The challenges of the “new economy” for monetary policy[1]

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Abstract

The advent and spread of information and communication technologies (ICTs) increase potential output growth. It is uncertain to what extent and for how long they do so. We use the term “new economy” (NE) to describe the acceleration in potential output growth and the attendant and partly temporary slowdown in inflation. Assessing the NE is, however, a complicated and delicate task. The impact of the NE on the conduct of monetary policy may differ depending on the timescale. In a long-run perspective, the central bank could capitalise on the NE to set lower inflation targets. In the short to medium term, central banks should be cautious when identifying changing patterns in potential output growth, as temporary errors in appreciation may have an asymmetrical impact on economic stability: the production instability that could result from central banks mistakenly perceiving the advent of an NE would be greater than that generated by the failure to recognise a genuine rise in potential output growth.

The advent and spread of information and communication technologies (ICTs) is an ongoing technological revolution driven by steady and galloping improvement in the performance of ICTs. A case in point: price indices for computer hardware, and more specifically microprocessors, which are supposed to take account of improvements in the performance of these goods using hedonic techniques, have shed an annual average of roughly 20% (for computer hardware) and 40% (for microprocessors) in some three decades. The impact of this revolution is twofold: it has boosted the potential output growth rate durably and dampened inflation, at least temporarily. The term “new economy” (NE) is used in this paper to depict this twofold effect.

Our aim here is to describe the impact of the NE on the conduct of monetary policy. We focus first on the impact of the NE on the variables that are crucial to monetary policy, namely output growth and inflation. We then go on to analyse the consequences for monetary policy, ie the setting by the central bank of a short-term interest rate that serves the dual objective of stabilising inflation and output.

1. ICTs, potential output growth and measuring potential output and inflation

Performance gains in production yielded by ICTs may impact significantly on the potential output growth rate. Various other questions and accounting uncertainties may influence assessment of the effects of the widespread use of ICTs on potential output growth or the measurement of price and wage developments.

[1] This study is a revised version of a paper presented at the 50th Annual Congress of the *Association Française de Science Économique* - AFSE (French Association of Economics), held in Paris on 20 and 21 September 2001 (Cette and Pfister (2002)). The views expressed herein are those of the authors and do not reflect those of the Bank of France or the Eurosystem. We thank our colleagues Pascal Jacquinot and Ferhat Mihoubi for their help and Antoine Magnier for his comments at the AFSE conference. All errors remain the sole responsibility of the authors.

1.1 The effects of the spread of ICTs on potential output growth[2]

ICTs may have a dual impact on potential output growth: a sustained impact in the medium to long term via capital deepening effects and gains in total factor productivity (TFP), and a more transient impact in the short to medium term resulting from the lagged adjustment of average wages to productivity.

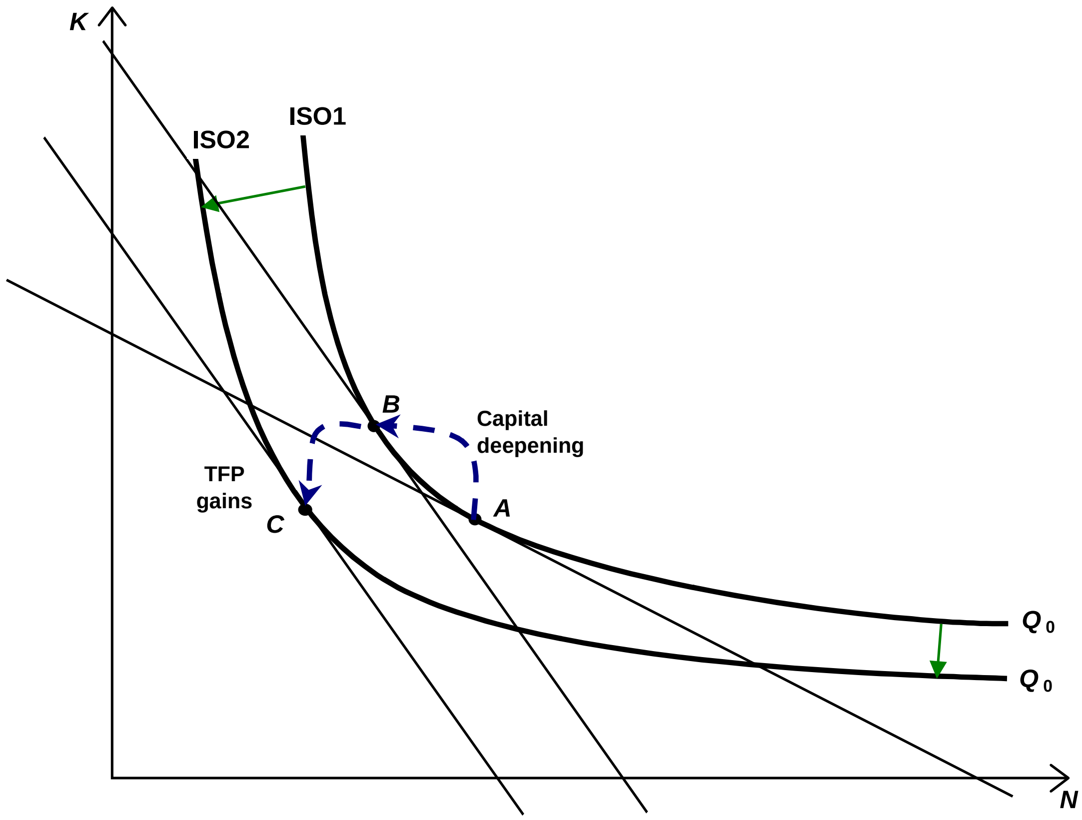
1.1.1 Medium- to long-term effects

The adoption and diffusion of ICTs may have a medium-term effect on potential output growth. This effect is the sum of two elements: changes in TFP gains and capital deepening brought on by differing trends in the price of investment.

Figure 1 below depicts the twofold ICT-induced effect on potential output. The figure assumes an output of Q_0. *A* represents the starting point, where the factor costs line is tangent to the initial isoquant ISO1. Changes in real factor prices brought about by the spread of ICTs - whose prices, due to gains in productive performance, tend to be lower than those for non-ICT investment - alter the slope of the costs line and shift the tangency with the isoquant ISO1 from *A* to *B*. The shift from *A* to *B* corresponds to the capital deepening effect referred to above. In addition, possible gains in TFP make it possible to achieve the same level of output (Q_0) with a smaller input. This corresponds to the shift from isoquant ISO1 to isoquant ISO2. The factor costs line is tangent to this new isoquant at *C*, which indicates the input combination minimising the costs of production following the spread of ICTs.

Figure 1

Uptake of ICTs: an illustration of the impact on the input combination



Q: Output; *K*: Fixed productive capital; *N*: Labour.

2 What follows builds largely on the insights of Cette et al (2002b). Appendix 1 reprises the formalisation, taken from this study, of the effects of the spread of ICTs on potential output growth.

The rise in the potential output growth rate is a gradual one. The gradual improvement corresponds to the time needed for ICTs to become pervasive. Once they are in widespread use, the new potential output growth rate is maintained thanks to the constant upgrading of ICTs. Two aspects must be stressed:

- The roles attributed respectively to TFP and substitution among factors of production in the modification of potential output growth depend primarily on the accounting treatment applied to the volume-price breakdown of investment series in nominal terms. This observation, which is often stressed - see Gordon (2000b)[3] or Stiroh (2001)[4], for instance - forces us to put the economic significance of possible changes in the estimated TFP rate into perspective. Two opposing cases are possible. If the volume-price breakdown is based entirely on a "factor costs" approach, the spread of ICTs has no effect on price inflation - potential output gains stem exclusively from gains in TFP.[5] Conversely, if the volume-price breakdown is based uniquely on a "services produced" approach, TFP gains amount to zero and gains in potential output growth result solely from capital deepening effects. The accounting treatment currently applied to the volume-price breakdown of ICT investment is based on two approaches.[6] The "services produced" approach is usually based on hedonic and matched model methods.[7] Computer hardware is mostly recognised under a "services produced" approach in France as well as in the United States. Accounting for computer software is based solely on "factor costs" in France. In the United States, some software is also recorded using a "services produced" approach, specifically prepackaged software and some custom software, ie a total of 50% of software expenditure. The volume-price breakdown of own-account and other custom software is based on a "factor costs" approach. Lastly, for telecommunications equipment, the volume-price breakdown is based on a "services produced" approach solely for digital telephone switching equipment in the United States, and otherwise on a "factor costs" approach. To conclude, let us point out that these approaches will no doubt evolve significantly in the coming years for computer software and telecommunications equipment, with hedonic methods being extended to these two types of ICT (Parker and Grimm (2000), Grimm et al (2002)). A number of economists, eg Jorgenson(2001)[8] and Gordon (2000b),[9] have called for such change.
- In an ICT-producing economy, if the volume-price breakdown is at least partially based on a "services produced" approach, the advent of ICTs may keep the lid on growth in output prices. In an exclusively ICT-using economy, trends in output prices will not necessarily be modified by the emergence of ICTs. The United States is close to falling within the first group, while France is close to falling within the second. In fact, if we consider the three components of ICT to be computer hardware, computer software and telecommunications equipment, it appears that, currently,[10] it is mainly prices of computer hardware - and not

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3 "Indeed, the faster the assumed decline in prices for software and communication equipment, the slower is TFP growth in the aggregate economy…" Gordon (2000b).

4 "Note that the neoclassical framework predicts no TFP growth from IT use since all output contributions are due to capital accumulation. Computers increase measured TFP only if there are nontraditional effects like increasing returns, production spillovers, or network externalities, or if input are measured incorrectly." Stiroh (2001).

5 These aspects are discussed in greater detail in Cette et al (2000, 2002a).

6 For a more detailed presentation of the methods used, see Jorgenson (2001) for the United States and Cette et al (2000), which compares the methods used in France and the United States.

7 Taking into account ICT performance gains using a "services produced" approach does not only involve using hedonic methods, it may also be carried out using matched model methods. Consequently, with regard to the US economy, several studies by Landefeld and Grimm (2000) show that these two methods arrive at price developments in IT equipment that are very similar.

8 "Unfortunately, software prices are another statistical blind spot with only prices of prepackaged software adequately represented in the official system of price statistics. The daunting challenge that lies ahead is to construct constant quality price indexes for custom and own-account software", Jorgenson (2001, p 12).

9 "The government deflators for software and telecommunication equipment exhibit implausibly low rates of price decline", Gordon (2000b, p 51).

10 Probably partly due to reasons linked to product-specific differences in the methodologies used in the national accounts to break down the capital expenditure into volume and price.

those of computer software or telecommunications equipment - that are diverging from those of other capital goods. As it happens, France and the euro area in general produce relatively small amounts of computer hardware.

It is difficult to assess the impact of the spread of ICTs on potential output growth. If the price of investment was perfectly measured under a "services produced" approach, the impact would be equivalent to the capital deepening effect resulting from the price differential between ICT investment and other capital expenditure. However, given that "services produced" are taken very partially into account in national accounts price estimates, part of the impact of ICTs on potential output growth is attributed in the accounts to TFP gains.

Cette et al (2002b) estimate that, overall, the spread of ICTs should contribute approximately 1.5 to 2 percentage points to the US potential output growth rate. This estimate is based on several conventional assumptions. The capital deepening effect on potential output growth should slightly exceed 1 percentage point annually and the more uncertain TFP effect should run at 1/4 of a percentage point to 1 percentage point. Though the latter figure may appear high, it may be attributed to the fact that quality changes are currently taken into account only for a limited fraction of ICT expenditure, as a factor costs approach is used to measure most of this expenditure (see above). Carried out for France, the same assessment finds an impact that is half as significant, given that the spread of ICTs is also half as extensive.

All in all, the spread of ICTs may appear to have a very substantial impact on potential output growth. However, the measurements compare a real situation in which ICTs exist to an extreme and theoretical situation characterised by the complete absence of ICTs. Moreover, the measurements assume that the differential between output price and investment price developments arises entirely from the spread of ICTs. This means that the impact of ICTs on potential output growth is magnified but also makes it possible to indirectly recognise ICT components that are embedded in capital goods and that are, as such, not recorded as ICT investment. Lastly, it should be pointed out that the hitherto very limited inclusion of quality effects in measurements of computer software and telecommunications equipment prices considerably reduces the capital deepening component.

1.1.2 Short- to medium-term effects

The lagged adjustment of average wages, more specifically average labour costs, to the productivity level reduces inflationary pressure during the ICT rollout period or, in other words, during the productivity boom, and subsequently during the period in which average wages progressively adjust to the new productivity path.

Let us assume that, prior to and following the spread of ICTs, labour productivity grows at a constant rate, and that productivity accelerates constantly as ICTs become widespread. Let us also assume a lag in the adjustment of average wages, more specifically average labour costs, to the productivity level, based for instance on the first-order error correction model proposed by Blanchard and Katz (1997). During the ICT diffusion period, the increase in average wages is smaller than the rise in productivity. Consequently, the gap between average wages and their equilibrium level increases as a percentage of this equilibrium level. Once ICTs have become widespread, growth in average wages outpaces that of productivity. The gap between average wages and their equilibrium level therefore gradually fades. Once adjustment is complete, barring other shocks, growth in average wages matches that of productivity.

During the entire transition period covering the spread of ICTs and the adjustment of levels in which average wages are below their equilibrium level, the NAIRU falls and consequently the level of potential gross domestic product (GDP) increases in comparison with a situation in which average wages immediately adjust to their equilibrium level. This process is described in several papers, for instance Meyer (2000b), Blinder (2000), Ball and Moffit (2001) and Ball and Mankiw (2002). Given identical trends in labour productivity, the size of this transition effect depends on the speed at which average wages adjust to productivity, which is very difficult to assess. For the United States, assuming a very gradual adjustment, Ball and Moffit (2001, pp 24 and 25) estimate the temporary drop in the NAIRU, following a productivity surge, at roughly 1 percentage point at the end of the previous decade. Assuming a more rapid adjustment - over three years - Cette et al (2002b) arrive at a temporary fall in the NAIRU of about 0.2 percentage points. In France, and the euro area as a whole, given the slower spread of ICTs and broad-based policies aimed at tempering the rise in productivity, productivity did not escalate and might in fact have flagged in the second half of the previous decade.

The temporary drop in the NAIRU observed in the United States is therefore not likely to have taken place.

1.2 Other accounting issues or uncertainties[11]

The magnitude and duration of ICT-induced gains in potential output growth are uncertain. There are, moreover, a large number of accounting issues pertaining to this constantly and rapidly evolving area.

1.2.1 The magnitude and duration of gains in potential output growth are uncertain

A great deal has recently been written on the uncertainties surrounding the extent and duration of TFP gains and of capital deepening effects stemming from the spread of ICTs. These uncertainties have already been dealt with in Cette et al (2002a,b,c) and shall therefore only be reviewed rapidly here.

Four types of uncertainty pertaining to the size of the impact of ICTs may be broadly distinguished:

- The observed speed-up in TFP gains in the US economy as a whole is very recent. It dates back to the mid-1990s. Consequently, some economists, Gordon (2000a,b) for instance, believe that a substantial part of this speed-up is likely to be cyclical and an outgrowth of US economic expansion in the 1990s. This is not a view that is shared by most other analytic studies such as Jorgenson and Stiroh (2000), Jorgenson (2001), Jorgenson et al (2001), Oliner and Sichel (2000, 2002) or Council of Economic Advisers (2001, 2002).
- Strong uncertainty also surrounds the sectoral allocation of TFP gains traceable to the spread of ICTs, and the spillover of gains from ICT-producing to ICT-using sectors. However, TFP gains are allocated essentially according to the rules applied to the volume-price breakdown used for ICTs. This difficulty, described by Cette et al (2000) and Brynjolfsson and Hitt (2000), requires us to be cautious in discussing the allocation of TFP gains to ICT-producing or ICT-using sectors.
- Another uncertainty is highlighted in the numerous studies based on individual data that focus on the conditions determining whether the spread of ICTs leads to productivity gains (see Greenan and Mairesse (2000) or Brynjolfsson and Hitt (2000) for a detailed examination of such studies). The spread of ICTs does not necessarily lead to gains in productive efficiency. The existence and extent of these gains is in fact largely determined by other aspects, which also hinge on human resources management.
- One last major issue concerns industrialised European countries' capacity to derive real benefits from the development of ICTs in respect of real and potential output growth and surges in productivity. Gust and Marquez (2000) conclude that the beneficial effects the new economy and ICTs have on labour productivity and TFP will eventually materialise in all industrialised countries. The magnitude of these effects and the duration of the time lag with the United States nevertheless remain uncertain. Uncertainty about the magnitude of the effects stems mainly from our patchy knowledge of the positive interaction, occurring via spillover effects, between ICT-producing and ICT-using industries. If this interaction is substantial, Europe will enjoy more limited ICT-induced gains than the United States given its smaller ICT-producing industry.[12]

There is also strong uncertainty about the duration of ICT-related performance gains. The main efficiency gains result from microprocessors, whose processing power has constantly kept pace with "Moore's Law", which predicts the doubling of processing power every 18 to 24 months. Jorgenson (2001) stresses that it would be rash to extrapolate this trend ad infinitum. Whether or not Moore's Law will continue to hold in ICT-producing industries is not the only vexed issue concerning

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[11] What follows is based to a large extent on Cette et al (2002a,b,c).

[12] Pilat and Lee (2001, pp 21-2) offer several reasons why a sizeable ICT-producing sector is not a prerequisite for deriving full benefits in terms of growth: proximity to producers of computer software could be more relevant than proximity to producers of computer hardware. Besides, several countries, for example Australia, appear to benefit significantly from using ICTs without necessarily boasting a large ICT-producing industry. The contribution of ICTs to economic growth in European countries could therefore expand substantially in Europe, and more specifically in France, in the coming years.

performance gains. Gordon (2000b) also raises doubts about human ability to fully exploit increasing computer capability.

1.2.2 Lingering accounting uncertainties

Methods used in the national accounts to refine estimations of new economy-related variables have improved significantly in recent years. These improvements aim for instance to take better account of quality effects and in particular the performance gains arising from business investment in ICT. This has led Gordon (2000b, 2002) to posit that the impact of the introduction and spread of ICTs on output and productivity growth is not necessarily more profound than that of previous technological "revolutions" such as the invention of the steam engine in the 19th century or of electricity at the start of the 20th. In fact, such a comparison is undermined by the fact that estimates of inputs and especially outputs have been extensively refined in recent decades. Via a drop in prices and an accompanying increase in volumes, these estimates now take better account of qualitative improvements that were overlooked in previous statistics, such as increasingly comfortable rail transport and housing. However, in an assessment of the US economy over a very long period, Crafts (2002) estimated that, since 1974 and especially 1995, the contribution made by ICTs to annual output and productivity growth has vastly surpassed that made by the steam engine in 1830-60, the period in which it was most widely used, and exceeded that made by electricity in 1899-1929 and even 1919-29. Fraumeni (2001) and Litan and Rivlin (2001) also underline that a raft of varying ICT-induced improvements in the quality of certain services, such as commercial and health services, are not recognised in national accounting statistics. Output growth would therefore appear to be currently understated.

Notwithstanding these improvements in national accounting methods, supply and use balances are still established according to conventions that have an impact on the assessment of GDP level and growth. Lequiller (2000) expounds on this. He shows that the breakdown of ICT resources between final use and intermediate use is based on different methodologies in the United States and in France, and more generally Europe. This apparently results in a larger share being attributed to final use, and therefore to higher GDP growth, in the United States than in Europe. Given that, on average, ICT-related activities tend to develop faster than other activities, this methodological difference should have a significant impact not only on the level of GDP but also its growth rate. Lequiller's analysis clearly illustrates some uncertainties in the assessment of growth that inevitably result from ICTs. It also highlights the uncertainties in the GDP estimate that may result from the complicated breakdown - based on accounting rules that are in themselves questionable - of the use of certain ICT-related goods and services, such as mobile telephony goods and services, between households and businesses.

In this constantly evolving area, accounting methods are changing in all countries and may differ from one country to another. The US consumer price index is a case in point: the Boskin report (1996) led to a host of methodological changes that were aimed at improving assessments of consumer price inflation. Volume-price breakdown methods applied to ICTs in particular have also evolved considerably in a number of countries. The changes aim to take better account of quality effects (Cette et al (2000)). When these accounting changes are not applied to the entire historical period available, they can lead to discontinuities that make it difficult to analyse developments in the prices and volumes of the variables concerned.

The consequences of methodological changes are more complex than they appear to be (Lequiller (2000)). Hence, a change in the volume-price breakdown that increases the volume for certain ICT goods and services may increase real GDP for the reasons referred to above, but this increase is tempered by the intermediate use that resident agents make of imports of these goods and services. Landefeld and Grimm's (2000) analysis of US Bureau of Economic Analysis methodology shows, on the basis of a large number of studies, that using hedonic techniques to carry out the volume-price breakdown of ICTs does not appear to significantly affect the measurement of real GDP and the GDP deflator. However, the authors propose a comparison with matched model methods, which take quality effects largely into account. A broader comparison with factor cost approaches, which are closer to those used to measure countless other goods and services, would be more appropriate here.

Another source of uncertainty lies in the fact that the share of ICTs in the output and expenditure of economic agents has expanded considerably in recent decades (Mairesse et al (2000)). Consequently, where a volume-price breakdown methodology has been established for each type of good, the methodology structure has evolved to increasingly include methods that take better account of changes in quality, for instance hedonic indices. This change in structure could therefore affect the "average methodology" of the volume-price breakdown, leading to a shift in emphasis from price to volume to an extent that is unknown.

Lastly, in the future, measurement methods shall continue to evolve to better capture quality changes in certain ICT goods and services. The example of computer software and telecommunications equipment discussed above is probably one of the most significant, as in France and the United States, these goods and services account for over 1.5% and 2.5% of GDP respectively. These methodological changes are bound to have a significant impact on the measurement of GDP prices and volumes. The same is true for other ICT goods and services that are on the rise, such as mobile telephony (Lequiller (2000)). Uncertainties about the measurement of ICTs and the volume-price breakdown methods that are applied to them are therefore relevant not only to the past but also to the future.

2. Taking the "new economy" into account in the conduct of monetary policy

Taking the "new economy" (NE) into account in the conduct of monetary policy is done here in the framework of a Taylor rule.[13] This raises two difficulties:

- In the long term, it is acknowledged that inflation, control of which is the primary objective of monetary policy, is a monetary phenomenon. Yet, growth in money supply is not taken into account in the simple Taylor rule. However, this rule does incorporate two factors that make it possible to determine whether monetary growth is inflationary: the inflation target and potential output or, more specifically, deviations in the trends observed in relation to these variables.
- The simple Taylor rule is generally not optimal, in the sense that it would make it possible to minimise a priori a quadratic loss function for the central bank. However, it does have advantages in terms of ease of use and communication. Furthermore, it is possible to modify some of its parameters in order to reduce the deviations of inflation and output from their target. We shall focus here on this approach.

Using simulations, we will examine how the NE can be taken into account in the conduct of monetary policy from a long-term and a short- to medium-term perspective.

2.1 What are the implications for the conduct of monetary policy in the long term?

In the long term, within a Fisherian approach, the nominal interest rate is the sum of real interest rate and expected inflation. Now, by raising the economy's potential output growth rate, the NE should result in a rise in the long-term equilibrium real interest rate: the productivity boom increases the profitability of investment, pushing up the real interest rate, which allows saving and investment to balance in line with full employment. Although monetary policy only controls the short-term nominal interest rate, it may take into account rises in the equilibrium real interest rate by reducing the gap between the "natural" and "market" rates, as defined by Wicksell.[14] However, as this form of passive adjustment of monetary policy to the NE is inevitable in the long term, it is not simulated in this paper. Furthermore, to the extent that monetary policy is credible, inflation expectations should correspond to the central bank's inflation target. Central banks then have two choices. They can either take advantage of the sustainable positive supply shock, arising from the NE, to lower their targets - to be credible, the target decrease must be a permanent one. Or they can choose to leave the inflation target unchanged and focus on stabilising inflation rather than stabilising output. For simplicity, these

[13] Taylor (1993).

[14] Meyer (2000a).

choices are simulated in a polar fashion: the simple Taylor rule is compared with a form of inflation targeting in which, in a Taylor rule, the inflation stabilisation coefficient is equal to one and the output stabilisation coefficient is zero. In reality, however, both choices can be combined, and this is made even easier if the NE spontaneously results in the economy becoming less cyclical, thanks to, for example, better management of durable goods inventories.[15]

We therefore compare two monetary policy variants affecting the parameters of the Taylor rule: lowering the inflation target, and stabilising inflation. The latter is sometimes recommended in the event of a permanent acceleration in productivity.[16] The simulations were carried out using a highly simplified model of a closed economy described in Appendix 2, and the MARCOS model developed at the Bank of France.[17] In the reference scenario, the NE is simulated by an exogenous increase in the growth rate of potential output (1% in the first model), or in productivity (0.2% in MARCOS). Where the inflation target is lowered, it is reduced by 1 percentage point. These simulations cannot claim to be a faithful representation of the economic reality, but are simply for illustrative purposes: the model is highly simplified, and the calculations made under the MARCOS model incorporate a technology shock in a single economy similar to the French economy. The results are summarised in Table 1 and show, for each variant, the corresponding loss (discounted quadratic sum of the deviations in inflation and output).[18]

Table 1

Monetary policy variants

Monetary policy rule	**Taylor rule**		**Stabilising inflation**	
Changing the inflation target	**Yes**	**No**	**Yes**	**No**
Simplified model				
Loss on deviation in inflation	0.013	0.020	0.012	0.019
Loss on output gap	0.078	0.117	0.077	0.114
Total loss	0.091	0.137	0.090	0.133
MARCOS				
Loss on deviation in inflation	5.22	2.20	13.69	10.19
Loss on output gap	35.18	40.18	37.71	45.98
Total loss	40.40	42.38	52.40	56.18

These variants provide the following information:

- Overall, the comparison of monetary policy rules comes out somewhat in favour of the Taylor rule. Indeed, the simplified model shows that there is a marginal advantage in stabilising inflation, but the substantial advantage of the Taylor rule in MARCOS is more consistent with a scenario in which taking the output gap into account results in a lower inflation rate.

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15 McConnell and Perez-Quiros (2000).

16 Cechetti (2002).

17 MARCOS (Modèle à Anticipations Rationnelles de la Conjoncture Simulée) is a calibrated rational expectations model of the French economy. It is chiefly designed for carrying out medium- to long-term simulations. It was built under the assumption of a small country with monopolistic competition in product and labour markets, in which wages are negotiated in accordance with a right-to-manage model of the labour market, and the consumption of households, which do not face liquidity constraints, is led by intertemporal optimisation behaviour under the life cycle hypothesis. See Jacquinot and Mihoubi (2000).

18 The discount rate is 3.5% in the simplified model and equal to the short-term real interest rate of the reference scenario in MARCOS.

- The reduction of the inflation target is always favourable, as the NE is spontaneously disinflationary. Furthermore, it only has a moderate impact on output, particularly in MARCOS.

It should, however, be noted that the effects of lowering the inflation target are analysed here in a highly simplified form, without considering the optimal non-zero inflation rate.[19] Much has been written about the economic costs of inflation, such as menu costs, "inflationary tax", greater price fluctuations leading to a higher degree of uncertainty of expectations, etc. Similarly, in the presence of downward nominal rigidities of wages and other prices, the "optimal" relative price adjustment could require a minimal level of inflation. Therefore, an inflation-unemployment trade-off would appear in the low inflation range, and lowering an already low inflation target could result in a cost in terms of output growth. While this representation is theoretically relevant, the empirical measurement of nominal rigidities, and thus of "optimal" inflation, is nevertheless difficult (INSEE (1997)). In addition, nominal rigidities are probably related to past inflation, which contributes to shaping expectations: for the same level of current inflation, these rigidities would be greater in the aftermath of periods of high inflation, and weaker following a prolonged period of low inflation, such as that experienced by industrialised countries since the mid-1980s. Lastly, these rigidities are not present across the board: ICT prices fall.

2.2 Managing the transition towards the "new economy" in the short to medium term

In the short to medium term, the new economy raises the issue of transition management - the same problem crops up, in opposing terms, once the NE has petered out. Specifically, the spread of the NE spawns new factors of uncertainty in the conduct of monetary policy. Uncertainties are pervasive in the measurement of output and prices, the duration of the trend that is placed under the NE banner (and hence its actual existence, as it must be sustainable in order to be qualified as such) and in changes in behaviour, and therefore in the accompanying monetary policy transmission channel.

2.2.1 Short- to medium-term dynamics

The spread of the NE has two opposing impacts on prices:

- A so-called "direct" disinflationary effect resulting from a lagged indexation of real wages to productivity that leads to a temporary drop in the NAIRU;[20] and
- A demand effect in the form of a double boom in corporate investment and household consumption. The boom in investment is triggered by the profit opportunities attendant on the uptake of new technologies, the drop in relative prices of high-tech equipment and the decrease in the cost of financing ICT investment due to the surge in the prices of equities issued by ICT-related companies. The boom in consumer spending is spurred by the wealth effect fed by soaring equity prices and the promising outlook for labour income.

In such an environment, the central bank is in a position to choose between two favourable scenarios: turning to advantage the speed-up in productivity growth to allow a further increase in output at an unchanged rate of inflation, or combining a reduction in inflation with a more gradual pickup in output. This alternative was presented by a governor of the Federal Reserve Board, who believes that the productivity surge was mainly used in the United States to boost output temporarily and, to a lesser extent, to lower inflation.[21]

This view could be taken even further:

- The "direct" disinflationary effect is a temporary companion to the more permanent effect resulting from the increase in TFP. It is this more sustained effect that may enable the

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[19] Akerlof et al (1996), Wyplosz (2000).

[20] Meyer (2000a,b), Ball and Mankiw (2002), Ball and Moffit (2001), Cette et al (2002b).

[21] Meyer (2000b). Gordon (2000a) also points out the following: "... by helping to hold down inflationary pressures in the last few years, the New Economy allowed the Federal Reserve to postpone the tightening of monetary policy for several years in the face of a steadily declining unemployment rate".

lowering of the inflation target, while the "direct" disinflationary effect permits an "opportunistic" slowdown of inflation.

- The "direct" disinflationary effect and the demand effect are to some extent mutually exclusive. Notably, the "direct" disinflationary effect can only occur if the spurt in productivity is unforeseen or deemed short-lived, but in such cases, the increase in corporate equity prices and expectations of a rise in labour income are not as robust. This is a point worth making in view of the potential spread of the NE worldwide and particularly in Europe. The precedent set in the United States could in fact lead private economic agents to adjust their demand to the rise in their permanent income, and to factor the pickup in productivity into wage negotiations more quickly than they did in the United States. The "direct" disinflationary effect would therefore be less pronounced.
- As concerns actions taken by the Federal Reserve (Fed), a study of the minutes of meetings of the Federal Open Market Committee (FOMC) shows that, contrary to what is suggested by Ball and Tchaidze (2002), FOMC members, while being aware as in 1996 of a possible acceleration in trend productivity growth, did not explicitly attach great importance to the drop in the NAIRU. In the second half of the 1990s, the FOMC appeared to be striving rather to stabilise one specific indicator of inflation, the core PCE deflator.[22] In any case, the Fed's policy has drawn mixed reactions. On the one hand it has been criticised for leaving a limited legacy by favouring "covert inflation targeting" over explicit rules.[23] On the other hand, the Fed under the chairmanships of Volcker and Greenspan has been applauded for taking better account of technology shocks than had been done previously.[24] On the latter point, it must nonetheless be noted that the NE emerged a long time after Paul Volcker had taken office (see below), and that it is easier for monetary policy to take account of supply shocks when these shocks are positive, as in the case of the NE, than when they are negative, eg rising oil prices.

2.2.2 Taking uncertainties into account

Economic policymakers are generally faced with three types of uncertainty:[25] uncertainty about the state of the economy or economic data, known as "additive" uncertainty (referred to here as type 1 uncertainty), uncertainty about the parameters of the model underlying the economy, termed "multiplicative" uncertainty (type 2) and uncertainty about the model itself (type 3).

Among the forms of uncertainty fed by the advent of the NE, type 1 uncertainty is probably the greatest in Europe. It is linked to the extent and timing of a new economy, and therefore to its measurement (see ECB (2001)). This type of uncertainty calls for an attenuated response to data that might be subject to measurement error - in this case output and inflation.[26] This approach, which appears to correspond to central bank behaviour,[27] presses the case for taking the NE cautiously and progressively into account in the conduct of monetary policy.

Uncertainty about the duration of the NE, and the behavioural changes that may go along with it, ranks as type 2 or even type 3 uncertainty. Studies conducted to date do not, however, arrive at an unequivocal conclusion on the impact of the NE on monetary policy transmission channels. Ehrmann and Ellison (2001), for instance, show that since 1984 US industrial response to monetary policy has been increasingly sluggish. The authors attribute this to the fact that new technologies enable companies to keep a closer eye on inventories and more easily adjust production levels. They therefore now prefer to wait for demand to change before adjusting production, whereas before they would have anticipated changes in demand. This study nevertheless raises at least two problems. The

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22 Wynne (2002).

23 Mankiw (2001).

24 Galí et al (2002).

25 Le Bihan and Sahuc (2002).

26 Orphanides (1998), Svensson and Woodford (2000).

27 Orphanides (1998), Rudebusch (2000).

first is a dating problem. The authors reprise research by McConnell and Perez-Quiros (2000), who show that there was a structural break in the volatility of output in the United States in the first quarter of 1984. However, in monetary policy terms, the break is usually situated in 1979, at the time Paul Volcker took up his post,[28] while in NE terms, the pickup in labour productivity in the United States was observed only in the second half of the 1990s. Ehrmann and Ellison then develop a model for output trends based on the capacity utilisation rate, even though ICTs might have led to a break in the "optimal" level of this variable precisely because inventories were managed more efficiently. Conversely, referring to the expectations hypothesis of the interest rate structure and to the fact that the NE has been accompanied by a reduction in the service life of capital, von Kalckreuth and Schröder (2002) maintain that the NE must have increased the efficiency of the transmission channel by cutting the time to maturity of the interest rate that enters into investment decisions. However, they do not verify their postulate. In any case, long-standing research shows that type 2 uncertainty, like type 1, calls for gradualism.[29] Admittedly, it has been proven more recently that an aggressive monetary policy may be justified in cases where inflation is very persistent.[30] However, if monetary policy is credible, there is little chance of this assumption being verified.[31] As far as type 3 uncertainty is concerned, it may, in a first instance, call for an aggressive strategy when the central bank, faced with radical uncertainty, wishes to ensure a minimum outcome[32] - in the case under consideration, it would allow real interest rates to drop sharply if it wished to ensure that the NE took off at all costs. In a second approach, robustness is achieved by ensuring that the monetary policy decision delivers similar results irrespective of the model used.[33] This is a stance typical of central banks, which often have several models or representations of the economy. It is the approach used here.

The NE and the faster productivity growth that comes in its wake create uncertainties for monetary policy. These uncertainties are simulated by two International Monetary Fund (IMF) economists using the MULTIMOD model. Three scenarios are analysed.[34] In the first scenario, the central bank and the private sector correctly perceive the productivity shock when it occurs. In the second, the central bank and the private sector mistakenly perceive a productivity shock of the same size and revise their mistaken perception after five years. In the third scenario, the central bank's error, one it makes alone, is that it only perceives the productivity shock five years after it has occurred. Compared with the baseline scenario, in which there is no shock, it appears that the central bank's error in being slow to perceive the emergence of the NE entails costs in terms of the stability of production and inflation. However, the highest costs result from the two sectors mistakenly perceiving the development of an NE. In this case, the inflation speed-up would need to be tamped down by a tough monetary policy stance - all the more so because potential output growth has fallen short of expectations.

The simplified model laid out in Appendix 2 finds these two results. The model simulates two types of technology shock that increase the potential output growth rate by 1 percentage point: a one-off shock that occurs in the first year, and a permanent shock. Like in Bayoumi and Hunt's (2000) simulation, the central bank is faced with a situation of uncertainty. In both cases, it may believe that a permanent technology shock has occurred and accordingly adjust its assessment of potential output. This affects the output gap used in the Taylor rule. If the central bank believes that a technology shock has occurred, it may revise its assessment of potential output and also lower its inflation target by 1 percentage point. The results are summarised in Table 2, which indicates total loss on inflation and output.

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[28] See, for instance, Clarida et al (2000).

[29] Brainard (1967).

[30] Söderström (2000).

[31] Cecchetti (2000).

[32] Hansen and Sargent (2000).

[33] McCallum (1999).

[34] Bayoumi and Hunt (2000), IMF (2000). The first paper includes a fourth scenario in which the central bank, unlike the private sector, does not believe in the emergence of an NE and is proven right. This results in output and inflation lower than that in the first scenario. The authors also show that a nominal GDP rule leads to a loss that is smaller than with inflation targeting, particularly in the third scenario.

Table 2

Uncertainty about the NE and monetary policy stance

Monetary policy rule	Taylor rule			Stabilising inflation		
Changing the assessment of potential output	**Yes**		**No**	**Yes**		**No**
Changing the inflation target	**Yes**	**No**	**No**	**Yes**	**No**	**No**
Loss in the event of a trend shock	0.091	0.137	0.175	0.090	0.133	0.162
Loss in the event of a one-off shock	0.198	0.200	0.181	0.193	0.196	0.156

The lessons from the simplified variants are as follows:

- Loss is exacerbated if the central bank is mistaken in its analysis, irrespective of whether the shock is a trend or a temporary shock. Error therefore entails a cost, which seems logical.
- Losses are greater when the central bank mistakenly perceives a trend shock than when it fails to recognise a true shock. This asymmetry, which stems primarily from loss on the stability of economic activity, may be "intuitively" explained as follows. If the central bank mistakenly perceives a trend shock, it spurs a speed-up in the output growth rate beyond the unchanged potential rate. Becoming aware of its mistake, the bank then strives to put a brake on output growth, to bring it below its potential rate until the inflationary pressures have dissipated, so as to finally allow output growth to match its potential rate. If the central bank fails to recognise a true rise in potential output growth, it strives to keep output growth at its previous potential rate. Once it perceives its error, it endeavours to propel output growth beyond its potential rate until the disinflationary pressures have dissipated to finally allow output growth to match its new potential rate. In other words, if, for the sake of simplicity, it is assumed that monetary policy is immediately and totally effective, the output growth rate would change three times in the first case and only twice in the second. This asymmetry requires the central bank to be cautious in identifying the possible development of an NE.
- If an NE is proven to have emerged, the losses are alleviated by the lowering of the inflation target. This is simply attributable to the fact that the lowering of the target goes along with the temporary disinflationary shock arising from the development of the NE. Conversely, if the central bank wrongly perceives a trend shock and lowers its inflation target, losses are higher. Central banks must therefore be especially prudent when lowering inflation targets.

In addition to uncertainty about the development of an NE, uncertainty about the measurement of inflation and GDP that ensues from this new situation could make a Taylor rule and inflation targeting temporarily less effective. In its conduct of monetary policy, it could therefore be in the central bank's interest to take account of other indicators that could help shore up its cyclical analysis. Potential indicators include:

- Money supply: the financial innovations brought on by the NE, such as the issuance of electronic money, financial disintermediation or the increased substitutability between financial assets that results from the fall in transaction costs, could nevertheless give impetus to the velocity of money, ie in the case of the euro area, they could curb the fall in the velocity of M3. This rise in velocity, which is difficult to assess, would counter the impact that the increase in potential output growth has on money supply. It is therefore quite difficult to speculate on how the long-term relationship between money and prices could evolve with the development of an NE.
- Nominal GDP: as the development of the NE could lead to an inflation measurement error that more or less offsets the GDP measurement error, the case could be made for paying closer attention to trends in nominal income when defining interest rate policy. However, the shortcomings inherent in targeting nominal income, rather than prices, remain patent,

particularly the fact that such a strategy implies potentially infinite inflation and output variances.[35] Consequently, this strategy would appear to be ill equipped to adequately protect the economy from shocks other than NE-related uncertainty, notably that arising from measurement error.

- Survey data or information provided by financial markets: given that they are partially subjective, these sources of information - more so than data resulting partly from accounting conventions - could take account of changes in behaviour that may occur with the advent of the NE. It is true that they could also reflect errors in perception made by the private sector, but at the end of the day, they would make it possible to cross-check the information supplied by the national accounts, increasing the soundness of the cyclical analysis.

3. Conclusion

The adjustment of monetary policy to the new NE-engendered environment has been analysed entirely from the perspective of interest rate policy. The role played by other economic policies, as well as the international environment or the difficulties that the NE could raise for the implementation of monetary policy have been overlooked. It is nevertheless worth touching on the findings of a number of studies carried out on these aspects. We shall do so by way of conclusion.

- Structural policies can pave the way for an NE to emerge and develop. They could do so notably by giving free rein to the different competitive forces in order to reduce nominal rigidities in the transition phase, and in the longer term by creating an environment that nurtures technical progress with a view to boosting potential supply and passing on the fall in production costs. Fiscal policy can also limit the rise in the real equilibrium interest rate by improving the government budget balance.[36]
- By acting as a driver of internal demand and improving corporate profitability, an NE worsens the current account balance and triggers capital inflows into the country in which it has developed, leading, in the short to medium term, to a rise in the exchange rate.[37]
- Various authors[38] have highlighted two ways in which monetary policy could lose its effectiveness and the central bank its financial independence as a result of the NE-related technology upheaval. The first way would be via the dwindling use of central bank money in transactions due to the spread of electronic money, held as a claim on securities, and the complete securitisation of the financing of the economy. The second way would be through an erosion in the demand for central bank reserves, with the same factors leading to the establishment of clearing systems outside the purview of the central bank, and possibly limiting demand for banknotes to the financing of underground activities. The only way to avoid what Friedman (2000) calls a “decoupling at the margin” that would render monetary policy ineffective and the level of prices indeterminate, would then be to impose legal constraints - for example, by making it mandatory for taxpayers to pay their taxes in liabilities drawn against the central bank, as suggested by Goodhart (2000). The risk of decoupling is, however, probably very slight. Above all, like Woodford (2000), we may question financial markets’ ability to generate an equilibrium interest rate that would allow intertemporal arbitrage while maintaining purchasing power. Financial markets would therefore continue to be in need of an institution that is not in competition with them, that entails no credit risk and whose balance sheet items provide a reference for the setting of short-term interest rates; namely, a central bank. Legal constraints would therefore be unwarranted.

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[35] Ball (1997), Rudebusch (2000).

[36] Meyer (2000a).

[37] Bailey et al (2001), Tille et al (2001).

[38] Cechetti (2002), Costa and De Grauwe (2001), Freedman (2000), Friedman (2000), Goodhart (2000), King (1999), Mésonnier (2001) and Woodford (2000).

Appendix 1:
Formalising the spread of ICTs and potential output growth

This formalisation is taken from Cette et al (2002b).

As indicated in the study, medium- to long-term effects are distinguished from short- to medium-term effects.

Medium- to long-term effects

Assume a Cobb-Douglas production function with unit returns to scale and autonomous Hicks-neutral technological progress (the effects of this technological progress therefore match TFP gains):

$$Q = A\, e^{\gamma t} K^{\alpha} N^{1-\alpha} \quad \text{and} \quad \text{output growth rate: } \mathring{Q} = \gamma + \alpha \mathring{K} + (1-\alpha)\mathring{N} \qquad (1)$$

In the long term, at the potential level of the variables, the capital output ratio remains constant:

$$\mathring{P}_Q + \mathring{Q}^* = \mathring{P}_K + \mathring{K}^* \quad \text{and} \quad \mathring{K}^* = \mathring{Q}^* + (\mathring{P}_Q - \mathring{P}_K) \qquad (2)$$

The following expression for potential output growth is derived from the previous equations:

$$\mathring{Q}^* = \frac{\gamma}{1-\alpha} + \frac{\alpha}{1-\alpha}(\mathring{P}_Q - \mathring{P}_K) + \mathring{N}^* \qquad (3)$$

In the absence of a differential between output price and investment price developments $(\mathring{P}_Q = \mathring{P}_K)$, we find the customary expression for potential output growth:

$$\mathring{Q}^* = \frac{\gamma}{1-\alpha} + \mathring{N}^*$$

The advent and spread of ICTs may have a twofold impact: an increase in TFP gains and a slowdown in the real price of investment. It is also assumed that in the medium to long term, the spread of ICTs does not change the potential employment level ($N^{*\prime} = N^*$), which means that in the medium to long term it impacts neither on the level of the NAIRU ($U^{*\prime} = U^*$) nor on the potential labour supply ($POP^{*\prime} = POP^*$). Therefore:

$$\mathring{Q}^{*\prime} = \frac{\gamma'}{1-\alpha} + \frac{\alpha}{1-\alpha}(\mathring{P}'_Q - \mathring{P}'_K) + \mathring{L}^* \quad \text{with: } \gamma' \geq \gamma \text{ and } \mathring{P}'_K \leq \mathring{P}_K;\ \ \mathring{P}'_Q \leq \mathring{P}_Q \qquad (4)$$

The gains in potential output growth resulting from the spread of ICTs are given as the difference between equations (4) and (3):

$$\Delta\mathring{Q}^* = \mathring{Q}'^* - \mathring{Q}^* = \frac{\gamma'-\gamma}{1-\alpha} + \frac{\alpha}{1-\alpha}\left[(\mathring{P}'_Q - \mathring{P}_Q) - (\mathring{P}'_K - \mathring{P}_K)\right] \qquad (5)$$

The change in the potential output growth rate caused by the spread of ICTs is the sum of the two elements. The first $(\frac{\gamma'-\gamma}{1-\alpha})$ corresponds to the effect of the change in TFP gains, the second $(\frac{\alpha}{1-\alpha}[(\mathring{P}'_Q - \mathring{P}_Q) - (\mathring{P}'_K - \mathring{P}_K)])$ to the capital deepening effect caused by the difference between the change in output price and the change in the price of investment.

Short- to medium-term effects

For simplicity, we assume that labour productivity grows at a constant rate, before and after the spread of ICTs, and that productivity accelerates at a constant rate during the rollout period. The ICT rollout period spans from date t_1 to date t_2. Labour productivity can be written in a simplified form using the following logarithms:

$(q-n) = \lambda_1 t + \lambda_3$ before the rollout period, when $t < t_1$ (6.1)

$(q-n) = \lambda_1 t + \lambda_2 (t - t_2) + \lambda_3$ after the rollout period, when $t > t_2$ (6.2)

$(q-n) = \lambda_1 \; t + \lambda_2 \; \dfrac{t-t_1}{t_2-t_1} \; t + \lambda_3$ during the rollout period, when $t_1 \le t \le t_2$ (6.3)

Labour productivity therefore rises at an annual level λ_1 before the ICT rollout period, $\lambda_1 + \lambda_2$ after this period, and $\lambda_1 + \lambda_2 \; \dfrac{t-t_1}{t_2-t_1}$ during this period.

For labour costs (more specifically per capita labour costs), we assume, as do Meyer (2000b), Blinder (2000), Ball and Moffit (2001) and Ball and Mankiw (2002), that growth in labour costs smoothly adjusts to the rise in productivity. This lagged adjustment is given by the simplified equation:

$$\overset{o}{W} = \beta_1 + \overset{o}{P}_{c-1} - \phi(L)(Q\overset{o}{/}N) - \beta_3 \, U_{t-1}, \quad \text{with } \phi(1) = 1 \qquad (7)$$

Before the spread of ICTs (ie before t_1) or once ICTs have become totally widespread (after t_2) and once growth in labour costs has adjusted completely to productivity, the "long-term" NAIRU is easily deducted from equation (7): $U^* = \beta_1 / \beta_3$

In the shorter term, during the ICT rollout period, due to the lagged adjustment of growth in labour costs to that of productivity, we have $\phi(L)(Q\overset{o}{/}N) \prec (Q\overset{o}{/}N)$. The NAIRU is therefore temporarily lower than its long-term level, as shown by Meyer (2000b):

$$U^*_{CT} = U^* - \frac{1}{\beta_3} \; (1 - \phi(L)) \; Q\overset{o}{/}N) \qquad (8)$$

The fact that the NAIRU is temporarily lower than its long-term level enables a temporary gain in potential GDP. Potential employment N^* is defined by the equation:

$N^* = (1 - U^*)POP^*$

where POP^* denotes the potential labour supply whose level is unchanged by the spread of ICTs ($POP^* = POP$).

From the logarithmic equation (1) and equation (9), we therefore derive the temporary gain in the potential GDP level:

$$\Delta \, q^*_{CT} \; = (1-\alpha) \; \Delta_{CT} n^* \approx (1-\alpha) \; (U^* - U^*_{CT}) = \frac{(1-\alpha)}{\beta_3} \; (1 - \phi(L)) \; Q\overset{o}{/}N \qquad (9)$$

This temporary gain in the potential GDP level corresponds to a similarly temporary gain in the economy's potential output growth.

Notations

Q	Volume of output
K	Volume of fixed productive capital
N	Volume of labour
POP	Labour supply
P_Q	Price of output
P_K	Price of investment in fixed productive capital
P_c	Price of household consumption
W	Per capita labour costs
U	Unemployment rate, with $N = (1 - U)POP$ and $L^* = (1 - U^*)POP^*$, U^* denoting the NAIRU
α	Elasticity of output as a ratio to capital
β_1, β_2, β_3	Coefficients in equation (7) denoting labour cost formation

λ_1, λ_2, λ_3	Coefficients in equation (6) denoting trends in labour productivity
γ	Autonomous technological progress, ie gains in TFP
t	Time variable
t_1 and t_2	Start and end of the ICT rollout period
L	Time lag operator
$\phi(L)$	Polynomial of the time lag operator in the labour cost equation (7), with $\phi(1) = 1$
"$_{CT}$"	as a subscript of a variable indicates that it is the short- to medium-term value of this variable
"^{o}"	above a variable denotes its growth rate
"*"	as an exponent of a variable denotes its potential level
"′"	as an exponent of a variable denotes its level during the ICT rollout period
"Δ"	in front of a variable denotes the differential between the two situations before and after the spread of ICTs

Variables in lower case correspond to their logarithms

"$_{-1}$"	as a subscript denotes a lagged variable

Appendix 2:
Technology shock and monetary policy: a highly simplified model

A highly simplified model illustrates the impact transitory and protracted technology shocks have on GDP growth and inflation, assuming different monetary policy responses. It corresponds to a closed economy or to the global economy.

We define ex ante potential output (*QEA*) as the level of potential output excluding the effects of fluctuations in the real interest rate. In the absence of a technology shock, ex ante potential output (*QEASC*) is assumed to grow at a constant rate. A technology shock alters the ex ante potential output growth rate, which is then denoted as *QEAAC*. There are two possible types of technology shock. The first, which is transitory, is characterised by a 1 percentage point pickup in the growth rate of ex ante potential output over one period. The second and protracted shock is typified by a steady 1 percentage point increase in the growth rate of ex ante potential output.

Variations in the real interest rate are prompted by supply shocks that gradually impact on the level of potential output. This effect is denoted by equation (1) assuming that the supply shock (as a percentage) is proportional to the smoothed and lagged gap between the real interest rate and real output growth. The gap is smoothed by averaging gap values over four periods:

$$etir = a \quad (TIRHC - \Delta TARGET - \overset{o}{Q})_{1,-1} \tag{1}$$

The volume of ex post potential output, ie including the supply shocks corresponding to fluctuations in the real interest rate, is therefore written:

$$qep = qeaac + etir \tag{2}$$

The adjustment of the volume of actual output (*Q*) to the volume of ex post potential output (*QEP*) is represented using a second-order error correction model. The advantage of this model is that it leads in the long term to a perfect adjustment, and in the short to medium term to cyclical differences that are supposed to correspond to the dynamic accelerator-multiplier equation and to the effects of economic agents' mistaken expectations about the nature and size of the technology shock. Therefore:

$$q = \phi(L)\ [qep], \qquad \text{with: } \phi(L) = \frac{b_0 + b_1 L + b_2 L^2}{1 + (-2 + 2\,b_0 + b_1)\,L + (1 - b_0 + b_2)\,L^2} \text{ where } \phi(1) = 1 \text{ is verified} \tag{3}$$

The ex ante (*eqea*) and ex post output gap is the (logarithmic) difference between the volume of actual output (*q*) and the volume of potential output, ex ante in the absence of a shock (*qeasc*) and ex post (*qep*) respectively:

$$eqea = q - qeasc \qquad \text{and} \qquad eqep = q - qep \tag{4}$$

Compared to a situation without a shock where the output gap is assumed to be zero, an inflation differential is created by the non-nullity of the smoothed ex post output gap (the gap is smoothed by averaging gap values over two periods):

$$\Delta \overset{o}{P} = c \quad eqep_1 \tag{5}$$

Lastly, monetary policy corresponds to the application of a Taylor rule. When applying this rule, the parameter for weighting the inflation differential and the output gap may, however, be modified, as the rule may be transformed into a simple inflation target (if $\alpha = 1$). We also use Bayoumi and Hunt's (2000) two opposing assumptions in which the central bank may fail to recognise a technology shock and therefore fail to modify its assessment of potential output, or on the contrary, take it into account. In the following notations, the central bank correctly perceives a shock where $d = 1$ and fails to do so where $d = 0$.

$$TIR = \alpha \ \Delta \overset{o}{P} + (1-\alpha)(d \ \ eqep + (1-d)\, eqea) + d \quad QE\overset{o}{A}AC + (1-d)\, QE\overset{o}{A}SC \tag{6}$$

Output (*PQ*) and inflation (*PP*) losses are calculated as the discounted quadratic sum over 100 years for output gaps and inflation differentials respectively:

$$PQ = \sum_{i=1}^{100} \frac{1}{(1+r)^i} eqep_i^2 \qquad \text{and} \qquad PP = \sum_{i=1}^{100} \frac{1}{(1+r)^i} (\Delta \overset{o}{P}_i - \Delta TARGET)^2 \tag{7}$$

Standard values are used for the various parameters of this simplified model: $a = -0.75$; $b_0 = 0.70$; $b_1 = 0.1$; $b_2 = 0.1$; $c = 0.5$; $d = 1$ if the central bank perceives an NE, and 0 if it does not; $0 \leq \alpha \leq 1$, $\alpha = 0.5$ if there is a Taylor rule and 1 if there is inflation targeting; $e = 0$ or 1; $r = 3.5\%$.

Notations

Q	Volume of actual output, denoted by equation (3)
QEASC	Volume of ex ante potential output in the absence of a shock, given by assumption
QEAAC	Volume of ex ante potential output in the presence of a shock, given by assumption
QEP	Volume of ex post potential output, denoted by equation (2)
eqea	Ex ante output gap (relative), denoted by equation (4)
eqep	Ex post output gap (relative), denoted by equation (4)
etir	Impact (as a relative gap) of real interest rate fluctuations on potential GDP volume, denoted by equation (1)
$\overset{o}{P}$	Inflation
TIR	Real interest rate, denoted by equation (6)
TIRHC	Level of real interest rate excluding variations in the central bank's inflation target
TARGET	Central bank's inflation target
r	Discount rate
PQ	Loss on output, denoted by equation (7)
PP	Loss on inflation, denoted by equation (7)
a	Parameter in equation (1) that reflects the impact of fluctuations in the real interest rate on output
b_0, b_1 and b_2	Parameters in equation (3) that reflect the adjustment of output to its potential level
c	Parameter in equation (5) that reflects the impact of the output gap on inflation
d	Parameter in equation (6) that reflects whether or not the central bank has identified a technology shock
α	Parameter in the Taylor rule, equation (6)
$\phi(L)$	Polynomial of the time lag operator *L*

A variable in lower case indicates that it is expressed logarithmically or as a relative gap for output gaps.

"o"	above a variable indicates the growth rate of this variable over time.
"Δ"	in front of a variable indicates the differential in this variable compared with a situation in which there is no technology shock.
"*l* "	as a subscript indicates that this is a smoothed variable, with equal weighting. Smoothing is carried out over four periods in equation (1) and over two periods in equation (5).
"−1"	as a subscript indicates that the variable has a time lag of one period.

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