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TECHNICAL PROGRESS, FACTOR PRODUCTIVITY AND MACROECONOMIC PERFORMANCE IN THE MEDIUM TERM

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INTRODUCTION

Economic theory is relatively clear about the positive long-term consequences of the introduction of new technologies which lead to increased factor productivity. Provided that the supply of production factors is not adversely influenced, higher productivity can be expected to raise potential output, and, if labour and product markets are sufficiently flexible, aggregate demand should adjust to this increased supply potential in the long-run. In such a new equilibrium, production, real wages, consumption and investment will all be higher, while unemployment will, at least, be unchanged. Despite this fairly straightforward neo-classical view, there are nonetheless concerns, especially for the short and medium term, that increased labour productivity associated with new technologies may reduce the demand for labour and thereby aggravate the already serious unemployment problem in the OECD area. It is argued, for instance, that the introduction of new technologies may lead to job destruction for some industries and some skill categories without creating sufficiently offsetting new job opportunities in others. However, such arguments are either partial in failing to take account of wider macroeconomic factors or rely on the view that the relevant adjustment mechanisms are not functioning properly.

Empirical macroeconomic models provide a useful framework for examining some of these issues and the possible short- and medium-term consequences of productivity changes, especially the dynamic links between productivity, wage and price setting, output and employment. Thus, simulations with such models help clarify likely magnitudes of the relevant responses and the influence of macroeconomic conditions and structural factors on the adjustment process, although they have relatively little to say about the effects of technological change on the composition of labour demand and associated adjustment requirements. In this paper, some of the possible short- and medium-term consequences of an increase in trend productivity are examined in the context of OECD's international macroeconomic model INTERLINK on the basis of a number of stylised simulations made on a ten-year horizon. These update previous OECD estimates of the macroeconomic effects of changes in trend productivity, for example those reported by Englander and Mittelstadt (1988), OECD (1988) and Torres and Martin (1990), but also examine in more detail the role and importance of structural factors. Major parts of the model have since been re-specified and re-estimated (see Turner *et al.* (forthcoming) and Turner *et al.* 1993] and simulations with the current version therefore provide a more up-to-date perspective.

The OECD INTERLINK model can be broadly categorised as being neo-classical in terms of structural specification and equilibrium properties, but "New Keynesian" in terms of short-term dynamics.' In particular, real and nominal rigidities in wage and price setting are seen as factors which significantly affect the period of adjustment towards equilibrium for certain shocks. It is an international model, with sub-models for 24 OECD countries and a trade block linking these and also the non-OECD regions, ensuring world-wide consistency of international trade flows, volumes and prices.

The various scenarios presented in this paper are representative of the results for a "standard" OECD economy, defined here as the simple average for the G7 countries. These should not be seen as precise estimates of the magnitude and timing of the macroeconomic consequences. Estimated lag structures and structural coefficients are uncertain and subject to statistical confidence intervals and outcomes may also depend on cyclical situations which a largely linear model may not be well suited to describe. Also, the outcomes for a specific OECD country may deviate substantially from those of the "standard" OECD country because of structural differences. Detailed analysis of such differences goes beyond the scope of this paper, although the importance of key differences in flexibility are illustrated.

The rest of this paper is organised as follows. The first section discusses the relationship between technology and factor productivity, and the corresponding specification of technology "shocks" used in the exercise. It also provides a general description of the main mechanisms involved and presents the simulated effects for changes in the level and rate of growth of productivity under specific assumptions. The second section goes on to describe how the adjustment process is likely to be influenced by wider macroeconomic considerations, in particular monetary conditions and exchange rates. It also illustrates the size of linkage effects associated with international diffusion. The relevance of structural factors for the adjustment process are highlighted in the third section. The final section provides summary comments and some general policy conclusions.

TECHNOLOGICAL CHANGE, PRODUCTIVITY GROWTH AND MACROECONOMIC ADJUSTMENT IN THE SINGLE COUNTRY CONTEXT

There has been a considerable debate about the economic consequences of technological progress over the last decades, especially in the field of information technologies and telecommunication and the links between technology and productivity have been the subject of a considerable number of studies.[2] At the macroeconomic level however, the expected positive impact of new technologies on trend factor productivity has not been easy to identify. On the contrary, as underlined by the often-quoted "Solow paradox",[3] most OECD economies experienced a slowdown in productivity growth in the aftermath of the first oil shock and the

subsequent pick-up in the 1980s and early 1990s is, at best, modest despite significant changes in information technologies. Explanations of this phenomenon tend to stress the gradual exhaustion of technological catching-up in Europe and Japan, relative to the United States, and difficulties of incorporating new technologies in the production system. Neither of these arguments contradict the existence of a direct link between changes in technology and productivity growth but they demonstrate a considerable degree of uncertainty regarding the strength of the link at the macroeconomic level and the transmission lags between technological change and factor productivity.

Uncertainties also exist about the links between technology and the composition of labour demand at the firm level. While recent microeconomic empirical evidence suggests a strong positive correlation between the use or introduction of new technology and the use of high-skilled employment, the causality remains unclear.[4] On the one hand, firms should be all the more innovative when their workers are better educated. On the other hand, technological change may be skill-biased, increasing demand for high-skilled workers and shifting demand away from unskilled labour.[5] Hence, if relative wages do not adjust sufficiently and the skill composition of the labour force is relatively fixed, excess supplies of unskilled labour or labour with outdated qualifications might develop.

The analysis of the effects of technological shocks with macroeconomic models is necessarily sensitive to the assumptions made about the impact of technological change on potential employment and the specific way in which trend labour efficiency may be affected. In the latter case, an important question is whether changes in technology translate into temporary or permanent gains in labour efficiency growth. Such assumptions are important because they may influence not only the size of the shock but, more fundamentally, the nature of long-term macroeconomic effects, in particular on unemployment. Indeed, in a number of empirical macroeconomic models, including INTERLINK, the rate of trend factor productivity growth is one of a number of important factors influential in the determination of wages, prices and thereby the equilibrium or non-accelerating wage rate of unemployment[6] (the NAWRU).

To illustrate the range and conditional nature of the effects of changes in trend factor productivity on main macroeconomic aggregates and the associated adjustment mechanisms, a range of alternative simulations have been carried out. Key results are reported in Table 1 on a comparative basis, and also in Figures 1 to 7 which follow. Unless otherwise stated, these simulations all assume government expenditures in real terms, real interest rates and nominal exchange rates to be unchanged from baseline. Though a number of specific factors vary across the individual cases considered, the key macroeconomic mechanisms involved are broadly similar and as described below.

Table 1. **Comparative estimates of the effects of an increase In the trend productivity growth rate under alternative assumptions**

Percentage differences from baseline

	simulation A	Simulation B	Simulation C	Simulation D	Simulation E	Simulation F	Simulation G	Simulation H
Real CDP level (per cent)								
After 3 years	0.6	0.6	0.7	0.4	0 6	1.0	0.4	1.2
After 5 years	1.5	1.5	2.0	1.7	1.5	2.3	1.3	2.4
After 10 years	3.6	1.7	2.5	2.6	2 1	2.1	1.7	1.7
Unemployment rate								
After 3 years	–0.2	–0.2	0.2	0.3	0 2	0.1	0.2	0.0
After 5 years	–0.4	–0.4	–0.1	0.0	0 1	-0.3	0.1	–0.3
After 10 years	–0.6	–0.2	–0.3	–0.5	0 0	0.0	0.1	0.0
Inflation rate (CDP deflator)								
After 3 years	–0.7	–0.7	–1.2	–1.6	–1 6	– 1.1	–0.6	–1.6
After 5 years	– 1.1	–1.0	–1.7	–2.3	–3 0	–1.4	–1.2	–1.8
After 10 years	–1.2	0.0	0.2	0.8	–2 6	–0.9	–0.2	0.6
Real wage level (per cent)								
After 3 years	0.3	0.3	0.0	0.0	0 2	0.2	0.3	0.0
After 5 years	0.9	0.8	0.3	0.1	0 6	0.8	0.6	0.3
After 10 years	2.8	1.7	1.3	0.9	1.6	1.8	1.3	1.5

Notes Simulation specifications

Simulation A A permanent 0 5 percentage point increase in the annual growth rate of trend labour efficiency, with nominal exchange rates, real interest rates and real government expenditures unchanged from base

Simulation B As simulation A, except that the annual growth rate of trend labour efficiency is raised during the first four years only

Simulation C "Reference simulation" as simulation B with an ex ante reduction of employment growth of 0 2 percentage point during the first four years

Simulation D As reference simulation with nominal interest rates unchanged

Simulation E As reference simulation with real exchange rates unchanged

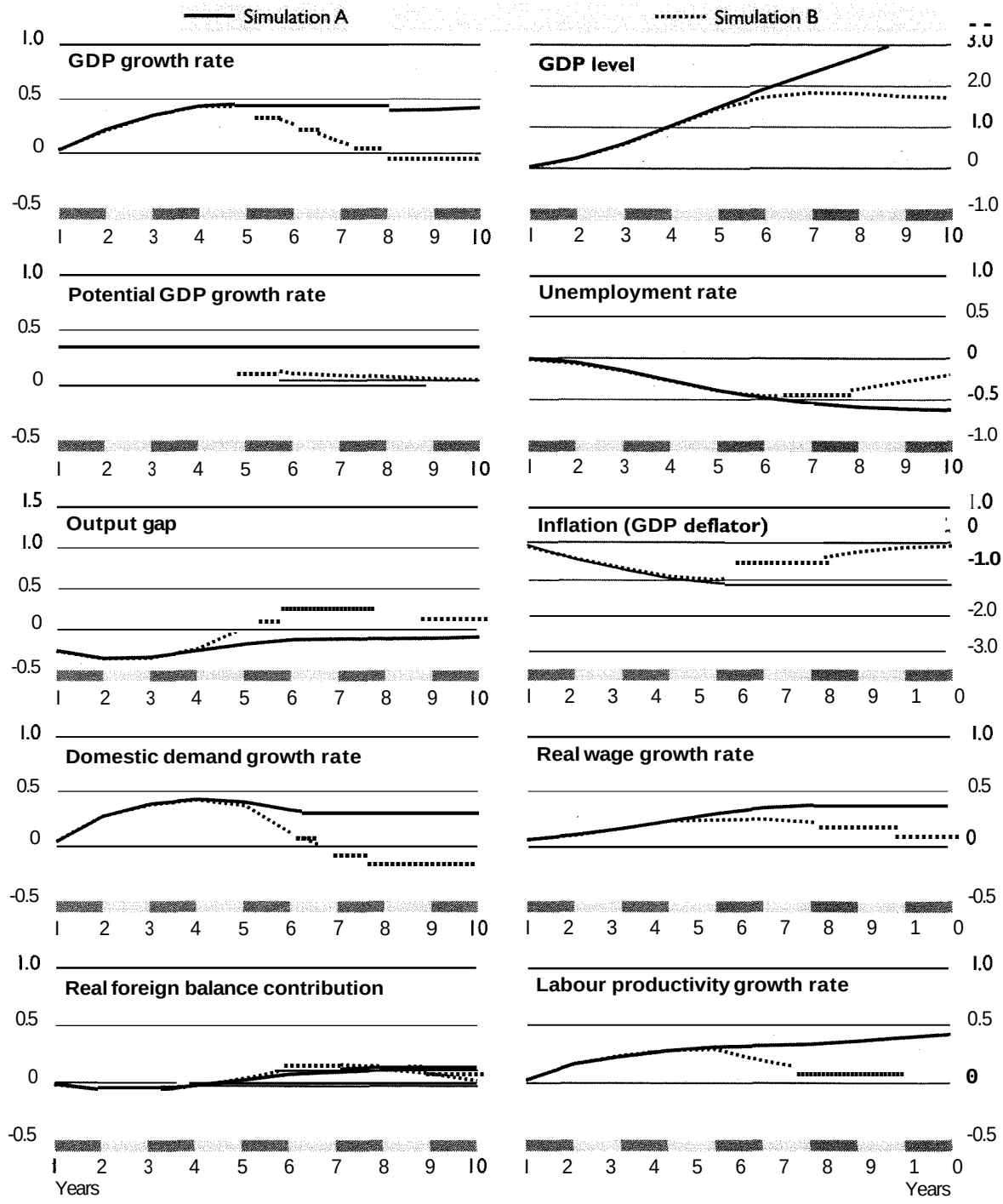
Simulation F As reference simulation with productivity increased simultaneously in all major seven OECD economies

Simulation G As reference simulation, with a permanent rise of NAWRU of 0 25 percentage point from the second year

Simulation H As reference simulation. with alternative rigidity assumptions (see text)

Source OECD INTERLINK model All estimates are average responses for the major seven OECD economies relative to baseline

Figure 1. ***Effects of a permanent and temporary increase in the trend productivity growth rate***
Difference from baseline *in* percentage points



Simulation A A permanent 0.5 percentage point increase in the annual growth rate of trend labour efficiency, with nominal exchange rates, real interest rates and real government expenditures kept unchanged.

Simulation B: As simulation A with the increase in the annual growth rate of trend labour efficiency for the first 4 years only.

In the short term, the main consequences of higher trend productivity arise through a positive influence on the level of potential output and a negative influence on costs per unit of production. Both these factors put downward pressure on domestic prices. If nominal wages adjust only slowly and a labour productivity increases, real wages and real disposable income will rise, having a positive influence on private consumption. The positive impact on demand may, however, be reduced by any initial negative impact of the rise in productivity on labour demand and employment which may arise, depending on the degree of restructuring and employment dislocation involved. However, more important and with a more permanent influence, the real income and consumer wealth should rise as inflation is reduced, with a positive influence on consumption and demand. At the same time, business investment will be stimulated both by the rise in output and any initial rise in profitability associated with the embodiment of the new technologies in capital goods. Unless nominal exchange rates adjust completely to eliminate price differentials,lower costs and prices will improve competitiveness, thereby stimulating exports and reducing imports. Thus, in the long run, adjustment of output to a higher new level of potential may be expected to have a positive influence on the demand for labour, offsetting progressively any initial reduction in employment and rise in unemployment associated with the change in factor requirements. Though the speed and timing of adjustment may vary, the economy converges to a new equilibrium with higher real wages, output and production per head.

As previously argued, the differences between the effects of changes in technology which have alternative permanent or temporary effects on trend factor efficiency growth are important, as illustrated by comparisons of simulations A and B in Figure 1. The former case assumes a permanent change in trend labour efficiency growth of ½ per cent per annum, whereas the latter assumes the change to be temporary over the first four years, though the levels of efficiency and supply potential are permanently raised thereafter.

The key difference is that a permanent increase in efficiency growth has a permanent effect on actual and potential output growth and, through wage/price dynamics, also the equilibrium unemployment rate, which is reduced by over ½ percentage points of a ten-year horizon. For a temporary rise in trend productivity growth, longer-term labour market equilibrium is unaffected and, after a period of positive adjustment, the economy adjusts back towards its long-term equilibrium as disinflation pressures come to an end. Indeed, once the effects of higher labour efficiency growth have dissipated, real wages tend to grow temporarily faster than productivity as a consequence of wage rigidities and mounting labour market pressures. With a less favourable inflation picture, demand and production growth fall back towards baseline levels after about eight years. Though lagging somewhat, medium-term employment gains disappear steadily thereafter and in the long run,

the temporary increase in labour efficiency growth translates into an upward shift in the levels of real income and productivity, but an unchanged rate of unemployment.

Both these simulations are somewhat artificial in that they abstract from possible negative direct effects of productivity improvements on labour demand. In fact, empirical evidence at firm and sector microeconomic levels suggest that introduction of new technology may often be associated with short-term employment dislocation[7] and, for several European countries, such evidence appears to be confirmed at the macroeconomic level by time-series econometric studies which identify a negative link between trend productivity growth and employment growth.[8]

While the importance of such a phenomenon is difficult to quantify at the margin, its consequences are illustrated in simulation C and compared with simulation B in Figure 2. In this case, the assumption made is that, on average, higher labour efficiency growth leads to an *ex ante* reduction of employment with a semi-elasticity of –0.4.[9] As a consequence, higher trend productivity leads to a temporary rise in unemployment by up to 0.2 percentage points. Nonetheless, the combination of a more subdued increase in real wages and rising labour productivity growth result in a more significant disinflation which, in turn, induces a more pronounced cycle in output. The negative effects on employment are fully reversed within four years but in the absence of any shift of the long-term equilibrium, a temporary cyclical fall in unemployment is eroded steadily thereafter. Thus in spite of differing assumptions about short-term employment consequences, the key difference in these two cases can be seen to be largely one of timing.

MACROECONOMIC CONDITIONS AND THE ADJUSTMENT PROCESS IN AN INTERNATIONAL CONTEXT

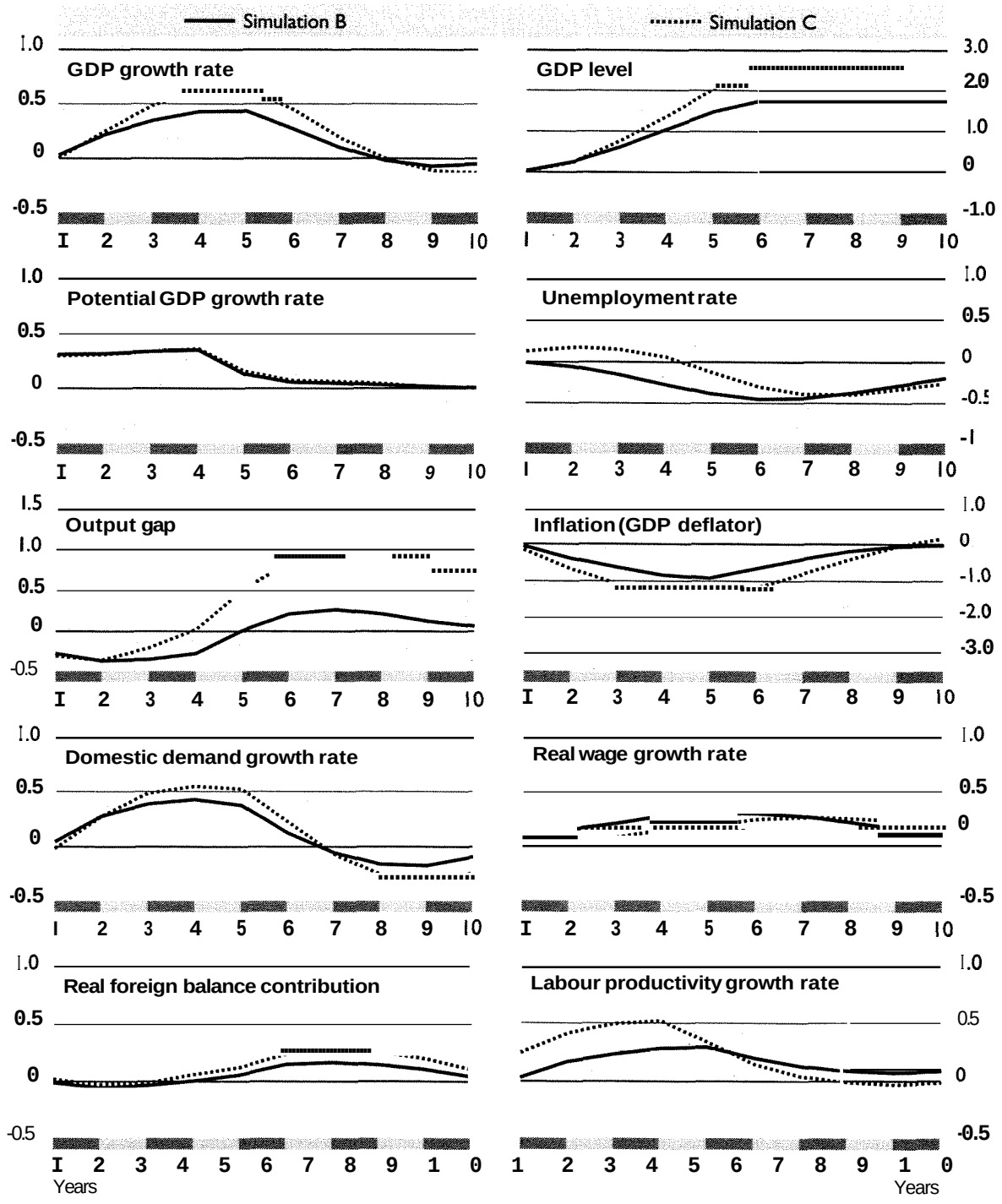
Monetary conditions and financial market influence

Monetary conditions and financial market reactions are seen as particularly important in re-enforcing or counter-acting the self-equilibrating tendencies of an economy following a perturbation. In the case of disinflationary shocks for example, lower real interest rates tend to stimulate private sector demand, reduce the output gap and, consequently, make for less disinflation. Conversely, if nominal interest rates are relatively fixed, for example because of wider monetary policy objectives or financial conditions, then real interest rates will rise with disinflation, tending to weaken the real economy and exacerbate the short-term effects of the initial perturbation.

As an illustration of this point for a change in trend productivity, Figure 3 compares the effects shown for simulation C (denoted hereafter as the Reference Case) with an alternative simulation D, in which nominal interest rates are assumed to be unchanged from base, implying higher real rates during the disinflation. In this case, maintaining unchanged nominal interest rates is seen to exacerbate the

Figure 2. ***Effects of a productivity rise with alternative short-term employment reactions***

Difference from baseline in percentage points

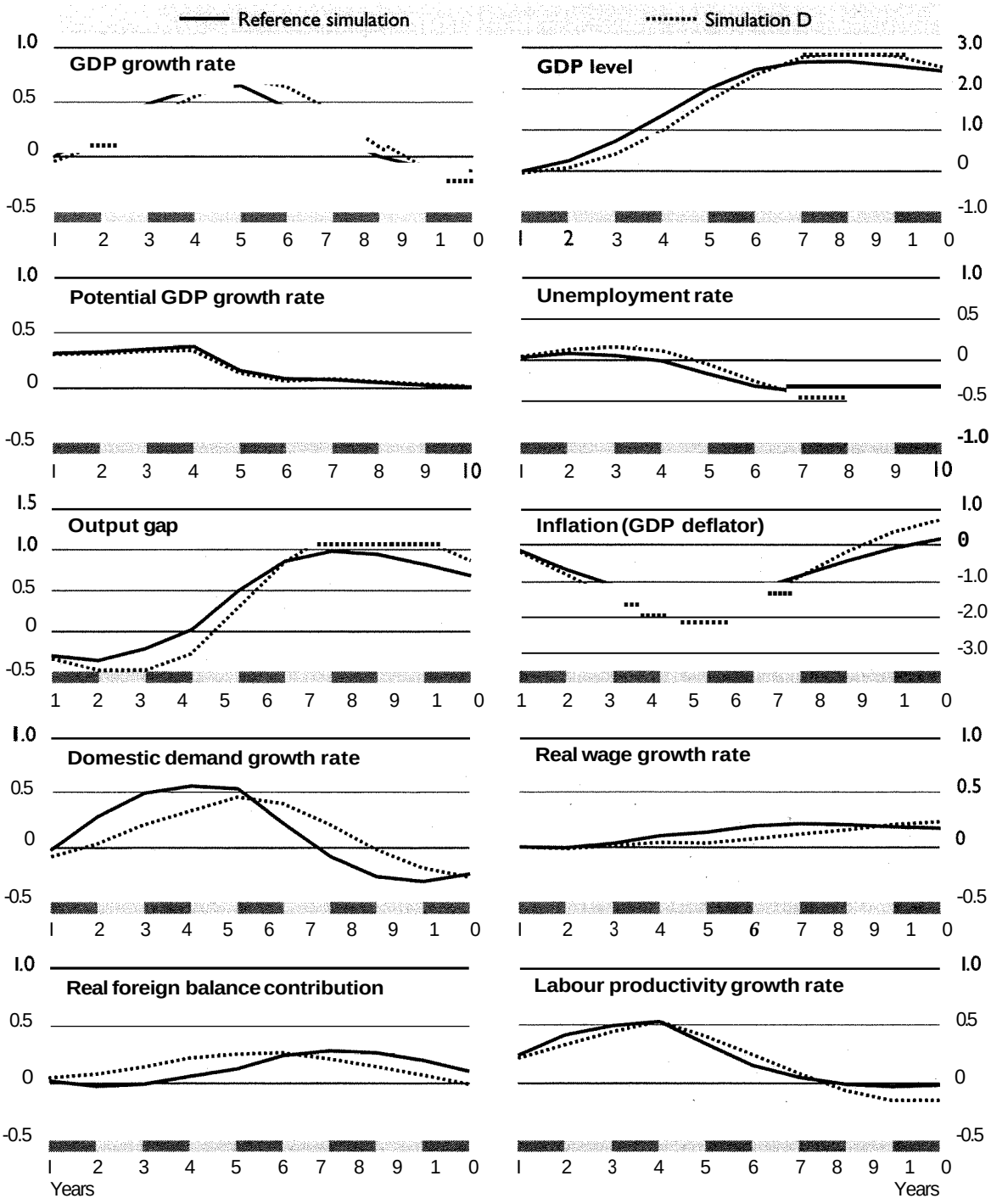


Simulation B see Figure 1.

Simulation C "Reference simulation"; as simulation B with an ex *ante* reduction of employment growth by about 0.2 percentage point during the first 4 years.

Figure 3. ***Effects of a productivity rise with alternative nominal interest rate assumptions***

Difference from baseline in percentage points



Reference simulation: See simulation C in Figure 2.
Simulation D: As the reference simulation with nominal interest rates instead of real interest rate unchanged from baseline.

initial imbalance between supply and demand in the economy, increasing and extending the negative impact on unemployment over the first five years and accentuating the degree of disinflation. However in the following years, real interest rates edge downward as inflation returns towards base, domestic demand picks up and, on a temporary cyclical basis, unemployment rate falls more markedly than in the reference simulation. Overall, the consequence of keeping nominal interest rates unchanged is to accentuate the cyclical profile and, hence, to delay the return of the economy toward long-term equilibrium.

Exchange rate influences

An important international element in the adjustment process arises from the international competitiveness gains acquired by a country benefiting from higher trend productivity. Such a mechanism may, however, be neutralised to the extent that nominal exchange rates appreciate in order to offset inflation differentials. To illustrate the relative importance of such competitiveness effects to the adjustment process, Figure 4 shows a case where exchange rates are assumed to be unchanged in real terms and the adjustment between demand and supply relies completely on the strengthening of domestic demand. In this case, domestic demand rises more swiftly than in the reference simulation because the fall in inflation is strengthened by the impact of exchange-rate appreciation on import prices. In contrast to the reference case, the foreign demand contribution to the activity is negative over the whole simulation period. Overall, real-side adjustment is less cyclical than in the reference simulation and disinflation more pronounced. Though unemployment adjustment is slower in the short term, the equilibrium is established relatively quickly with little variation beyond five years.

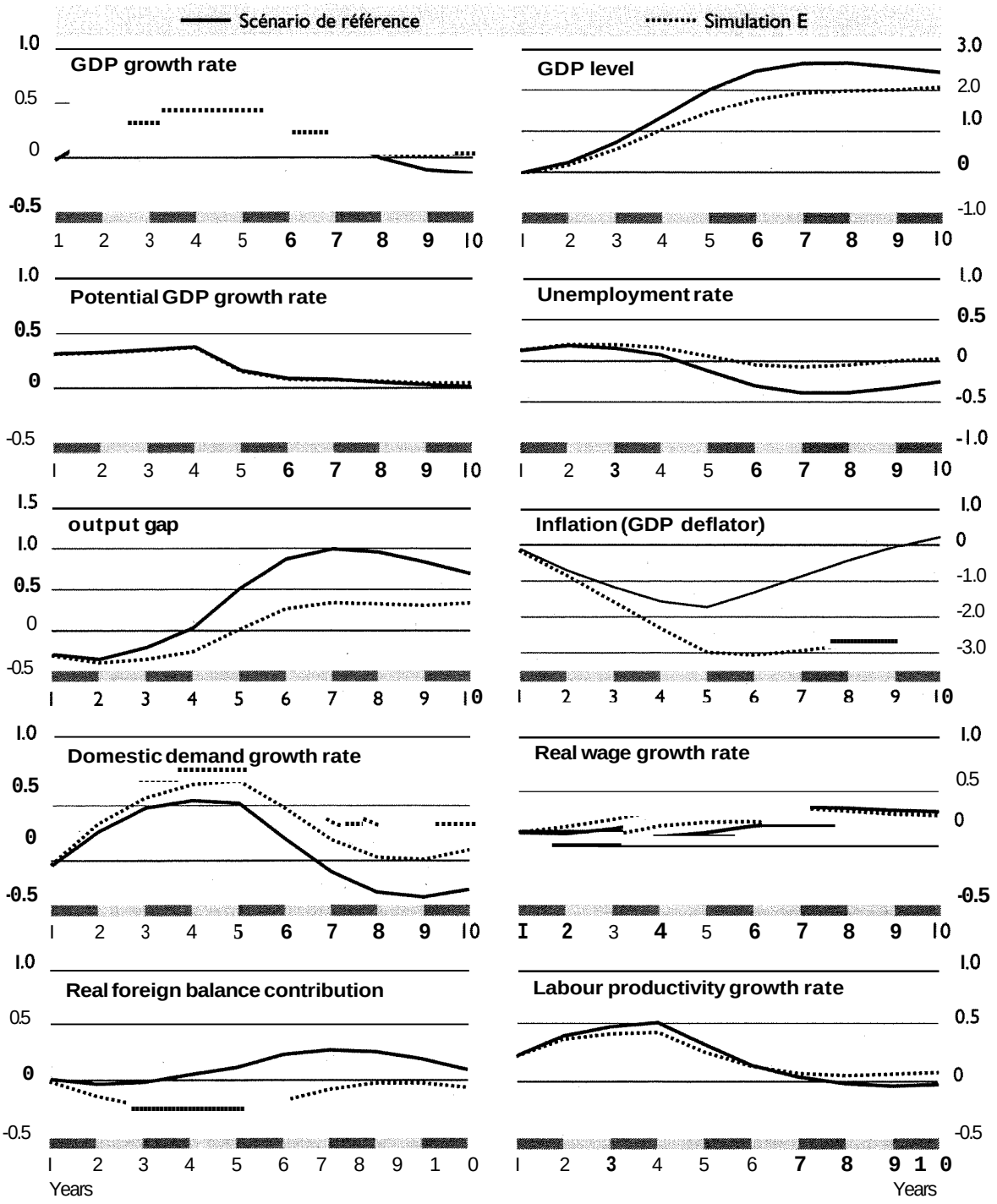
International linkage and the diffusion of technical progress

Since technological change is, by and large, a global phenomenon its macroeconomic effects are likely to be larger to the extent that trend productivity is enhanced in all OECD countries at approximately the same time. An illustration of the scale of global effects is given in Figure 5, where simulation F assumes the same change in trend productivity in each of the seven major OECD economies.

Overall, compared with the reference simulation, the self-equilibrating process of the economy is not fundamentally modified. Despite the international character of the shock, supply conditions in each country are affected in the same way as in the reference simulation. However, the positive adjustment of demand to supply takes place faster because the rise in domestic demand in each country is transmitted to other countries through trade, reinforcing the self-equilibrating mechanism. Even though export markets expand in each country, a *priori* none of them benefits from international competitiveness gains, so that, on average, the foreign trade

Figure 4. ***Effects of a productivity rise under alternative exchange rate assumptions***

Difference from baseline in percentage points

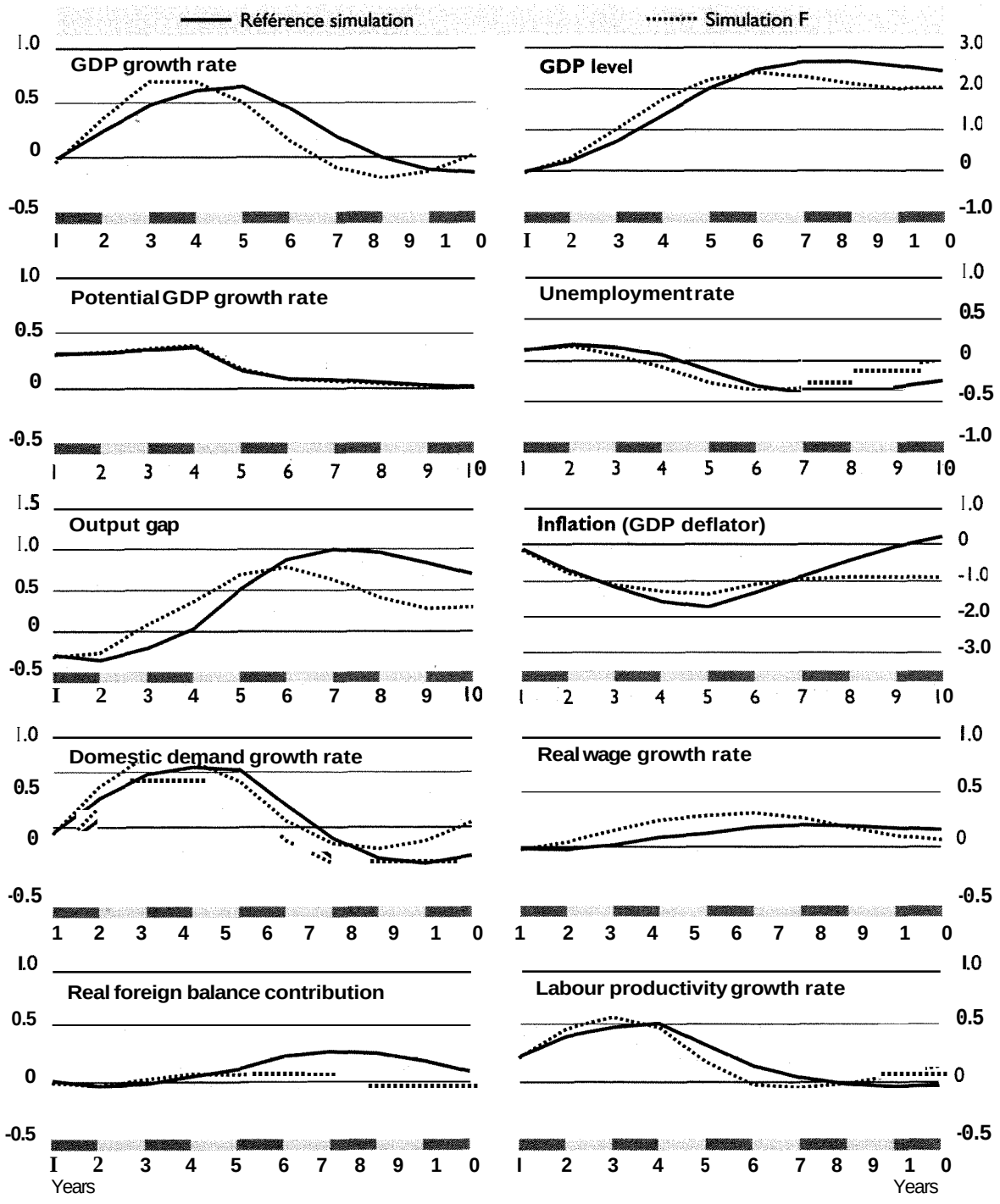


Reference simulation: See simulation C in Figure 2.

Simulation E As the reference simulation with real exchange rates unchanged from baseline.

Figure 5. ***Effects of a simultaneous productivity rise in the major seven countries***

Diference from baseline in percentage points



Reference simulation: See simulation C in Figure 2.
Simulation F Simultaneous productivity rise in all major seven OECD economies.

contribution to growth is limited compared with the reference case.[10] Another key difference relates to inflation which stabilises at a lower level in the long run as disinflation is transmitted to the whole OECD region. Because the demand reaction takes place faster, the initial rise in unemployment is much smaller and more short-lived than in the reference case, as is the subsequent cyclical adjustment path. Overall, the adjustment of the economies toward long-term equilibrium is significantly speeded-up in the case of an area-wide shock.

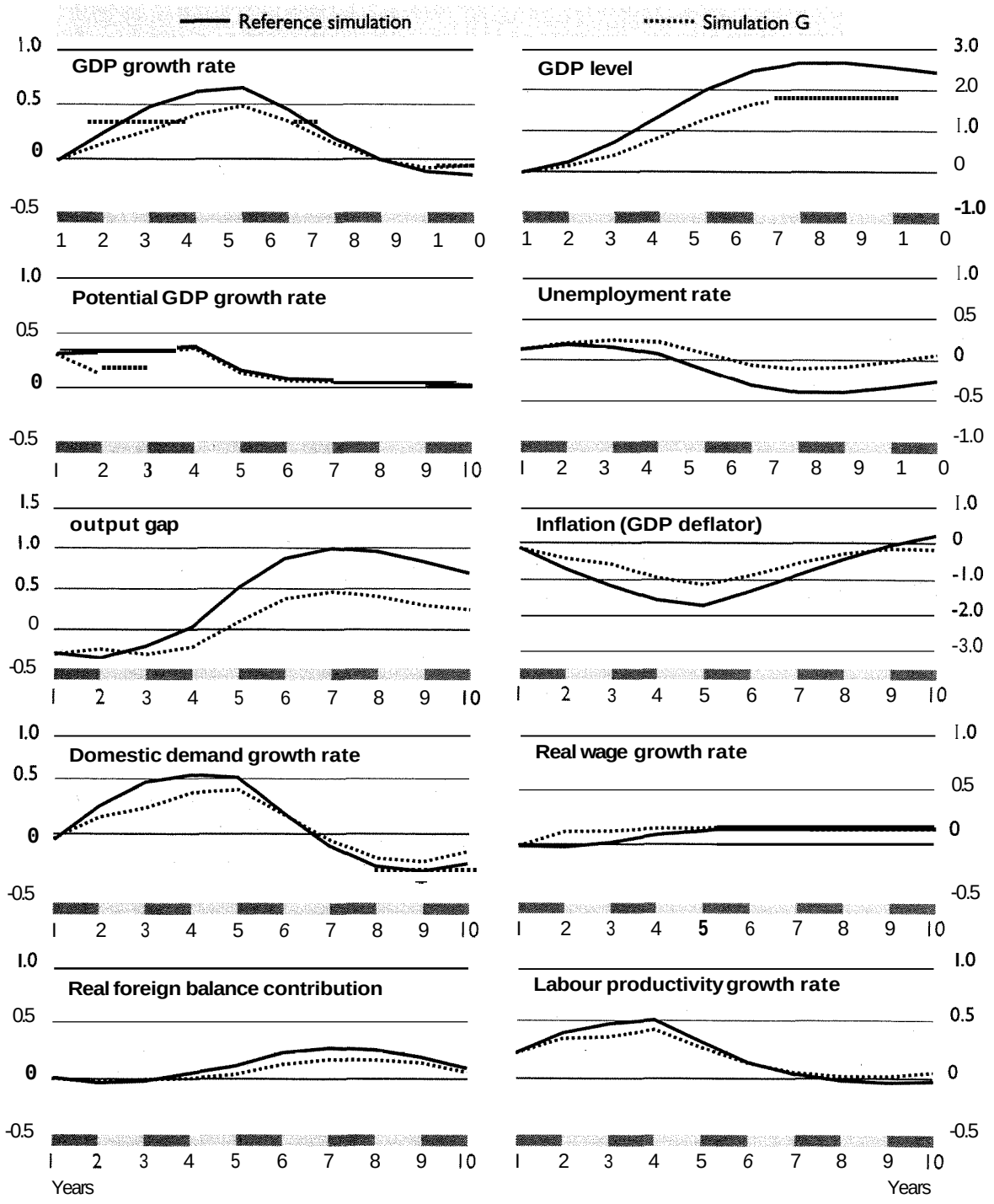
INFLUENCE OF STRUCTURAL FACTORS ON THE ADJUSTMENT PROCESS

Quite apart from macroeconomic conditions, the pace of the adjustment process depends crucially on the flexibility of the labour and product markets. Especially important is the wage determination process and the extent to which the gap between actual unemployment and the NAWU influence real wages.[11] Usually the NAWRU is considered to be determined by underlying structural factors, such as regulations and institutional factors. Nonetheless, it cannot be wholly excluded that the introduction of new technologies could lead to an upward drift in the NAWRU, for example, due to the erosion of the skills of the unemployed and to insider/outsider mechanisms following an initial rise in unemployment. As mentioned earlier, some researchers have concluded that current technological developments are in favour of skilled workers and against unskilled ones. A rise in the NAWRU might, therefore, also be seen as the consequence of technological changes detrimental to low-skilled workers and beneficial to high-skilled workers, leading to an increased mismatch of demand and supply in the labour market.

As an illustration of the possible consequences, Figure 6 reports a further case where the technological improvement is assumed to be accompanied by a permanent upward shift of the NAWRU of a quarter percentage point.[12] In this case, the fall in inflation is less pronounced and as labour market conditions remain relatively tight due to the shift in the NAWRU, real wages tend to pick up more strongly in the near term. With a less favourable inflation response, the domestic demand improvement is smaller than in the reference simulation, while net exports increase less due to a smaller gain in competitiveness and the weaker reaction of demand lengthens the adjustment process. Unemployment remains above baseline for longer, while the period over which the output gap is negative is prolonged. Overall the assumed shift in the NAWRU both lengthens the adjustment process and raises the rate to which unemployment adjusts in the longer term.

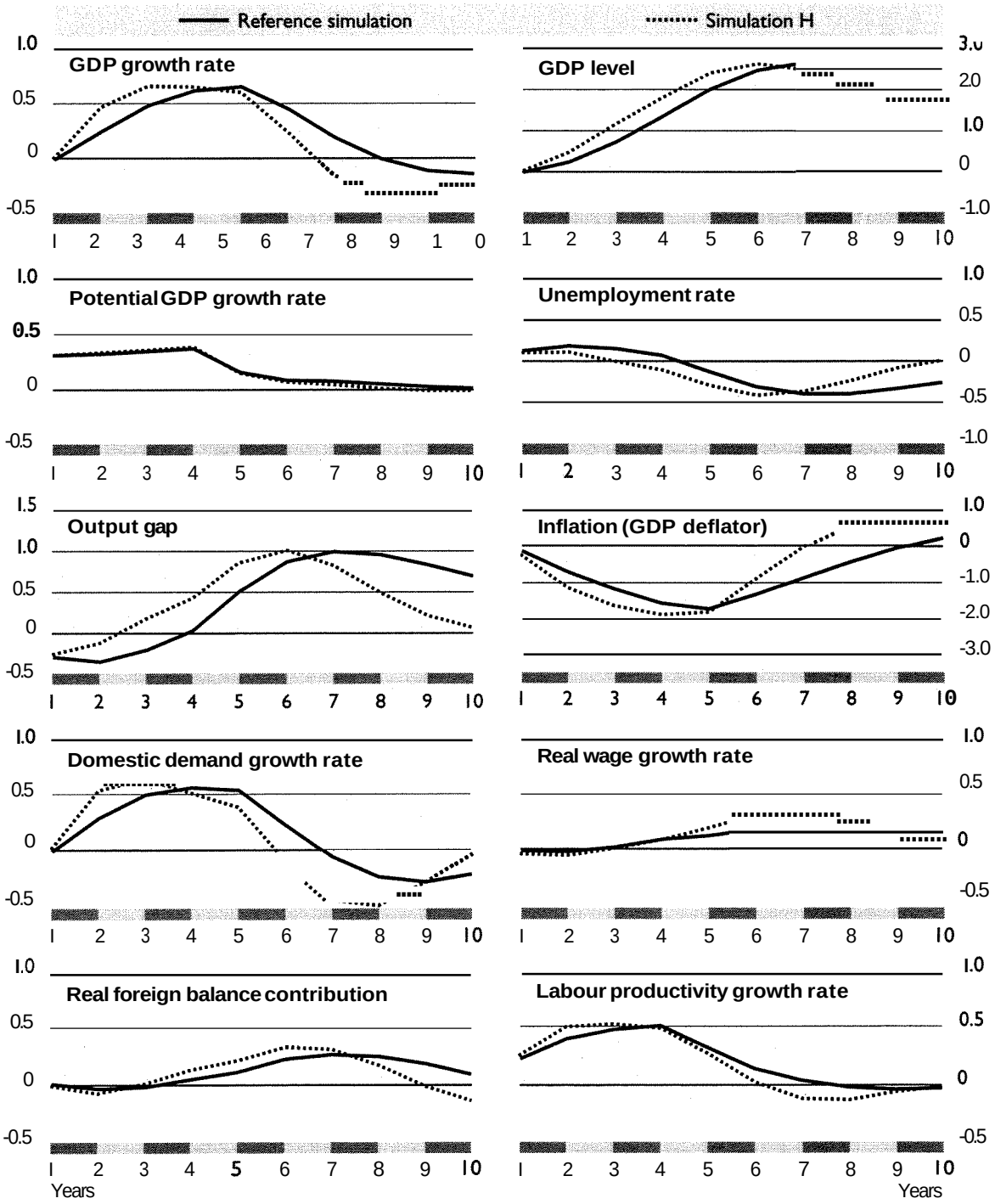
OECD countries differ substantially in labour and product market flexibility and the degree of such rigidities can be summarised by various measures of the "cost of disinflation" (see Layard *et al.*, 1991 and Turner *et al.*, 1993). While there are quite large uncertainties about the precise magnitude of estimated rigidities in different countries, there is a reasonable agreement across studies with respect to ranking

Figure 6. ***Effects of a productivity rise under alternative NAWRU assumptions***
Difference from baseline in percentage points



Reference simulation: See simulation C in Figure 2.
Simulation G: As the reference simulation with a permanent rise of NAWRU of 0.25 percentage point from the second year.

Figure 7. ***Effects of a productivity rise under alternative rigidity assumptions***
Diference from baseline in percentage points



Reference simulation: See simulation C in Figure 2.
Simulation H: As the reference simulation **but** with sacrifice ratio reduced **by** 75 **per** cent.

Table 2. **A comparison of alternative estimates of the cost of disinflation'**

	Turner et *al.* *(1995)*	Layard *et al* (1991)*	OECD *(1989)*
United States	134	0.80	1.23
Japan	0 10	0.05	0.05
Germany	1.87	0.49	0.57
France	0 74	0.20	0.43
Italy	1.78	0.14	0.26
United Kingdom	2.36	0.70	1.65
Canada	1.50	1.37	0.98

1. The cost of disinflation or "sacrifice ratio" represents the cumulative rise in unemployment required to bring about a 1 percentage point permanent reduction in the annual inflation rate. For further details, the derivation from estimated wage and price equation coefficients, see Turner *et al.* (1993).

Source: OECD (1989); Layard *et al.* (1991);Turner *et al.* (forthcoming).

across major OECD countries, with estimated rigidities being very low for Japan and relatively high for the United States and Canada. Estimates for individual major European countries differ somewhat, but most studies suggest that the degrees of real and nominal rigidities in these countries lie somewhere between those for Japan and the United States (see Table 2).

To illustrate the relative importance of such differences in structural rigidities, Figure 7 shows a further case where the basic shock is repeated with real and nominal rigidities assumed to be significantly lower. In this case, real wages are assumed to be more responsive to the unemployment rate, while prices are more responsive to the output gap. A reduction of nominal rigidities is achieved by assuming a speedier impact of prices and wages on each other. In this specific case, the assumed revisions to wage and price coefficients correspond to a reduction of the notional "cost of disinflation" by 75 per cent. Overall, this case provides a clear illustration of how lower rigidities imply a shorter and less painful adjustment process, particularly for unemployment.

CONCLUSIONS

The possible consequences of the introduction of new technologies have been examined in this paper on the basis of stylised simulations with the OECD's recently re-estimated macroeconomic INTERLINK model. In view of the range of uncertainties, such a model can only give partial answers to a number of questions related to this subject, but it provides a convenient framework for analysing the key macroeconomic consequences in specific cases, and for illustrating the sensitivity

of the main short- and medium-term adjustment mechanisms of an economy to a number of macroeconomic and structural factors.

Overall, these simulations suggest that a rise in trend factor productivity will eventually lead to a higher levels of production and real income, but the adjustment will depend on the extent to which the long-term equilibrium of an economy is affected by a given technological change. If trend labour efficiency growth is permanently stronger, a sustained fall in unemployment may also be possible if real wages adjust only slowly to the rise in labour efficiency.

Though in the short to medium term, temporary increases in unemployment following a rise in trend productivity cannot be excluded, there are, nevertheless, important adjustment mechanisms in market economies, which, if functioning correctly, prevent a substantial pick-up in unemployment for a prolonged period. Potential output should rise and real domestic demand increase with dis-inflation and the increases in real wages associated with higher productivity. Stronger foreign demand should also contribute to reversing the initial gap between the increased potential output and demand as competitiveness improves or, more likely, as export markets expand if productivity accelerates simultaneously in other OECD countries. All these results are consistent with previous OECD studies (See Englander and Mittelstadt, 1988; and Torres and Martin, 1990) and with other studies at the macroeconomic level, for example those reported by Meyer-Krahmer, 1992.

At the same time, the adjustment process is likely to be affected by a variety of different factors. Monetary conditions and financial market reactions are particularly important in reinforcing or counter-acting the self-equilibrating tendencies of an economy. For instance, if nominal interest rates are unchanged the adjustment profile is accentuated and the return of the economy toward its long-term equilibrium delayed. Alternatively, if real interest rates remain unchanged or even fall as inflation decelerates, then the resulting stimulative demand effects may substantially shorten the adjustment process and thereby limit the extent of possible initial increases in unemployment associated with industrial re-structuring.

The degree of market flexibility is also crucial to the adjustment process. Indeed, not only do market rigidities tend to lengthen the duration of the adjustment of an economy towards long-term equilibrium but, in the extreme case of imperfect labour market adjustment resulting in an increased NAWRU, the benefit of a technological change could even be partially lost. Hence, the need to reduce market rigidities is all the more important in a world of rapid technological improvements.

NOTES

1. The main features of the model of key importance to the present exercise are briefly described in the Annex.
2. See Technology and Economy: The Key Relationships, OECD (1991); Technology and Productivity: The Challenge *for* Economic Policy, OECD (1991); and The *OECD Jobs* Study (1994), in particular Chapter 4 entitled "Technological change and innovation".
3. See The *OECD Jobs* Study, referred to in footnote 2.
4. See, for example, Dreze and Sneessens (1994), and Chennels and Van Reenen (1995).
5. This, however, need not always be the case. For example, where technologies enhance the demand for less skilled labour, such as seems likely to have happened at the time of the industrial revolution.
6. The possibility of trend factor efficiency growth and the terms of trade affecting the underlying equilibrium rate of unemployment is discussed at length by Manning (1992), Elmeskov (1993) and, more recently, Turner and Rauffet (1994). For a number of countries, the empirical evidence suggests that wages adjust only sluggishly to changes in the level of trend productivity. If so, particular combinations of wage/price dynamics can imply that a permanent rise in the trend labour efficiency growth reduces the long-term equilibrium unemployment rate, defined in terms of the non-accelerating wage rate of unemployment or NAWRU.
7. See, for example, Hunt and Hunt (1983), Watanabe (1986) and, more generally, Section IV*a*, Chapter 4 of The *OECD* jobs Study (1994).
8. Within INTERLINK the labour demand equations for Germany, France and the United Kingdom in particular incorporate significant negative trend productivity effects.
9. Such a semi-elasticity is consistent with the average estimates reported by Turner et al. (forthcoming) embodied in the standard version of INTERLINK.
10. In fact the foreign trade contribution is slightly positive on average because neither the smaller OECD countries nor the non-OECD regions are assumed to benefit from a rise in trend productivity.
11. This equilibrium-restoring wage reactions is consistent with available empirical evidence, see Elmeskov and MacFarlan (1993) and Turner et *al.* (1993).
12. The magnitude of the assumed shift is seen as being maximal, given the scale of the initial rise in unemployment, and is consistent with perfect hysteresis.

Annex

MAIN FEATURES OF THE INTERLINK MODEL

This annex describes the key features of the most recent version of INTERLINK and their relevance to the analysis of the effects of productivity changes.

Over the last four to five years, major parts of the OECD macroeconomic model INTERLINK have been re-specified and re-estimated (Turner *et al.* (forthcoming) and Turner *et al.* 1993).INTERLINK, with sub-models for 24 OECD countries and a substantial trade block linking those countries and the non-OECD regions, can be broadly described as being neo-classical in terms of structural specification and equilibrium properties and "New Keynesian" in terms of short-term dynamics. In particular, the presence of real and nominal rigidities in wage and price setting equations implies a protracted period of adjustment before an equilibrium is reached for some shocks.

A key element to the supply sectors of the individual country models is a Cobb-Douglas production function with constant returns to scale and labour and capital as production factors. Labour is assumed to be a homogeneous production factor and no distinction is made between skilled and unskilled labour. Technical progress is assumed to be disembodied and specified through a labour efficiency index.

Thus:

$$\ln Y = a\,(\ln E + \ln N + \ln H) + (1 - a)\,K \qquad [1]$$

where:

- Y : business-sector value added
- E : labour efficiency index
- N : business employment
- H : average hours worked in the business sector
- K : business sector capital stock

Given the Cobb-Douglas production specification, the labour efficiency index can easily be rewritten as a total factor productivity index, with technical progress seen both as Harrod-neutral (labour-augmenting) as well as Hicks-neutral.

Thus:

$$\ln Y = \ln TFP + a (\ln N + \ln H) + (1 - a) \ln K \quad [2]$$

$$\ln TFP = a \ln E \quad [3]$$

where:

TFP: total factor productivity

Long-run demands for labour and capital are determined as the result of profit maximisation by firms and are consistent with the production function. Therefore, the long-run labour-output ratio depends on real wage costs, while the long-run capital-output ratio is dependent of the real user-cost of capital (see Turner *et al.* 1993). Error-correction relationships are then used to ensure that actual demand for labour and capital adjust to such a long-run equilibrium. These mechanisms are supplemented with temporary direct effects on actual demand, for instance of output on capital demand (accelerator). However, there are no temporary direct effects of profitability or spare capacity on capital demand.

Prices are also specified to be consistent with the production function and profit maximisation in the long-run. In the short-run, prices are sensitive to demand pressure and therefore deviate from unit costs. Moreover, costs do not feed through instantaneously to prices due to nominal rigidities. Real wages depend on labour productivity in the long run but the adjustment of real wages to a change in productivity is only sluggish. In the short and medium term, differences between the actual and the natural rate of unemployment influence real wages negatively. Due to nominal rigidities, prices do not feed through instantaneously into nominal wages.

Assuming simplified dynamics:

$$\ln (W/P) = g0 - g1\ U + \ln PR - g2\ d \ln PR \quad [4]$$

$$d \ln PR = \ln PR - \ln PR(-1) \quad [5]$$

where:

W : nominal wages
P : prices
U : unemployment rate
PR: trend labour productivity

In equilibrium, real wages increase in line with trend productivity and price inflation is constant if, and only if:

$$U = NAWRU = (g0 - g2\ d \ln PR)/ g1 \quad [6]$$

where NAWRU represents the natural or non-accelerating wage rate of unemployment.

Equation [6] shows that the equilibrium or natural rate of unemployment is influenced by a permanent change in the growth rate in trend productivity.

The specification of the demand side within INTERLINK is relatively conventional. Real private consumption depends on real disposable income and real wealth, proxied by the real interest rate and the rate of inflation. Residential investment depends on real disposable income and real interest rates. Exports are linked to world demand and price competitiveness. Imports depend on price competitiveness and on domestic demand. The multi-country dimension of INTERLINK is important for the short- and medium-term simulation properties of the model. For example, in the case of a simultaneous autonomous domestic demand rise in all OECD countries, output of individual countries is not only influenced negatively by leakage of demand through imports but also influenced positively by the increased foreign demand for its export products.

A main characteristic of the model is that autonomous demand changes have a substantial impact on output and unemployment in the short- and medium-term but are fully crowded-out in the long-term if real interest rates are unchanged. An autonomous demand rise (fall) is eventually entirely offset by the negative (positive) impact of higher (lower) inflation on consumption and exports. As a consequence, the unemployment rate returns to the equilibrium rate. In the long-run, a change in demand leads only to a shift in the equilibrium inflation rate, and output is fully determined by supply factors.

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