# North–South linkages and international macroeconomic policy

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CAMBRIDGE
UNIVERSITY PRESS

# 7 Dynamic response to external shocks in Classical and Keynesian economies

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## 1 Introduction

A bewildering variety of macroeconomic tools is available to macroeconomic policymakers and analysts. The model developed here forms part of a small but growing sub-family of macroeconomic frameworks which, while firmly based on microanalytic foundations, introduce critical real world features – such as short-run wage rigidities and liquidity constraints – which generate persistent deviations from the frictionless full-employment outcome of the unconstrained neoclassical paradigm. The dynamic general equilibrium model developed here nests as special cases the classical and neo-Keynesian benchmarks, and assumes rational expectation formation. Hence short-term equilibria depend on current and anticipated future trajectories of policy and external variables.

Forward-looking behaviour based on microanalytical foundations is a feature that this paper shares with an increasing number of recent models applied to open-economy issues such as oil shocks, interest rate changes or policy coordination in multicountry frameworks (Sachs, 1983; Giavazzi *et al.*, 1982; Lipton and Sachs, 1983; Bruno and Sachs, 1985; McKibbin and Sachs, 1989; McKibbin and Sundberg, 1990; McKibbin and Wilcoxen, 1992). Nesting of classical and Keynesian benchmarks characterizes also the model by McKibbin and Sachs (1989), although they do not discuss its implications for the response of the economy to shocks. This paper extends previous work in four dimensions. First, it extends the analytical structure by incorporating simultaneously several realistic features that are relevant for most open economies: nominal wage rigidity, import content of capital goods, foreign holdings of domestic equity, public investment and monetary finance of budget deficits.[1] Second, it explores in some detail the short- and long-term consequences of liquidity constraints affecting private consumption and

investment behaviour. Third, the paper compares the differential effects of external shocks in neoclassical and Keynesian benchmark economies, for both permanent/transitory and anticipated/unanticipated disturbances. Finally, the simulations are performed by solving the full non-linear model, in contrast with the conventional procedure that uses a linear approximation, whose accuracy can be highly unreliable when simulating 'large' shocks.

The plan of the paper is as follows. Section 2 summarizes the model structure. Section 3 describes the steady state and the stability properties of the economy. Section 4 presents simulation results for two favourable external shocks: a unilateral foreign transfer and a rise in the external terms of trade, brought about by a decline in the world price of an intermediate input (say an oil-price windfall in the case of an oil-importing economy). Section 5 closes the paper with some concluding remarks.

## 2 The model[2]

The economy produces one single good, that can be used for consumption and investment at home, or sold abroad (thus there is no distinction between production for domestic and export markets). It is an imperfect substitute for the foreign final good – which likewise can be used for consumption and investment – and its production requires the use of an imported intermediate input. The economy is small in its import markets, but faces a downward-sloping demand for its exports.

There are three basic agents in the model: the consolidated public sector, the domestic private sector and the external sector. The first lumps the non-financial and financial (central bank) public sector together, the second aggregates private firms and consumers, and the third adds foreign investors, creditors and trade partners. The private sector comprises one group of intertemporally optimizing agents with another of liquidity-constrained (or myopic) agents. Private firms take all production and investment decisions, own the economy's entire capital stock and benefit from a lump-sum public investment subsidy.

Domestic private agents hold four assets: money, domestic debt issued by the consolidated public sector, foreign assets, and equity claims on the domestic capital stock. Foreigners hold domestic equity but not domestic public debt. In turn, the public sector also holds foreign assets.[3] There are no restrictions on capital mobility and, in the absence of risk and uncertainty, all non-monetary assets are assumed to be perfect substitutes; hence their anticipated rates of return must be equalized at each point in time. In turn, imperfect substitutability between base money and

other assets is reflected by a conventional transactions-based money demand.

Both goods and asset markets clear continuously. Equality between demand and supply of the domestic good determines the real exchange rate. Under a flexible nominal exchange rate regime, money market equilibrium then determines the nominal exchange rate. By contrast, the labour market may not clear instantaneously due to the existence of nominal and/or real wage rigidity.

The dynamics of the model arise from two basic sources: the accumulation of assets/liabilities, dictated by stock–flow consistency of the sectoral budget constraints, and the forward-looking behaviour of private agents. Expectations are formed rationally, which in this context of certainty amounts to perfect foresight. Thus, anticipated and realized values of the variables can differ only at the time of unexpected shocks or due to the arrival of new information about the future paths of exogenous variables.

Technology and preferences are kept as simple as possible, by assuming unit elasticities of substitution.[4] The production technology is summarized by a Cobb–Douglas production function for gross output, which combines value added (capital and labour) and intermediate imports. Harrod-neutral technical progress ensures the existence of steady-state growth, at a level given by the sum of the rates of technical progress and population growth, both of which are exogenous. In addition, a Cobb–Douglas investment technology is used to combine domestic and foreign goods into capital goods, whose accumulation is subject to quadratic adjustment costs. This allows separation between the intertemporal aggregate investment decision and its intratemporal allocation to domestic goods and imports (see Gavin, 1991; Serven, 1991; or Hayashi and Inoue, 1991). Consumers' preferences also display unit inter- and intratemporal substitution elasticities, likewise allowing two-stage budgeting in consumption decisions.

Behavioural rules combine explicitly two benchmark specifications: the neoclassical case of unconstrained, intertemporally optimizing firms and consumers, along with full wage flexibility (ensuring continuous full employment), and the Keynesian case of liquidity-constrained firms and households, along with wage inflexibility.

Firms' use of variable inputs (labour and imported intermediates) is determined by the standard marginal productivity conditions. In turn, investment decisions are different for constrained and unconstrained firms. The latter derive their investment plans from market value maximization; following the standard theory of investment under convex adjustment costs (Lucas, 1967; Treadway, 1969), their investment is

linked to Tobin's marginal $q$ (Tobin, 1969), i.e., the present value of the additional profits associated with the marginal unit of capital relative to its installation cost (Hayashi, 1982).[5] By contrast, liquidity-constrained firms gear their investment expenditure to their current profits. Aggregate investment is then a weighted average of investment by constrained and unconstrained firms.

Consumption by unconstrained consumers is derived from standard maximization of intertemperal utility over an infinite horizon, subject to the intertemporal budget constraint (e.g., Ramsey, 1928). Solving the maximization problem yields the standard result that consumption is equal to the subjective discount rate (net of effective labour growth) times total (human and non-human) wealth. Unconstrained consumers are of course Ricardian, as they internalize the government's intertemporal budget constraint by anticipating the entire stream of current and future tax payments; since they face the same discount rate as the government,[6] they are indifferent between tax, debt, or money financing of the public deficit (Barro, 1974). By contrast, some labour-income earners are liquidity-constrained and cannot borrow against their human wealth; hence they consume their current net labour income.[7] Total private consumption demand is an aggregate of consumption by unconstrained and constrained consumers.

Real or nominal wage rigidity may prevent continuous full employment of the labour force. In such case, employment is determined by labour demand, as conventionally assumed, and wages follow an indexation rule linking nominal wage growth to current and lagged consumer price inflation and also to current labour market conditions.

Finally, the public sector is assumed to determine its policy exogenously; hence public consumption and investment expenditures follow pre-determined trajectories. To finance its activity, the public sector can choose among taxes (which fall exclusively on labour income), money, domestic debt or external borrowing (or any combination of them).

## 3 Steady state, model solution and parameterization

### *3.1 The steady state*

The long-run equilibrium of the model is characterized by constant output in real per-capita terms (so that long-run growth equals the growth rate of the effective labour force), constant per-capita real asset stocks, constant relative prices, and constant real wages with full employment. Thus, the government's budget must be balanced, and the current-account deficit must equal the exogenously given flow of foreign

investment, which in turn is just sufficient to keep foreign equity holdings (in real per-capita terms) unchanged.

Since the per-capita real money stock is constant, long-run inflation equals the rate of expansion of per-capita nominal balances. In turn, with a constant real exchange rate, domestic and foreign real interest rates are equalized by uncovered interest parity, and nominal exchange depreciation is determined by the difference between domestic and (exogenously given) foreign inflation. Hence, across steady states changes in the rate of money growth are fully reflected in the inflation rate (and thus in the nominal interest rate) and in the rate of nominal depreciation.

By combining the model's equations, the steady-state equilibrium can be reduced to two independent relations in the real exchange rate and real wealth: a goods-market equilibrium condition and a zero private wealth accumulation condition (in real per-capita terms). Together they imply a constant stock of per-capita net foreign assets. Goods-market equilibrium defines an inverse long-run relationship between real wealth and the real exchange rate: higher wealth raises private consumption demand and requires a real exchange rate appreciation for the domestic goods market to clear.

In turn, real wealth accumulation can cease only when per-capita consumption equals the per-capita return on wealth. This poses the well-known requirement that, for a steady state to exist, the rate of time preference must equal the exogenously given world interest rate.[8] But then the zero-wealth accumulation condition provides no information whatsoever on the steady-state *level* of wealth: with the return on wealth being entirely consumed, *any* wealth stock is self-replicating. In other words, we are left only with the goods market equilibrium condition to determine both long-run wealth and the real exchange rate – an obviously impossible task.

This means that the steady-state wealth stock must be found from the economy's initial conditions and from its history of wealth accumulation or decumulation along the adjustment path. Hence the steady-state values of wealth and the real exchange rate (and therefore all other variables related to them) depend not only on the long-run values of the exogenous variables, but also on the particular trajectory followed by the economy. In other words, the model exhibits hysteresis. As noted by Giavazzi and Wyplosz (1984), this follows from the assumption of forward-looking consumption behaviour derived from intertemporal optimization by infinitely lived households with a constant rate of time preference and facing perfect capital markets.

An important implication of the model's hysteresis property is that transitory disturbances have long-run effects. For the case of fiscal

policy, this has been recently highlighted by Turnovsky and Sen (1991).[9] But in our framework even transitory monetary disturbances can have permanent real effects: if some consumers are liquidity-constrained (or myopic), a transitory increase in inflationary taxation matched by a reduction in direct taxes will raise disposable income and consumption, leading to reduced wealth accumulation and eventually causing a fall in long-run wealth and a permanent real depreciation.[10]

The fact that production requires the use of imported inputs (intermediates and capital goods) has important consequences for the economy's long-run properties: across steady states, real output (and also the capital stock and the real wage) is inversely related to the real exchange rate. The reason is that a real depreciation raises the real cost of imported inputs and therefore reduces the profitability of production.

### *3.2 Dynamics and stability*

The model's dynamics combine predetermined variables (i.e., asset stocks) subject to initial conditions, and 'jumping' variables (i.e., Tobin's $q$, the real exchange rate, real money balances, human wealth, the present value of the investment subsidy, and the present value of the cost of holding money). For the dynamic system not to explode, these non-predetermined variables have to satisfy certain terminal (transversality) conditions. Solving the model basically amounts to finding initial values for the non-predetermined variables such that, following a shock, the model will converge to a new stationary equilibrium. The necessary and sufficient conditions for the existence and uniqueness of such initial values are known for the case of linear models,[11] but not for non-linear systems such as the one at hand.[12] While a formal proof of stability cannot be provided, numerically the model was always found to converge to the new long-run equilibrium under reasonable parameter values.

The requirement that the predetermined variables satisfy initial conditions, while the jumping variables must satisfy terminal conditions, poses a two-point boundary-value problem, for whose numerical solution several techniques exist. Two leading examples are the 'multiple shooting' method proposed by Lipton *et al.* (1982), and the 'extended path' algorithm of Fair and Taylor (1983). For the simulations below, we combine both techniques as follows. First, we solve the model over an arbitrarily chosen time horizon using multiple shooting. To prevent the solution from being distorted by the choice of too short a time horizon (which would force the model to reach the terminal conditions too early), we then extend the horizon and recompute the solution path until the resulting changes in the solution

trajectory of the endogenous variables fall below a certain tolerance,[13] at which time the process stops. In practice, the length of the simulation horizon required for this procedure to converge is strongly affected by two parameters governing the speed of adjustment of the system: the elasticity of real wages to employment (i.e., the slope of the expectations-augmented Phillips curve), and the magnitude of adjustment costs associated with investment.

### *3.3 Parameterization*

Within the general structure spelt out above, three economies will be considered: (i) a neoclassical (*NC*) benchmark with full employment and no liquidity constraints, (ii) an economy with liquidity constraints but with full employment (*LCFE*), and (iii) a Keynesian benchmark combining liquidity constraints and unemployment (*LCUN*). In the latter two economies, 50 per cent of the households and enterprises face liquidity constraints; in addition, in the Keynesian benchmark nominal wages are fully indexed to the average of current and lagged consumer price inflation (recall that wages are fully flexible in the first two economies).

The remaining parameter values are representative of open, developing economies. For a full description of the parameters and exogenous variables, as well as their initial values for all three economies, see Schmidt-Hebbel and Serven (1992). Numerical values for most coefficients in the structural equations were borrowed from empirical estimates (Serven and Solimano, 1991; Elbadawi and Schmidt-Hebbel, 1991; Haque *et al.*, 1990) and preceding simulation models (McKibbin and Sachs, 1989; Giavazzi *et al.* (1992) for various countries, complemented by estimates deemed to be representative for open economies.

Scale parameter values were chosen so that real output equals unity at the initial steady state. Hence the values of all variables reported below can be interpreted as relative to initial output. Recall also that initial (and final) steady-state output growth is determined exclusively by the rate of growth of the labour force in efficiency units, which was set at 3 per cent.

Finally, to close the model it is necessary to specify how the public and private sectors finance their activity – i.e., which two endogenous variables are determined residually by their budget constraints. For the simulations discussed below, the adjusting variable for the public sector is total taxes, and for the private sector the residual budgetary variable is foreign asset holdings.[14]

## 4 Simulation results

To explore the impact of external disturbances, we simulate the dynamic adjustment to a favourable foreign transfer shock (an external grant to the public sector) and a favourable terms-of-trade shock (a decline in the price of the intermediate import used in production, say oil). In a companion paper (Schmidt-Hebbel and Serven, 1993) we have explored the model's response to fiscal and monetary policy shocks.

The first-round magnitude of both shocks is common, equivalent to a 4 per cent gain of initial steady-state output. In the case of the foreign transfer shock, we consider three alternatives: a permanent unanticipated (*P*) disturbance (hitting the economy in period 1 and lasting forever), a transitory unanticipated (*TU*) shock (hitting during periods 1–4), and a transitory anticipated (*TA*) shock (hitting during periods 2–5). In the case of the oil-price windfall, only a permanent (*P*) shock will be considered.

To discuss the simulations below, we start from an initial steady-state equilibrium (represented by period 0), and distinguish between the impact effects (in period 1) and the transition toward the new steady-state equilibrium (from period 2 to terminal period $T$, which is in the range of 60–80 periods). The discussion will follow the figures depicting the dynamic paths of the main endogenous variables. For the foreign transfer simulations, each figure is divided into an upper panel, which reports the dynamic trajectories under the three types of shocks (*P*, *TU* and *TA*) for the *NC* case, and a lower panel which combines the three shock types with two remaining economies: *LCFE* and *LCUN*. For the oil price windfall simulations (which are limited to a permanent shock), each panel represents a different variable, depicting three dynamic trajectories – i.e., one for each benchmark economy.

### *4.1 A foreign transfer shock*

With taxes being the adjusting variable in the public-sector budget, a foreign transfer to the public sector is fully passed on to the private sector through a tax reduction. Private disposable income and wealth rise accordingly, leading to increased consumption. Thus, on impact higher private consumption causes both a real exchange rate appreciation and an increase in output. Over time, output increases further due to capital accumulation, which responds gradually to the decline in the real cost of imported capital goods triggered off by the appreciation, and causes a gradual depreciation of the real exchange rate.

The dynamic trajectories of the main endogenous variables in response to a 4 per cent of output transfer from the rest of the world to the public

sector are shown in Figures 7.1–7.6, for different model categories and types of shocks.[15] Consider first the neoclassical economy (*NC*), positively affected by a permanent shock. Ricardian consumers internalize the government's intertemporal budget constraint and anticipate not only current but also future tax cuts and higher output; thus, their consumption increases sharply in period 1, by over 4 percentage points of output (Figure 7.1). In the long run, consumption increases by 9.7 per cent.[16]

The consumption-based increase in aggregate demand causes a contemporaneous output expansion (Figure 7.2) and a real appreciation (Figure 7.3).[17] Higher production in period 1 is made possible by importing more intermediate goods in response to the appreciated real exchange rate, and hence by shifting the input mix away from value added. In subsequent periods the real exchange rate depreciates as a result of aggregate supply shifts due to higher capital. Therefore the real exchange rate initially overshoots its new long-run level – a result of the existence of adjustment costs to investment. In the new steady state, the real exchange rate exhibits a 7.4 per cent appreciation relative to the initial long-run equilibrium, while output has risen by 2.8 per cent.

With the adjustment path characterized by a gradual real exchange rate depreciation, the domestic real interest rate slightly exceeds its foreign counterpart throughout the transition. Nevertheless, the fall in the real cost of capital goods is sufficient to promote an investment expansion despite the higher real interest rate; thus investment rises initially by some 1.5 percentage points of output (Figure 7.4). Subsequent additions to the capital stock drive down the profitability of new projects and hence investment levels off towards its new long-run value; the latter exceeds the initial value (relative to output) due to the higher capital-intensity of production, which requires higher replacement investment.

An important result refers to the current-account adjustment. In the long-run equilibrium, the current-account deficit is unchanged – equal to the exogenous flow of direct foreign investment. But along the transition path, the current account *deteriorates*: the reason is that Ricardian consumers immediately raise consumption in anticipation of future output gains, causing an increase in the current-account deficit by about 0.5 per cent of output in period 1 (Figure 7.5). The increased deficit is gradually reversed in subsequent periods as the anticipated output gains materialize.[18]

Finally, the initial increase in aggregate demand and subsequent rise in the capital stock stimulate labour demand. However, since wage flexibility ensures full employment, higher labour demand is entirely reflected in a real wage increase; the new long-run real wage exceeds its initial level by 2.8 per cent.

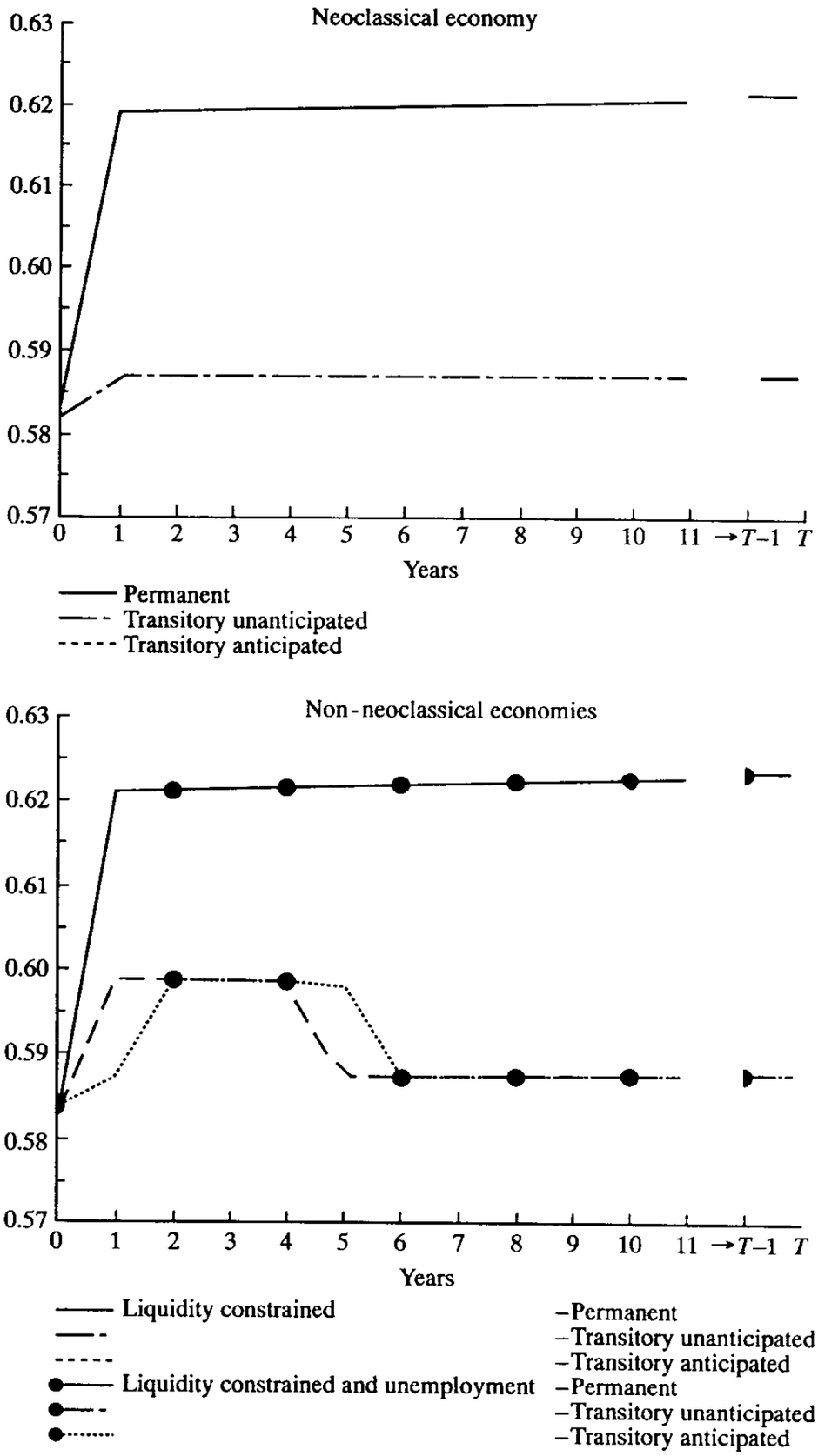



**Figure 7.1 Foreign transfer shock: private consumption/output**

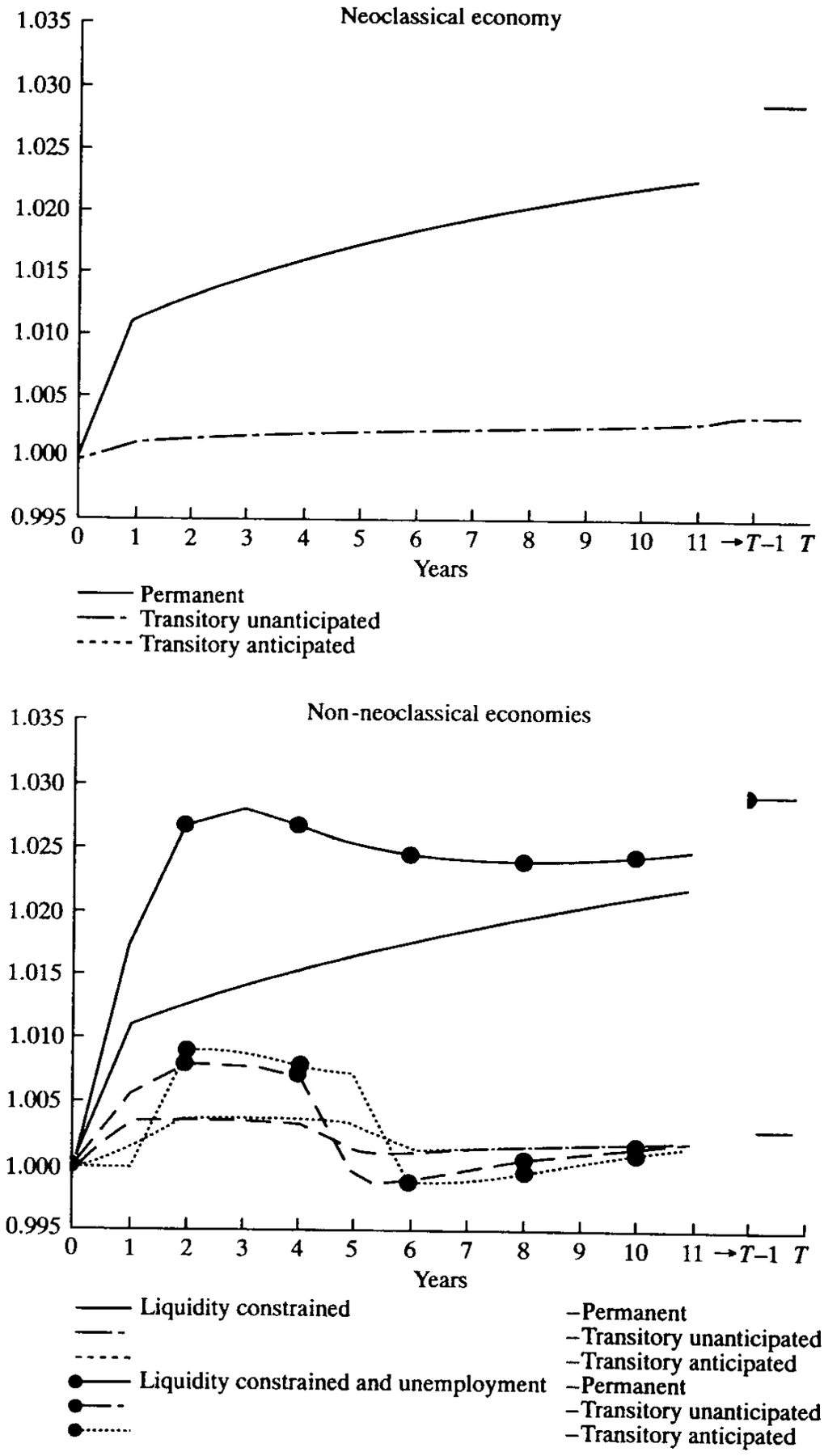



**Figure 7.2 Foreign transfer shock: output**

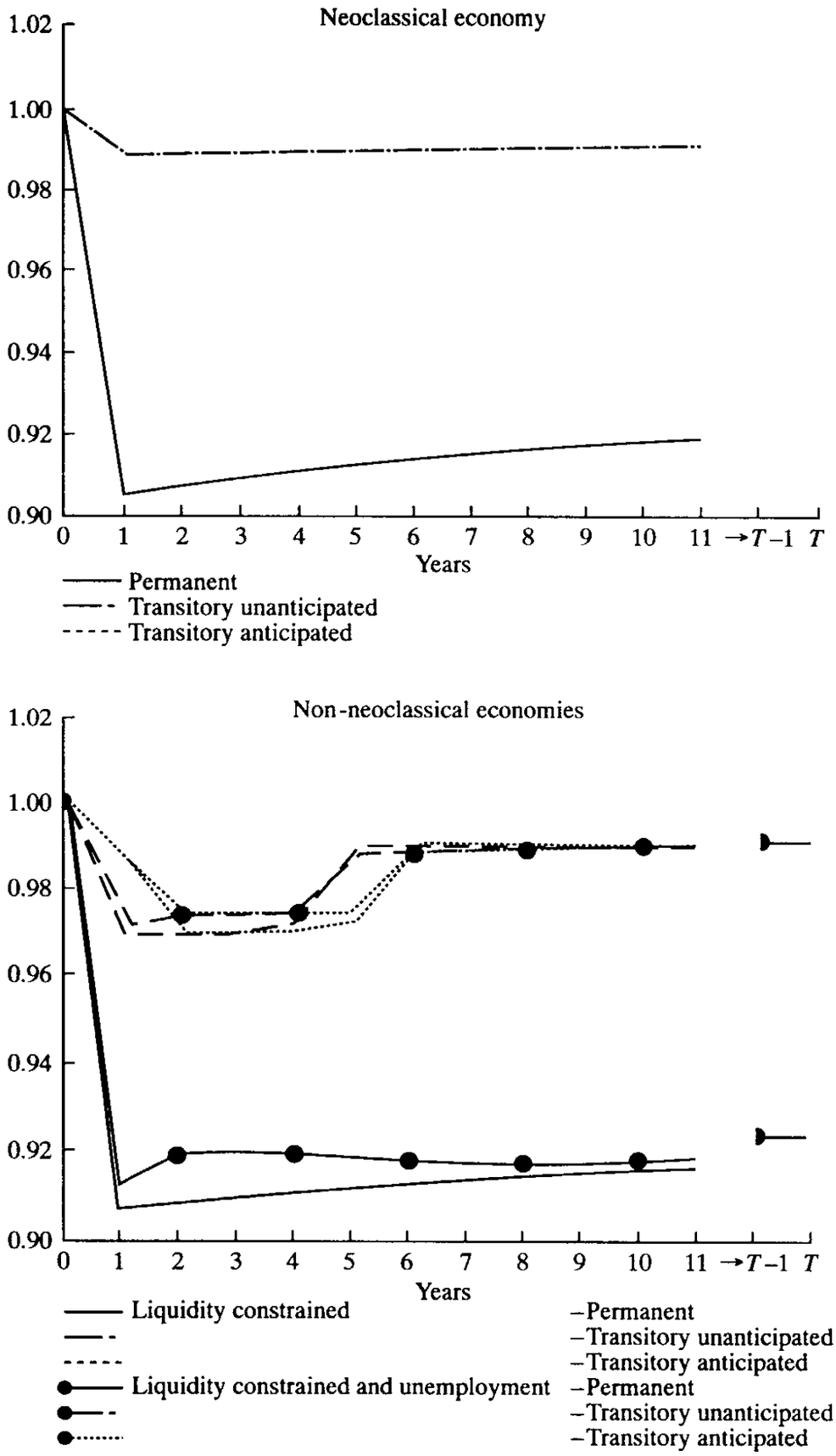



**Figure 7.3 Foreign transfer shock: real exchange rate**

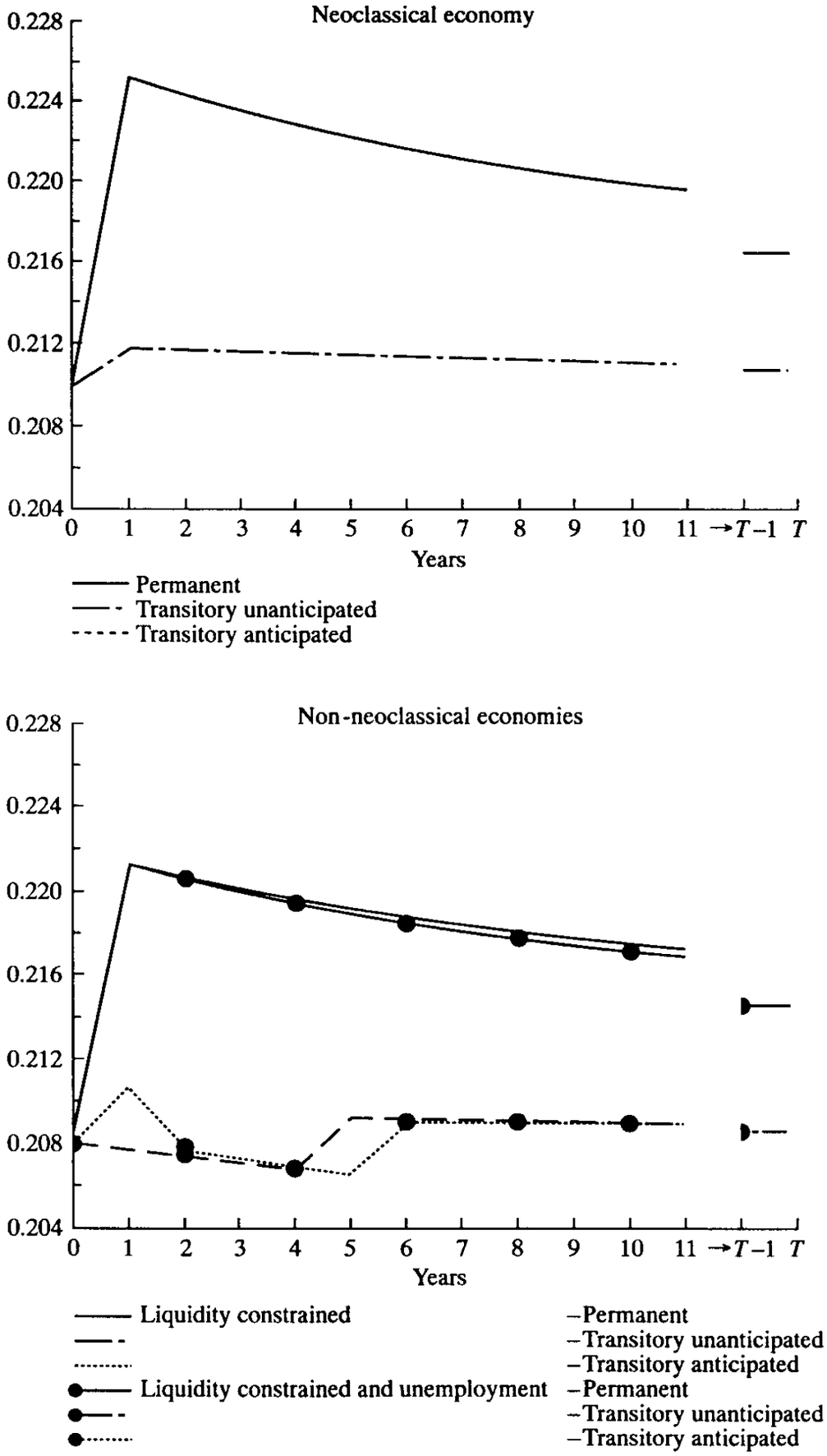



**Figure 7.4 Foreign transfer shock: private investment/output**

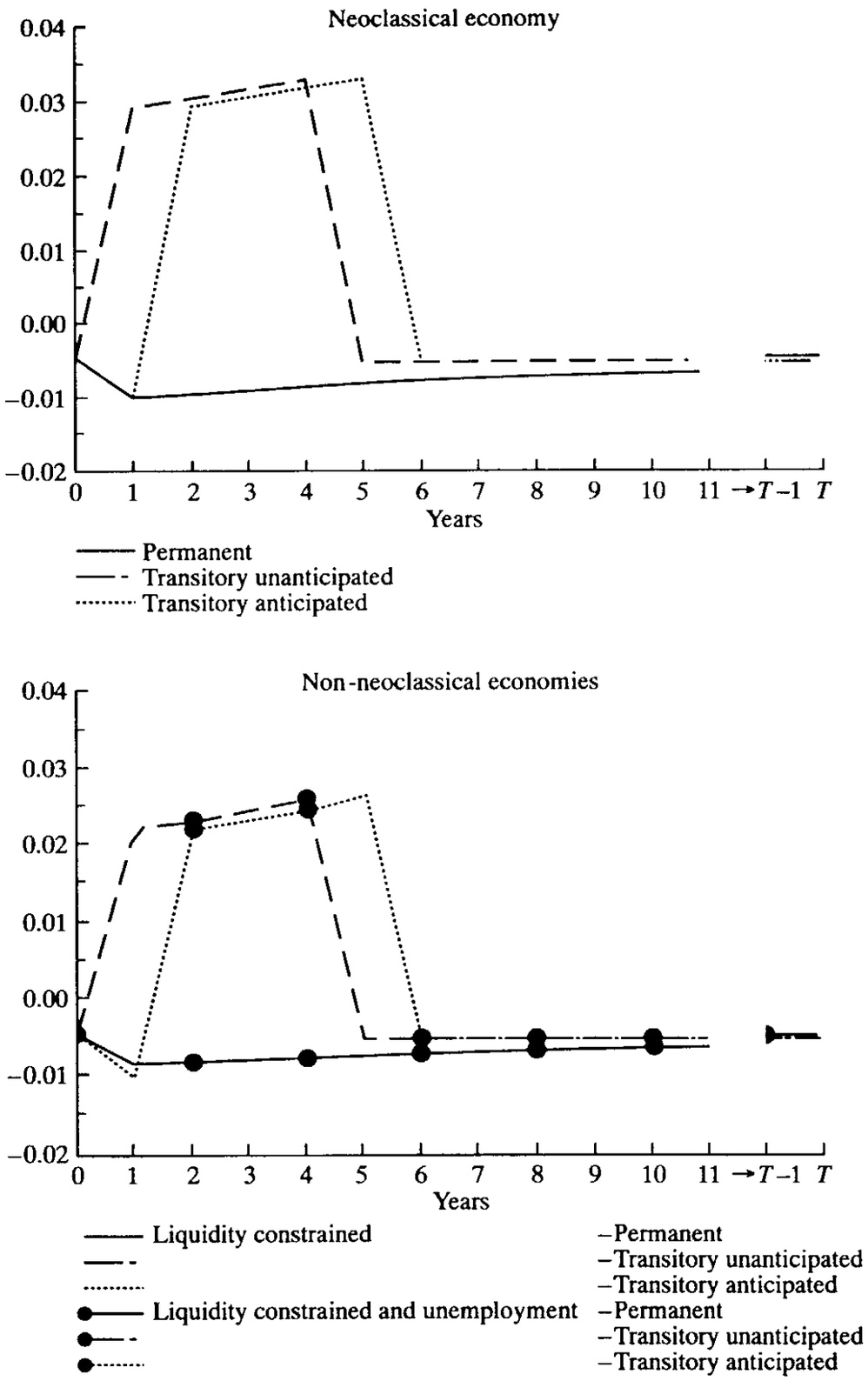



**Figure 7.5 Foreign transfer shock: current account/output**

It is worth underscoring that all these dynamic effects arise because of the *import content of production*. If capital goods had no import content, and if no imported materials were required for production, adjustment to the transfer shock would simply entail an instantaneous rise in private wealth and consumption, along with a real appreciation, without any change in real output, the capital stock, or the current account.

Consider next the case of a temporary unanticipated (*TU*) foreign transfer in this neoclassical economy, lasting from periods 1 to 4. As Figures 7.1–7.6 show, the qualitative effects on most variables are very similar to the case of a permanent shock. However, a temporary decrease in taxes raises permanent income by only a small amount, hence consumption increases by only a little. Consequently, all the effects described above occur with diminished force. The only qualitative difference is that now the current account shows a significant surplus while the shock lasts – a surplus of approximately 4 per cent of output as compared to deficit under the permanent shock – as consumers accumulate wealth to smooth out their consumption over the entire future horizon (see the dashed line in the top panel of Figure 7.5).

Consider now the case of a temporary anticipated (*TA*) shock, which takes place during periods 2 to 5. The effects are nearly identical to the unanticipated temporary shock. Consumption rises already in period 1 in anticipation of future lower taxes.[19] The current account goes initially into deficit, followed by four periods of surplus while the transfer lasts.

Next we focus on a full-employment economy with liquidity-constrained consumers and firms (*LCFE*). Aggregate consumption and investment respond only in part to forward-looking variables (wealth and Tobin's *q*), while now they are also sensitive to contemporaneous flow variables (consumer disposable income and operational profits).

For the permanent shock the dynamic paths of the endogenous variables in the *LCFE* economy are similar to the neoclassical case. By contrast, richer dynamics are observed under temporary shocks. Because temporary tax cuts relax the liquidity constraints of some consumers, aggregate consumption is boosted far beyond the smooth consumption levels of the *NC* economy during the four periods of shocks (cf. upper and bottom panels, Figure 7.1). Thus the *LCFE* economy exhibits a more pronounced cycle. Output expansion and real exchange rate appreciation are stronger than under the comparable temporary shocks in the *NC* economy, following U or inverted-U patterns during the four periods (bottom panels, Figures 7.2 and 7.2).

These real exchange rate fluctuations are reflected in a cycle in the real interest rate. Under a *TU* shock, the real exchange rate appreciates initially and then depreciates gradually for three periods (2 to 4); in

period 5 it depreciates abruptly – due to the decline in consumption by liquidity-constrained agents (see Figure 7.3). Therefore, the real interest rate must rise sharply in period 4, in anticipation of the strong real exchange rate depreciation. By contrast, under a *TA* shock – which arrives in period 2 – the real exchange rate is expected to appreciate in period 2 and to depreciate abruptly in period 6. Hence the real interest rate must fall in period 1 and rise sharply in period 5. Under both types of shocks, the rise in the real interest rate after the arrival of the shock causes an aggregate investment slump until the fiscal expansion is reversed (Figure 7.4).

Finally, notice also that the transitory current-account surplus is lower than in the *NC* economy (Figure 7.5). The reason is that consumption is now higher due to the four-period relaxation of liquidity constraints.

The third and last economy to consider is the Keynesian benchmark, which combines liquidity constraints with wage rigidity and unemployment (*LCUN*). The new long-run values of all endogenous variables are similar to those attained in the previous full-employment economy (*LCFE*). The difference lies in the adjustment path: now real wages do not rise as much in response to higher labour demand, allowing a transitory increase in employment above the full-employment level. Lagged wage indexation introduces a strong cyclical pattern in output and employment, which is absent in the full-employment economies.

In the case of a *P* shock, consumption rises more than in the *LCFE* case, a result of the anticipation by unconstrained consumers of higher employment and production during the adjustment period. However, as a ratio to (also higher) output, consumption remains practically unaltered from the previous economy. Output follows an oscillatory path, first rising to a temporary peak in period 3, then declining to reach a trough in period 8, and finally converging towards its long-run value (which exceeds the levels achieved by the full-employment economies). The output dynamics are a result of slowly increasing capital and the cyclical pattern of employment. The latter exhibits a peak of 2.3 per cent overemployment in period 2 (as real wages decline in that period due to lagged indexation), after which it starts an asymptotic convergence back to full employment (Figure 7.6). The real exchange rate mimics the dynamics of output after period 1.

Higher operating profits from higher output contribute to raise investment by constrained firms and hence aggregate investment, above the levels attained in the *LCFE* economy. However, as a ratio to output, it remains roughly at the same level as in the *LCFE* economy.

Concerning the simulation results for temporary shocks in a Keynesian (*LCUN*) economy, the main point to be emphasized is related to the

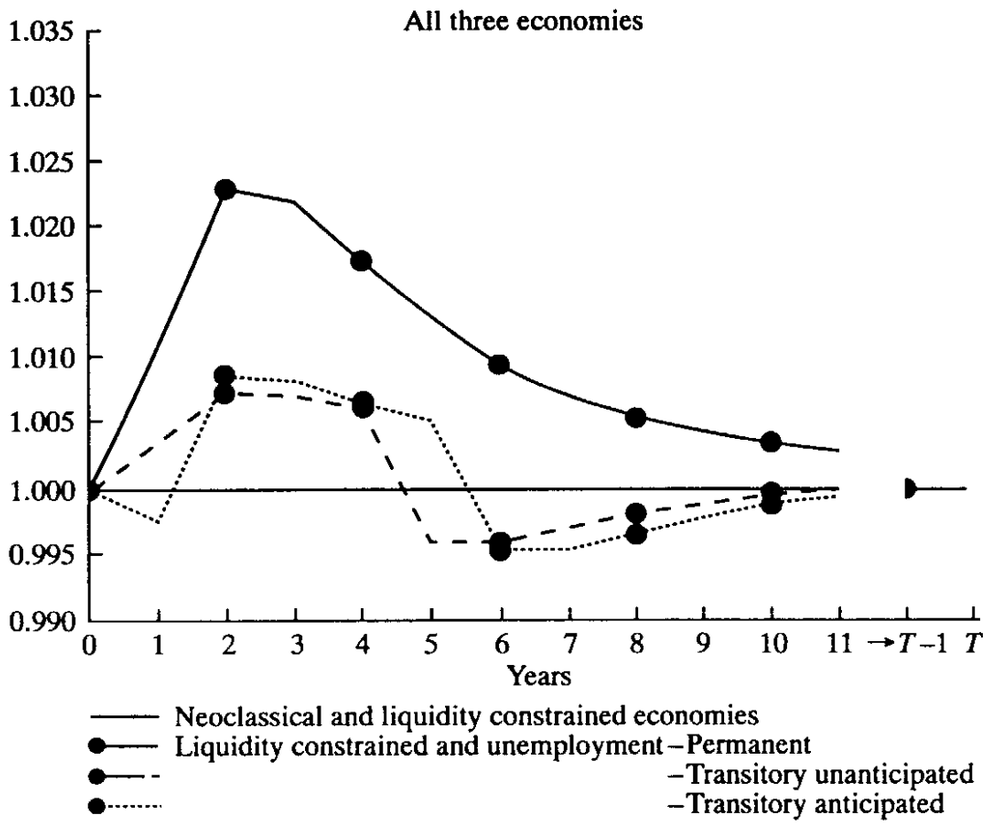



**Figure 7.6 Foreign transfer shock: employment**

cyclical behaviour of output. Aggregate demand, and hence output, rise much more during the four periods of foreign transfers, and then decline to lower levels than in the preceding full-employment economies. We conclude that, like liquidity constraints under temporary transfer shocks, wage rigidity intensifies the amplitude of the adjustment cycle to both temporary and permanent transfer shocks.

### *4.2 A permanent oil-price windfall*

We analyse now the dynamic response to a permanent decline in the price of intermediate imports. This can be interpreted as an oil price fall in an oil-importing economy. The shock has been normalized again to a first-round gain (or direct effect) of 4 per cent of output, reflecting a 40 per cent drop in the international price of intermediate imports, whose output share equals 10 per cent initially. Figures 7.7–7.9 report the dynamic trajectories of the main macroeconomic variables in response to a permanent oil price windfall, for each of the three economies.

While the first-round magnitude is similar to that of the foreign transfer analysed above, a lower oil price entails a production substitution effect in addition to the transfer's income effect. That is, even before

considering second-round income and substitution effects stemming from induced real exchange rate changes, the oil price fall encourages the substitution of capital and labour by cheaper oil.

Again consider first the *NC* economy (represented by continuous lines in Figures 7.7–7.9). Consumption (Figure 7.7) exhibits a dynamic pattern which is qualitatively similar to that in response to a transfer shock: a strong first-period increase and subsequently a gradual convergence to higher long-run levels. Wealth rises by a similar amount to that under the transfer shock. But private consumption increases by much less (long-run consumption as a share of output is now 58.7 per cent instead of 62.1 per cent before), due to a strong *increase* in the private consumption deflator, caused in turn by the real exchange rate depreciation.

Output grows much more than under the foreign transfer shock. The impact effect on output is now 5.4 per cent (as compared to 1.1 per cent before), and long-run output is 6.8 per cent higher (as compared to 2.8 per cent under the transfer shock). This significantly higher output level reflects the massive incentive to change the input mix away from value added and towards intermediate imports, in response to the lower international price of the latter. The strong supply expansion causes a 3.5 per cent initial real exchange rate *depreciation* (Figure 7.8), which stands in contrast to the initial *appreciation* under a foreign transfer shock. In the long run the real exchange rate depreciates by 5.4 per cent, while it had appreciated by 7.4 per cent under the transfer shock. Long-run intermediate imports grow now by a massive 69 per cent, a result of a positive substitution effect (a significantly lower international oil price slightly dampened by the moderate real exchange rate depreciation) and a positive scale effect; by comparison, they rose only 11 per cent under the transfer shock, resulting from a more modest scale effect and a substitution effect stemming only from the real exchange rate appreciation. The significant substitution effects – in both cases – reflect the high (unitary) elasticity of substitution between imports and value added, embodied by the Cobb–Douglas production technology.

Investment reflects the conflicting effects of the anticipated output rise, which boosts profitability, and the real depreciation, which makes capital goods more expensive due to their import content. Hence aggregate investment rises in period 1 by only a moderate amount (Figure 7.8). The long-run capital–output ratio is now 2.94, lower than in the initial steady state, as a result of the real exchange rate depreciation; by contrast, under the foreign transfer shock it had risen to 3.09, helped by the real exchange rate appreciation. Therefore the new long-run investment ratio to output must be lower after the oil-price windfall.

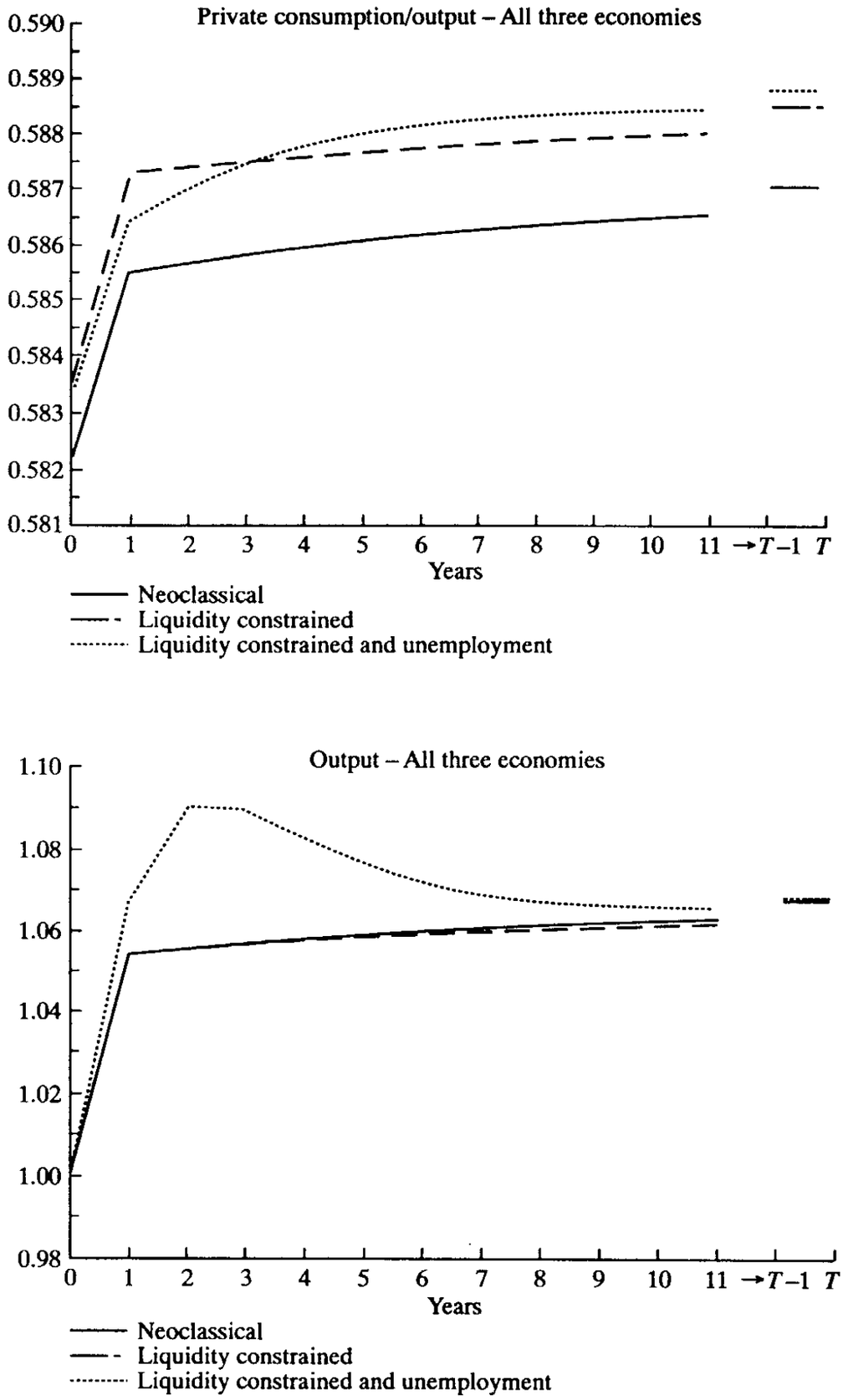
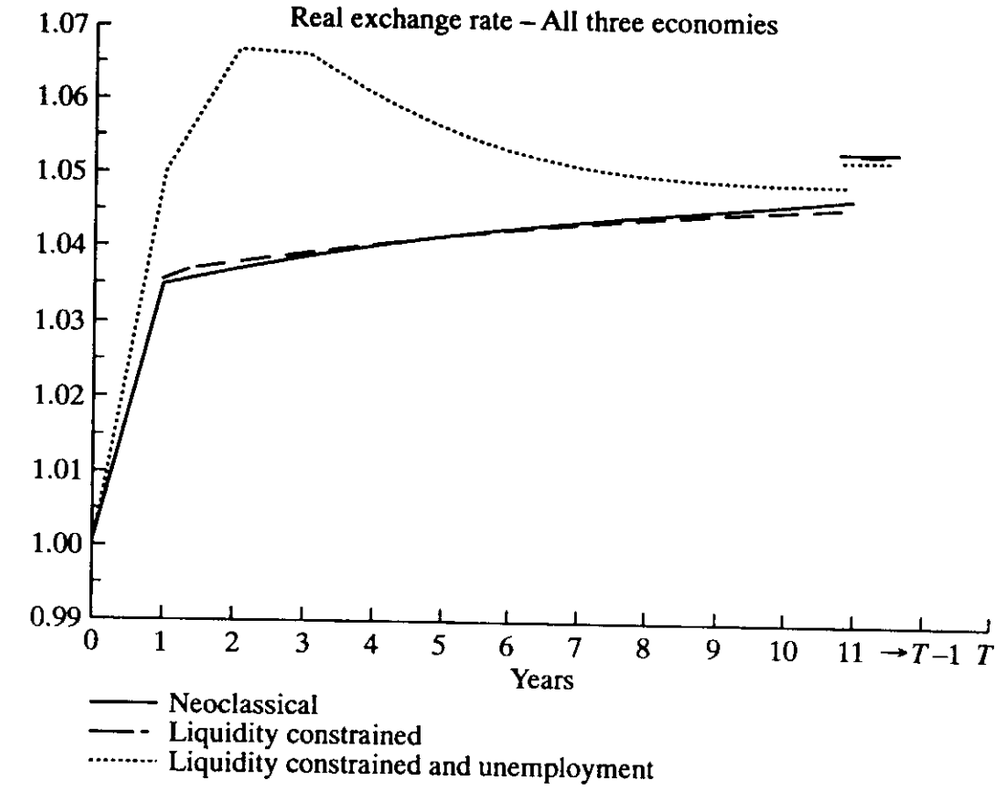



**Figure 7.7 Permanent oil-price windfall: private consumption/output and output**



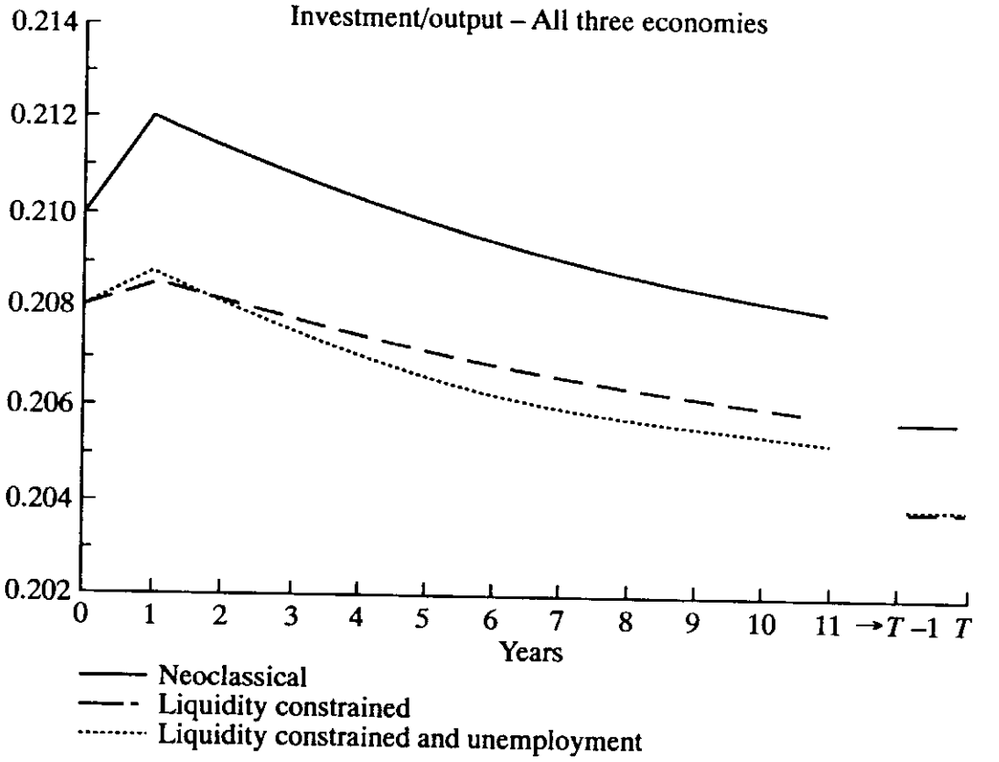




**Figure 7.8 Permanent oil-price windfall: real exchange rates and investment/output**

The current account again replicates the interesting result that a favourable external shock causes a transitory *deficit* (Figure 7.9), due to the combination of investment adjustment costs (which delay the capacity expansion) and forward-looking consumers (who anticipate higher future income levels and therefore raise their current spending). Finally, with full employment holding continuously, real wages are boosted by the higher output levels. The long-run real wage increases in the same proportion as output (6.8 per cent), exceeding significantly the 2.8 per cent rise observed under the foreign transfer shock.

The full-employment economy with liquidity constraints (the *LCFE* case, depicted by dashed lines in Figures 7.7–7.9) displays a pattern very similar to that of the fully neoclassical case. The chief difference is that liquidity-constrained consumers do not initially adjust their consumption in anticipation of future output gains. As a result, the current-account deficit is now smaller, allowing for additional asset accumulation, which in the long run leads to higher wealth and sustains an increased consumption–output ratio.

The Keynesian benchmark *LCUN* (represented by the dotted lines in Figures 7.7–7.9) yields richer dynamics, due to the more pronounced change in output made possible by transitory overemployment. While consumption rises further than in the *LCFE* economy, as a share of (higher) output it follows a path which is very similar to the previous one. The short-term real exchange rate depreciation exceeds significantly the levels reached under the full-employment economies, due to the additional output expansion made possible by sluggish real wage adjustment. Real output reaches a peak in period 2, with a level which is 9.0 per cent higher than in the initial steady state, and also exceeds significantly the 5.6 per cent increase in the full-employment economies. Subsequent catch-up of real wages reduces output (which reaches a local minimum of 1.066 in period 10) until convergence to its new long-run equilibrium of 1.069. The real exchange rate mimics the cyclical pattern of output; in turn, investment as a share of output shows similar behaviour as in the *LCFE* economy.

Finally, consider the dynamic pattern of employment under a permanent external transfer. The real wage, determined by backward nominal indexation, reaches a trough in period 2, reflecting the price deflation of the initial period. Afterwards it catches up fast to converge towards its higher long-run value. Employment reflects this real wage pattern, reaching an all-time high of 5.4 per cent overemployment in period 2, subsequently returning asymptotically to full employment. Average overemployment is 3.8 per cent during periods 1 to 5, exceeding significantly the corresponding average of 1.7 per cent in the Keynesian

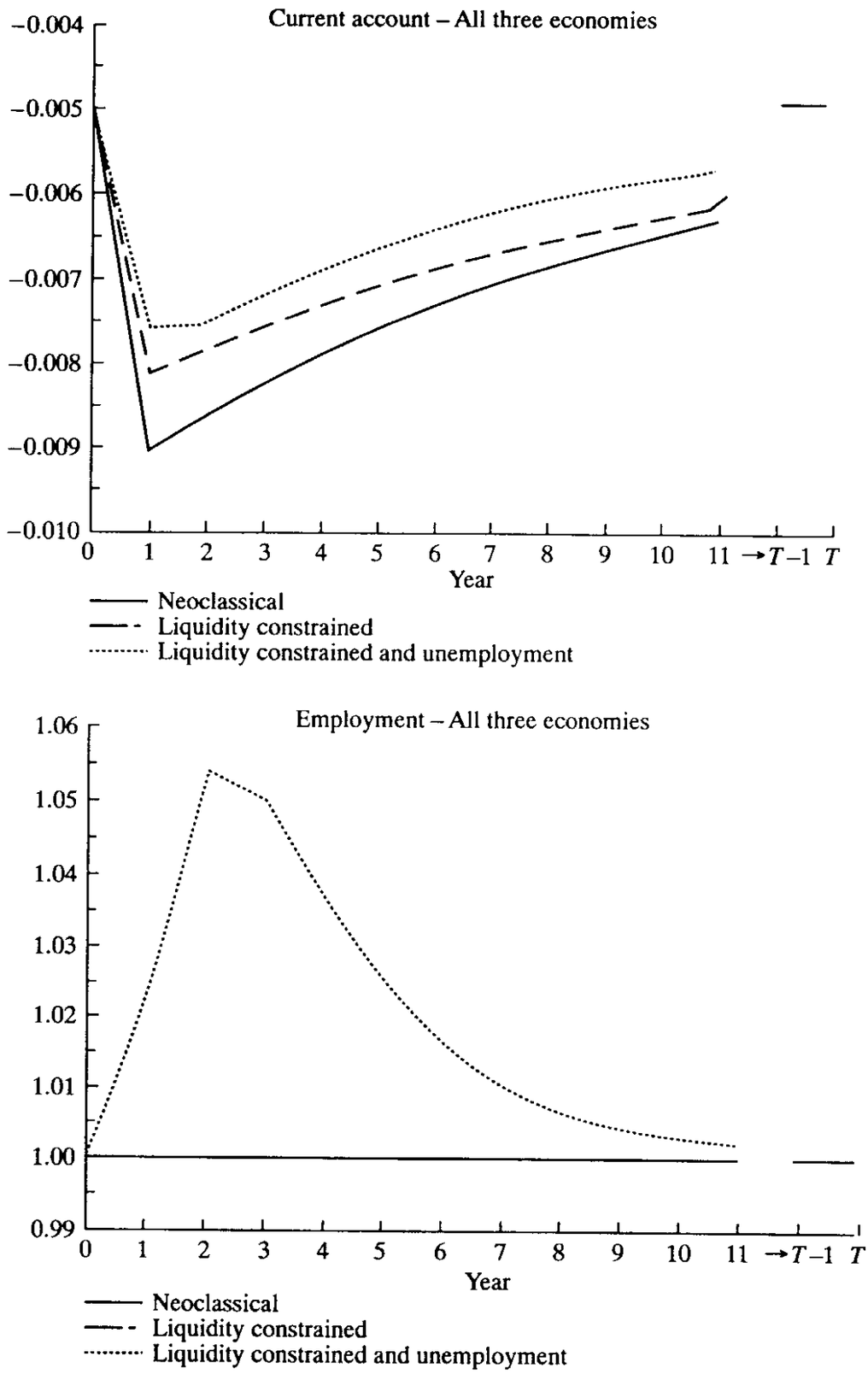



**Figure 7.9 Permanent oil-price windfall: current account/output and employment**

economy affected by a permanent transfer shock. Thus, like in the case of the transfer shock, wage rigidity intensifies substantially the amplitude of the cyclical response to an oil-price shock.

In concluding, the main difference between the oil-price windfall and the permanent transfer is that the former involves both a favourable supply shock – which boosts production directly and depreciates the real exchange rate – and a real income gain, while a foreign transfer implies only an income effect which boosts aggregate demand and appreciates the real exchange rate – with an indirect induced effect on supply. Apart from the real exchange rate, most other variables behave in a qualitatively similar fashion under both shocks, although the quantitative response is significantly more intense under the oil-price windfall.

## 5 Concluding remarks

This paper has developed a dynamic macroeconomic general equilibrium model encompassing three economies: a neoclassical case with frictionless, instantaneous clearing in goods, assets and labour markets, a full-employment economy with groups of liquidity-constrained consumers and investors, and a Keynesian benchmark with liquidity-constrained agents and wage rigidity giving rise to temporary deviations from full employment.

The model has been applied to simulate the impact, transitional and steady-state effects of permanent, temporary unanticipated and temporary anticipated external shocks. Two shocks have been considered: a rise in foreign transfers and a fall in the international price of intermediate imports.

The simulations demonstrate the usefulness of a consistent framework based on first principles for tracing out and understanding the macroeconomic response to disturbances. The numerical exercises illustrate three main points. First, due to the import content of production in the model, both permanent *and* transitory external shocks lead to long-run changes in productive capacity and real output, as well as in the other endogenous variables. Second, when favourable permanent shocks lead to higher steady-state capital and output (as is the case in the simulations above), their short-run effect is to cause a current-account *deterioration*. The reason is that consumption by unconstrained consumers immediately rises in response not only to current, but also to anticipated future real income gains, and the latter accrue only gradually, due to the existence of investment adjustment costs. This is in sharp contrast with the effect of favourable transitory shocks, which unambiguously *improve* the current account while they last. Third, market imperfections have

important consequences for the dynamic response of the economy to exogenous disturbances. In contrast with the smooth, monotonic adjustment pattern displayed by the neoclassical benchmark economy in the simulations above, liquidity constraints or wage rigidity tend to amplify the cyclical response to external shocks. This suggests that market imperfections could be a major factor behind the complex dynamic adjustment patterns observed in actual economies.

## Appendix The model

This appendix describes the structure of the model, preceded by notation and definition of variables. All prices are defined relative to the price of the domestic good or to the foreign price level. All lower case variables other than prices and interest rates are defined in real terms (relative to the domestic or foreign price level, as applicable) and scaled to the labour force in efficiency units.[20] The model is written in continuous time. Dots over variables denote right-hand time derivatives.

### *Notation and definition of variables*

#### *1 Labour and employment*

| | |
|---|---|
| $pg$ | Labour force growth rate |
| $tg$ | Harrod-neutral technical progress rate |
| $g = pg + tg$ | Growth rate of labour force in efficiency units |
| $l$ | Employment (relative to labour force in efficiency units) |

#### *2 Incomes, transfers and capital flows*

Domestic

| | |
|---|---|
| $d$ | Dividends paid |
| $op$ | Operational profits |
| $td$ | Taxes |
| $yd$ | Private disposable income |
| $prem$ | Profit remittances abroad |

External (all exogenous):

| | |
|---|---|
| $ftrg$ | Foreign transfers to the public sector |
| $ftrp$ | Foreign transfers to the private sector |
| $yf$ | Foreign income |
| $dfi$ | Direct foreign investment |

#### *3 Stocks*

Domestic

| | |
|---|---|
| $a$ | Non-human wealth of the private sector |
| $bg$ | Domestic debt of the public sector |
| $fe$ | Stock of domestic equity (shares in domestic firms) held by foreigners |

| | |
|---|---|
| *hb* | Domestic base money |
| *hu* | Human wealth of the private sector |
| *k* | Physical capital |
| *pvig* | Present value of government investment subsidy |
| *pvihb* | Present value of cost of holding money |
| External | |
| *fbg* | Foreign assets held by the public sector |
| *fbp* | Foreign assets held by the private sector |

### 4 *Goods flows*

| | |
|---|---|
| *y* | Gross output of final goods |
| *cp* | Private aggregate consumption |
| *cmp* | Private imported goods consumption |
| *cnp* | Private national goods consumption |
| *cng* | Public national goods consumption |
| *inv* | Gross domestic investment |
| *in* | Private national goods investment |
| *im* | Private imported goods investment |
| *ig* | Public investment subsidy |
| *iac* | Investment adjustment costs |
| *x* | Exports |
| *mr* | Intermediate imports |

### 5 *Various rates*

| | |
|---|---|
| Domestic rates | |
| *i* | Nominal interest rate on public debt |
| *r* | Real interest rate on public debt |
| *nmg* | Rate of growth of the nominal money stock |
| External Rates (all exogenous) | |
| *if* | Nominal interest rate on foreign assets/liabilities |
| *rf* | Real interest rate on foreign assets/liabilities |

### 6 *Goods prices*

| | |
|---|---|
| Domestic (all relative to the price of the domestic final good): | |
| *pc* | Private aggregate consumption deflator |
| *pi* | Aggregate investment deflator |
| External (all relative to the price of the foreign final good and exogenously given): | |
| *pcmp* | Private imported goods consumption deflator |
| *pim* | Imported goods investment deflator |
| *pmr* | Intermediate imports deflator |
| *px* | Deflator of export-competing goods |

### 7 *Other prices*

| | |
|---|---|
| Domestic prices | |
| *q* | Real equity price (Tobin's *q*) in units of domestic output |

| | |
|---|---|
| $v$ | Real wage per effective labour unit |
| $W$ | Nominal wage per labour unit |
| $PC$ | Nominal private consumption deflator |

Real exchange rate

| | |
|---|---|
| $e=(EP^*)/P$ | Real exchange rate |
| $E$ | Nominal exchange rate |
| $P$ | Nominal price of the domestic good |
| $P^*$ | Nominal price of the foreign final good |

## *Model structure*

### *Budget constraints*

Public-sector budget constraint

$$[td + e\,ftrg - cng - pi\,ig] - (r-g)bg + (g + \dot{P}/P)hb + e(rf-g)fbg = e\dot{fbg} - b\dot{g} - \dot{hb} \tag{1}$$

External-sector budget constraint (balance of payments)

$$\left[\frac{x}{e} - pcmp\ cmp - pim\ im - pmr\ mr + ftrg + ftrp\right] + (rf-g)[fbp + fbg] - \frac{prem}{e} = (\dot{fbp} + \dot{fbg}) - dfi \tag{2}$$

Private-sector budget constraint

$$[y - pi\,inv - pi\,iac - e\,pmr\,mr + e\,ftrp - td + pi\,ig - pc\,cp] - (g + \dot{P}/P)hb + (r-g)bg - prem + (rf-g)\,efbp = \dot{hb} + \dot{bg} - e\,dfi + e\dot{fbp} \tag{3}$$

### *Market equilibrium conditions*

Goods market

$$y = cnp + cng + in + pi\,iac + x \tag{4}$$

Money market

$$hb = \phi_1 y^{\phi_2} exp(\phi_3 i) \tag{5}$$

where $\phi_1,\ \phi_2 \geq 0,\ \phi_3 \leq 0$.

Bond market

$$r = rf + \frac{\dot{e}}{e} \tag{6}$$

Equity market

$$\dot{q} = r\,q - \frac{d}{k} \tag{7}$$

Standard Fisher equation

$$i = r + \frac{\dot{P}}{P} \tag{8}$$

*Labour market*

The nominal wage equation in discrete time form

$$W = exp(tg)l^{\omega}\left(\frac{PC}{PC_{-1}}\right)^{\theta}\left(\frac{PC_{-1}}{PC_{-2}}\right)^{1-\theta} W_{-1} \tag{9}$$

where $\omega \geq 0$, $0 \leq \theta \leq 1$.
The relation between the nominal wage and the real (product) wage per effective labour unit

$$\frac{W}{P} = exp(tg\ t)\ v \tag{10}$$

where $t$ is the time index.

*Firms*

Production function

$$y = \alpha_0 l^{\alpha_1}\ k^{\alpha_2}\ mr^{(1-\alpha_1-\alpha_2)} \tag{11}$$

where $\alpha_0 \geq 0$, $0 \leq \alpha_1,\ \alpha_2 \leq 1$.
Investment adjustment costs

$$iac = \mu\left[\frac{(inv - (g+\delta)k)^2}{k}\right] \tag{12}$$

where $\mu > 0$.
The evolution of the capital/effective labour ratio

$$\dot{k} = inv - (g+\delta)k \tag{13}$$

Marginal productivity condition for labour

$$l = \alpha_1 v^{-1}\ y \tag{14}$$

Marginal productivity condition for imported inputs

$$mr = (1 - \alpha_1 - \alpha_2)(e\ pmr)^{-1}\ y \tag{15}$$

Investment demand

$$inv = \beta_1\left[\frac{k}{2\mu}\left[\frac{q}{pi} - \frac{pvig}{pik} - 1\right] + (g+\delta)k\right] + (1-\beta_1)\left[\beta_2\frac{op}{pi} + ig\right] \tag{16}$$

where $\beta_1$ is the share of non-constrained firms and $\beta_2$ is the marginal propensity of liquidity-constrained firms to invest out of operational profits; $0 \leq \beta_1, \beta_2 \leq 1$. The present value of the public investment subsidy

$$\dot{pvig} = (r - g)\, pvig - pi\, ig \tag{17}$$

Aggregate operational profits

$$op = y - v\,l - e\,pmr\,mr \tag{18}$$

Dividends

$$d = op - pi\,inv - pi\,iac + pi\,ig + q(\dot{k} + gk) \tag{19}$$

Share of domestic goods in aggregate investment

$$in = \gamma\, pi\, inv \tag{20}$$

Share of imported goods in aggregate investment

$$im = (1 - \gamma)\left[\frac{pi}{e\,pim}\right] inv \tag{21}$$

where $0 \leq \gamma \leq 1$.

The aggregate investment deflator

$$pi = (e\,pim)^{(1-\gamma)} \tag{22}$$

*Consumers*

Private-sector non-human wealth

$$a = hb + bg + e\,fbp + q(k - fe) - pvihb \tag{23}$$

The path of money holding costs

$$\dot{pvihb} = (r - g)\, pvihb - i\, hb \tag{24}$$

The path of human wealth

$$\dot{hu} = (r - g)hu + [td - vl - e\,ftrp] \tag{25}$$

Total private consumption demand

$$cp = \lambda_1\left[(\lambda_2 - g)\frac{a + hu}{pc}\right] + (1 - \lambda_1)\left[\frac{yd}{pc} + (\lambda_2 - g)\frac{a}{pc}\right] \tag{26}$$

where $0 \leq \lambda_1 \leq 1$ is the share of unconstrained consumers, and $\lambda_2$ is the subjective discount rate.

Disposable income

$$yd = v\ l + e\ ftrp - td \tag{27}$$

Share of domestic goods in aggregate private consumption

$$cnp = \eta\ pc\ cp \tag{28}$$

Share of imported goods in aggregate private consumption

$$cmp = (1 - \eta)\left[\frac{pc}{e\ pcmp}\right] cp \tag{20}$$

where $0 \leq \eta \leq 1$.
The aggregate private consumption deflator

$$pc = (e\ pcmp)^{(1-\eta)} \tag{30}$$

The accumulation of per-capita real balances

$$\dot{hb} = [nmg - (\dot{P}/P) - g]hb \tag{31}$$

where *nmg* is endogenous under money-financing of the public deficit, and exogenous otherwise.

*Foreigners*

Foreign demand for the domestically produced good

$$x = \rho_1 (e\ px)^{\rho_2}\ yf^{\rho_3} \tag{32}$$

where $\rho_1,\ \rho_2,\ \rho_3 \geq 0$.
Path of foreigners' equity holdings

$$\dot{fe} = \frac{e\ dfi}{q} - g\ fe \tag{33}$$

Profit repatriation

$$prem = \frac{fe}{k} d \tag{34}$$

## NOTES

We are indebted to Warwick McKibbin and Steven Symansky for stimulating discussions of model solution and simulation techniques, and to David Currie and Warwick McKibbin for their very valuable comments. We also thank Leonardo

Auernheimer, Michael Ellis and participants at the XIth Latin American Meetings of the Econometric Society, the World Bank Macroeconomics Seminar, and the Oxford North–South Conference for useful comments. Very efficient research assistance by Paul Bergin and Gylfi Zoega is gratefully acknowledged.

1 Three of these features (wage rigidity, import content of capital goods and foreign holdings of domestic equity) are considered in different forms by previous models, in particular McKibbin and Sachs (1989). Explicit inclusion of public investment and monetary finance of budget deficits are novel features of this framework.
2 The model's variables and equations are listed in the appendix to this paper. For a more complete description of the model, see Schmidt-Hebbel and Serven (1992).
3 Foreign assets held by the domestic private and public sectors are net assets (equal to gross foreign reserves plus other gross foreign assets less gross foreign liabilities) and therefore can have either sign.
4 However, the model can be easily extended to allow a less restrictive formulation of substitution possibilities in consumption, production and investment.
5 The general reasons that cause marginal and average $q$ (which represents just the market value of existing capital) to diverge are spelt out in Hayashi (1982). In our framework they differ due to the lump-sum investment subsidy that firms receive from the government. Marginal $q$ equals average $q$ minus the present value of the subsidy per unit of capital. Hence the subsidy has no effect whatsoever on the investment decisions of unconstrained firms, due to its lump-sum nature. It does affect, however, investment by liquidity-constrained firms.
6 The assumption of equal discount rates is crucial for Ricardian equivalence to hold. Higher private-sector discount rates, whether due to finite lifetimes (reflected by a given probability of death, as in Blanchard, 1985) or to a risk premium on consumers' debt relative to the borrowing cost of the government (e.g., McKibbin and Sachs, 1989) would cause Ricardian equivalence to break down.
7 For discussion and empirical analyses of the implications of liquidity constraints for consumer behaviour – as well as for Ricardian equivalence – see Hayashi (1985), Hubbard and Judd (1986), Bernheim (1987), Leiderman and Blejer (1988), Seater (1993) and Easterly *et al.* (1994).
8 Recall that, because of perfect asset substitutability, the per-capita real return on wealth is just equal to the real interest rate (net of effective labour force growth) times the wealth stock. In turn, steady-state consumption equals the rate of time preference (also net of effective labour force growth) times the wealth stock.
9 Turnovsky and Sen (1991) use a non-monetary model with intertemporally optimizing consumers in which transitory fiscal disturbances have long-run effects. Their result depends critically on the endogeneity of labour supply in their framework, which makes long-run employment endogenous. In our case, the dependence of the long-run capital stock on the real exchange rate ensures that transitory fiscal shocks have permanent effects despite the constancy of full employment across steady states. This issue is investigated analytically in Serven (1993).

10 Without liquidity constraints, the experiment would just amount to a change in the composition of taxation between the inflation tax and direct taxes, without any effect on wealth, consumption, or any other real variable.
11 See Blanchard and Kahn (1980) and Buiter (1984).
12 In principle, we could linearize the system around a steady state to determine analytically the conditions under which the transition matrix possesses the saddle-point property. Given the large dimensionality of our system, however, this would be an intractable task.
13 We used a very strict convergence criterion, requiring that the maximum relative change between solutions in any variable at any time period not exceed one-thousandth of 1 per cent. This typically required a horizon between sixty and eighty periods for convergence. For the actual simulations, the model was made discrete.
14 Recall that Walras' law ensures that one of the three sectoral budget constraints (of the public, private and foreign sectors) holds identically when markets clear. Hence we do not need to specify a third residual variable.
15 Note that in Figures 7.1–7.9 different schedules often overlap. For instance, the schedules for temporary unanticipated and temporary anticipated shocks are virtually the same in the upper panels of Figures 7.1, 7.2 and 7.3. The schedules for any given shock coincide for the liquidity-constrained and liquidity-constrained with unemployment economies in the lower panels of Figures 7.1 and 7.5. Finally, the employment schedule coincides exactly for the neoclassical and liquidity-constrained economies in the bottom panel of Figure 7.9.
16 Long-run consumption rises more than real wealth. The reason is the decline in the private consumption deflator, prompted by the real exchange rate appreciation.
17 In Figure 7.3, an appreciation is represented by a decline in the value of $e$, in accordance with the model's definition of the real exchange rate.
18 This result, however, depends on our choice of parameter values. In general, the change in the current account is given by two main factors. First, the degree of intertemporal substitutability in consumption: the lower substitutability, the stronger the consumption-smoothing effect described in the text and the more likely a current-account deterioration. Second, the magnitude of adjustment costs to investment: the higher adjustment costs, the smaller the investment rise, and the more likely a current-account improvement. The analytical details are provided in Serven (1993).
19 The rise is slightly smaller than under *TU* because the temporary tax reduction must be discounted one additional period.
20 Labour force in efficiency units is equal to the actual labour force augmented by Harrod-neutral technical progress.

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