, the cross terms, the effect on total variance of the fact that there is a systematic relationship between variation in demand growth and the variation in inventory changes.

Figure 3 shows that the overwhelming proportion of inventories' contribution to business-cycle variance comes from the covariance cross-term, and comes in the years of recession and of immediate post-recession bounce-back. Thus, there is essentially no information in the aggregate data about whether information technology was moderating the business cycle between the 1991 recession and 2000. What news there is from the 2001 recession is



Source: Author's calculations from year-to-year GDP component changes

Figure 3: Contributions to the variance of annual output growth

[8]Blinder (1981) pointed out that, in a typical recession, the fall in inventory investment is 50–100% of the peak-to-trough fall in real GDP, but it is not clear that this is the most useful statistic to gauge the contribution of inventory forecast errors to macroeconomic variability.

bad: the contribution of the covariance cross-term is unusually large relative to the size of the 2001 recession. (It is not that the covariance term in 2001 was unusually large for a recession year, but that the other terms – and indeed the magnitude of the recession itself – were unusually small.)

VI. Productivity Growth and the Labour Market

Faster aggregate productivity growth has large potential collateral benefits. Faster productivity growth produces faster growth in real incomes – a very good thing in itself. However, faster productivity growth is also very likely to ease the macroeconomic management dilemmas produced by labour market structure. To the extent that one attributes a large part of Europe's macroeconomic problems over the past generation to the interaction of the productivity slowdown of the 1970s with labour market structure, one would expect an acceleration of productivity growth to pay enormous business-cycle benefits as well – and it seems very safe to bet that the current ongoing technological revolutions will produce rapid productivity growth for quite some time to come (Blanchard 2000; Bruno and Sachs 1985).

In the USA, the boom of the 1990s is a prime candidate for the responsibility for the remarkable favourable shifts in the Phillips curve that the US economy exhibited in the 1990s. At the end of the 1980s, the conventional wisdom among US macroeconomists estimated the economy's natural rate of unemployment as somewhere above 6%. These estimates were based on long historical experience:

- In the 1960s inflation increased when the unemployment rate fell below 5.5%.
- In the early 1970s, it seemed as though inflation fell when the unemployment rate rose above 5.5%.
- By the late 1970s it seemed as though it required an unemployment rate of 6.5% or more to put downward pressure on inflation.
- In the 1980s, it seemed as though the workings of the labour market were worse: only when unemployment rose above 7% did inflation fall noticeably.
- In the late 1980s and early 1990s, it seemed as though inflation rose whenever the unemployment rate fell below 6.5%, and fell when the unemployment rate rose above 6.5%.[9]

[9]See Staiger et al. (1997) who stress the uncertainty surrounding our estimate of the natural rate at any moment in time.

Yet, starting in the mid-1990s, the co-movements of inflation and unemployment went off the historical track (Figure 4). The fall in unemployment to 6% in the mid-1990s did not lead to any acceleration in inflation, nor did the fall in unemployment to 5% and then 4.5% in the late 1990s. Only as the unemployment rate fell to 4% at the end of the 1990s were there signs of rising inflation. This recent apparent shift in the NAIRU is very small in the context of the European experience, but it is remarkably large in the context of the US experience.

It is not possible to trace the fall in the NAIRU directly to high-tech driven structural change. It is simply not plausible to argue that online job searches have made the labour market's frictions less important (Autor 2001). On the other hand, it is equally difficult to trace the fall in the NAIRU to demographic factors affecting the composition of the labour force or to changes in work organization. Demographic factors' plausible effects are an order of magnitude too small. Also, the timing is wrong to account for a large, sudden fall in the NAIRU in less than a decade (Katz and Krueger 1999).

It is, however, possible that the natural rate of unemployment is linked to the rate of economy-wide productivity growth. The era of slow productivity growth from the mid-1970s to the mid-1990s saw a relatively high natural rate. By contrast, rapid productivity growth before 1973 and after 1995 has

Source: 2002 edition of the *Economic Report of the President*

Figure 4: US inflation and unemployment, 1960–present

been associated with a lower natural rate. If workers' aspirations for real wage growth themselves depend on the rate of unemployment and do not depend directly on productivity growth, then a speedup in productivity growth will appear reduce the natural rate, for a while at least (Ball and Mankiw 2002; Blanchard and Katz 1999). With a higher rate of productivity growth, firms can afford to pay higher real wage increases without going bankrupt. The unemployment rate consistent with real wage growth aspirations that match productivity growth is lower, as long as real wage growth aspirations are formed naively – as a function of the unemployment rate, but without knowledge of economy-wide productivity growth.

There is no strong microeconomic evidence for this model in any form. The attribution of the fall in the NAIRU in the 1990s to the 'new economy' – as an indirect consequence of the acceleration in productivity growth – is plausible and enticing, but far from proven. However, it is likely to be the most important effect of our current structural changes on macroeconomic performance.

VII. Institutional Capacity to Manage the Macroeconomy

Former US Treasury Secretary Lawrence Summers has long feared and has argued (DeLong and Summers 2002) that a technology-driven boom may degrade the government's institutional capability to manage the business cycle. The end of a period of euphoria and boom inevitably brings a reduction in confidence and thus in investment spending: that is what the end of a boom is. As desired investment spending falls, maintaining full employment requires that some other component of aggregate demand – consumption, government purchases, net exports – rise. Thus the task of macroeconomic management at the end of a boom is a delicate task of expenditure-switching.

During a period of boom-driven euphoria, counter-cyclical policy becomes less important. After a period of boom-driven euphoria, counter-cyclical policy becomes more important than at any other time. Nobody in Japan in the late 1980s paid *any* attention at all to problems of business cycle management, few in Japan in the early 1990s paid *sufficient* attention to problems of business cycle management, and today, when everyone in Japan is paying attention, the fruits of a near-decade of neglect are that Japan's macroeconomic problems have grown so large as to become politically and possibly economically intractable. The Japanese and the world economies today are suffering from that lapse (DeLong and Summers 2002).

The unproductive US political debate about a 'stimulus package' in the wake of the 911 terror-attack on New York's World Trade Centre may count as evidence of such a degradation in the government's institutional capability to carry out successful demand-management policy. In a situation in which it appeared that monetary policy might not be able to be stimulative enough to keep demand from falling sharply, the US Congress proved incapable of passing a bill until after it was clear that the recession trough had passed (Taylor 2000; DeLong 1996). Of the factors surveyed in this paper, this is surely the weakest – and also the one that is most within our collective control. To a large extent, to be forewarned against this possibility is to be forearmed.

VIII. Financial Market Surveillance

Now consider the difficulties of financial market surveillance and regulation that come with the increasing complexity of financial markets and of the financial instruments traded on them. To the extent that a principal goal of economic policy is to keep chains of large-scale bankruptcies from disrupting the financial sector, it is essential for government regulators to understand the capital structure and the portfolio risk profile of financial services firms. This may become more and more difficult in the future as the complexity of the financial instruments that financial services firms can design outrun the ability of regulators and other actors to determine, quickly and reliably, the risks of financial firms' portfolios and the consequences of their distress.

This potential danger was highlighted in 1998 by the sudden and unexpected collapse of the highly-leveraged hedge fund Long Term Capital Management (Lowenstein 2000). LTCM's creditors, in spite of being on the hook to the firm for amounts in the tens of billions, found themselves unable to evaluate its portfolio in the time necessary for making decisions about whether and on what terms to lend it money. The reliability of the firm's risk-management tools – thought to be among the most sophisticated – was undermined by whispered rumours that, according to LTCM's models, its losses during August 1998 had been 'a nine standard deviation event'.[10]

It is unclear whether to attribute such possible future difficulties in regulation to minimize systemic risk to the information technology revolution. If there is one constant in financial history, it is that financial markets always contain some participants who are very good at figuring out previously unimagined ways of gambling for resurrection with other people's money, or following trading strategies that turn out to destabilize prices, or to evade previously established internal and external controls. Nevertheless, the inability of outside private or public-sector analysts to grasp quickly LTCM's risks and liabilities in the summer of 1998 is a datapoint suggesting that, once again, the capacity of large private firms to find ways to run large risks had outrun the

[10]Under a normal distribution, the expected time before one draws a nine standard deviation event if one draws once a second is on the order of two trillion years.

capacity of regulatory surveillance to identify and monitor them before things go wrong.

It became clear that these problems were more serious than anyone had recognized during 2002, when the sheer magnitude of financial misstatements and frauds by companies like WorldCom, Enron and Adelphia became public. The US model of corporate control and financial regulation rests (or, rather, surfs) on top of a massive torrent of high-quality public information about how our corporations are functioning. Attention is limited. Even the most industrious and sleep-deprived professional investor cannot construct the information base to evaluate *de novo* which companies need new management or general shaking up. Financial markets must rely on what corporations report. That means that the information that flows out must be trustworthy. For the past century, to an astonishing degree, it has been.

A year and a half ago, we had no idea of the damage that the stock-market bubble of the 1990s had done to our collective system of corporate surveillance and supervision. Few would have thought it possible for a firm's officers to try to pump $3 billion out of a public company, as happened at Adelphia. Even those who were most suspicious of WorldCom's acquisition frenzy would never have guessed that it was busy overstating its 'EBITDA' – earnings before interest, taxes, depreciation, and amortization, a semi-useful proxy for the difference between the amount of money the corporation is taking in and the amount of money it is paying out. Who would have imagined that Enron could simply not disclose massive financial obligations and its Chief Financial Officer's [CFO's] massive ethical conflicts of interest, and that everyone – outside directors, audit committee members, auditors, the SEC itself, prestigious legal counsel and others – would simply not notice or would not care?

Such big lies have real effects: Adelphia's games made it look like a profitable, successful concern even as it paid through the nose for its most recent cable acquisitions. Investors and competitors looking at Adelphia thought, 'Aha, look at how profitable it is', and concluded (reasonably) that those recently acquired cable systems were worth their high prices. Thus (i) investors were spurred to imitate Adelphia and to sink money into acquiring cable customers at high prices too, and (ii) competitors upped their estimates of the worth of a cable customer. WorldCom's accounting tricks, especially from 1999 to 2001, also made its business model appear too successful. Competing executives looked at its numbers and felt pressure from investors to imitate it or be fired, as investors punished companies that could not match WorldCom's success. Billions of dollars of financial capital and a great deal of human capital was wasted – allocated to the wrong industry sectors at the wrong time – as a consequence of the way that WorldCom misrepresented itself. Finally, Enron's shenanigans gave the appearance of tremendous profits to be made in the emerging field of energy trading. Pressure to keep up with Enron convinced many energy companies to flock into Enron's business. (And the resulting competition meant that Enron had to defraud harder just to keep its numbers up.) Current stock and bond prices suggest that this was unwise: there was no pot of gold. Enron's shenanigans made these mistakes in judgement easy to make.

Big lies, while undetected, lead to judgements that put capital in the wrong place. Real investments – not just paper profits – turn out not to be worth what people had reasonably expected. Economic growth slows. The country is a poorer place. The financial markets are, after all, social capital allocation mechanisms: our equivalent of the investment directorate of the late Soviet Union's GOSPLAN. Our financial markets work a lot better than GOSPLAN – but not if the information they are fed and that they act on is made out of garbage.

It is unclear how much weight to put on the increased complexity of financial transactions made possible by the information age as a factor in this regulatory and surveillance breakdown. Does added complexity really make problems of financial regulation more difficult? Or does it just present the same old moral hazard problems in a different guise, and post no new regulatory dilemmas? WorldCom, for example, simply misreported current expenditures as capital expenditures. You don't need a great deal of computer power to do that – firms have been doing that as long as there has been limited liability.

At the moment, I do not believe anyone knows the extent to which modern information technologies are making problems of surveillance and regulation more severe.

IX. Conclusion

This paper simply raises questions: it does not give answers. The extraordinary pace of the technological revolutions in data processing and data communications that are ongoing raise the possibility that the resulting structural shifts will have significant albeit cross-cutting effects on macroeconomic vulnerabilities. Two things seem clear:

- As long as the ongoing technological revolutions and their associated uncertainty proceed, we should expect to see larger proportional asset price fluctuations. These raise the stakes and raise the magnitude of required actions by central banks and other participants in stabilization policy. Confronted with larger shocks arising in asset markets, macroeconomic policy will, in all likelihood, have to be more aggressive in response.

- There is good reason to hope that the faster productivity growth in the aggregate associated with the ongoing technological revolutions will produce faster average real wage growth, which will grease the wheels of the labour market. There is good reason to believe that labour market frictions and structural rigidities will play a smaller role in the macroeconomic disturbances of vulnerabilities of the next generation than they have played in the past.

However, at least four things are *not* clear:

- The quantitative magnitudes of all the effects that are up for grabs
- Whether the pattern of boom and bust likely to be generated by an ongoing technological revolution will degrade governments' institutional competence at managing the business cycle
- How much more difficult problems of financial market surveillance are going to be made by the increasing complexity of financial instruments and transactions made possible by the revolution in information technology; and to what degree future financial crises will be blameable on the information technology revolution, as opposed to the long-recognized human propensity to try to raise the stakes and go double-or-nothing a few too many times
- Whether information technologies will really manage to tame the inventory cycle, or whether this particular theoretical promissory note will be dishonoured when presented for payment.

The answers to these questions are unknown. We will start to see the answers to them in the next decade.

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