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## APPENDIX 1: ESTIMATION TECHNIQUE

The estimation technique used was the Engle and Yoo (1991) three-step procedure, which is an extension of the Engle-Granger (1987) two-step procedure. This approach consists first, of a simple test for the presence of cointegration between variables, indicating whether a particular set of variables represents a combination that is consistent with a long-run equilibrium relationship.

At the second stage, an ECM is constructed in order to estimate the short-run or dynamic adjustment process to long-run equilibrium. The ECM indicates the dynamic relationship between variables, i.e. fluctuations in the dependent variable around its long-run trend are explained by fluctuations in the explanatory variables around their long-term trends. "The idea is simply that a proportion of the disequilibrium from one period is corrected in the next" (Engle and Granger 1986: 254). Long-term effects are accounted for by the inclusion of the error term (*e*) of the long-term cointegration relationship in the ECM (Harris 1995: 24).

All the variables in an ECM were transformed (differenced) into stationary variables. A regression of the stationary form of the dependent variable on the other stationary variables and the first lag of the error term of the cointegrating regression was then performed. Other variables besides those included in the cointegrating regression may be considered for inclusion in the ECM. Examples of such variables are those which were discarded from the cointegrating regression, stationary variables (in levels) and variables, which theoretically will only influence the short-run trend of the dependent variable and were therefore also not considered for inclusion in the cointegrating regression. Since all the variables in the ECM are stationary, the assumptions of classical regression analysis are fulfilled. Therefore, standard diagnostic tests can be used to determine which variables should be included in the final specification of the ECM (Harris 1995: 24).

The third step is applied to adjust the coefficients and *t*-statistics so that they are closer to their true values. This ensures that the variables included in the long-run regression could be evaluated statistically. Engle and Yoo (1989) have proposed a "third step" in addition to the Engle and Granger two-step estimation technique, which step is computationally tractable and overcomes two of the disadvantages of the two-step procedure.

This step provides a correction to the parameter estimates of the first stage, static regression that makes them asymptotically equivalent to FIML and provides a set of standard errors, which allows the valid calculation of standard *t*-tests.

The third step consists simply of a further regression of the conditioning variable from the static regression multiplied by minus the error correction parameter, regressed on the errors from the second-stage error correction model. The coefficients from this model are the corrections to the parameter estimates while their standard errors are the relevant standard errors for inference.

The three steps are then:

i) First estimate a standard cointegrating regression of the form:
$Y_t = \alpha^1 X_t + Z_t$

where $Z_t$ is the OLS (ordinary least square) residual to give first-stage estimates of $\alpha^1$.

ii) Then estimate a second-stage dynamic model (ECM) using the residuals from the cointegrating regression to impose the long-run constraint:
$\Delta Y_t = \Phi(L)\Delta Y_{t-1} + \Omega(L)\Delta X_t + \delta Z_{t-1} + \mu_t$.

iii) The third stage then consists of the regression:
$\mu_t = \varepsilon(-\hat{\delta} X_t) + \upsilon_t$.

The correction for the first-stage estimates is then simply: $\alpha^3 = \alpha^1 + \varepsilon$ and the correct standard errors for $\alpha^3$ are given by the standard errors for $\varepsilon$ ($SE_\varepsilon$) in the third-stage regression.

The $t$-values for $\alpha^3$ are given by:

$$t = \frac{\alpha^3}{SE_\varepsilon}$$

## APPENDIX 2: SIMULATION ERROR STATISTICS

*Root mean square simulation error:*

$$\text{RMSE} = \sqrt{\frac{1}{T}\sum_{t=1}^{T}(y_t - \hat{y}_t)^2}$$

*Mean absolute simulation error:*

$$\text{MAE} = \frac{1}{T}\left|y_t - \hat{y}_t\right|$$

*Root mean square percentage error:*

$$\text{RMSPE} = \sqrt{\frac{1}{T}\sum_{t=1}^{T}\left(\frac{y_t - \hat{y}_t}{y_t}\right)^2}$$

*Mean absolute percentage error:*

$$\text{MAPE} = \frac{1}{T}\sum_{t=1}^{T}\left|\frac{y_t - \hat{y}_t}{y_t}\right|^2$$

*Theil inequality coefficient:*

$$\text{U} = \frac{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(y_t - \hat{y}_t)^2}}{\sqrt{\frac{1}{T}\sum_{t=1}^{T}(\hat{y}_t)^2}\sqrt{\frac{1}{T}\sum_{t=1}^{T}(y_t)^2}},$$

that lies between zero and one, where zero indicates a perfect fit.

The Theil inequality coefficient can be decomposed into three proportions:

$$\text{Bias, } \text{U}^{\text{M}} = \frac{(\bar{\hat{y}} - \bar{y})^2}{\frac{1}{T}\sum_{t=1}^{T}(y_t - \hat{y}_t)^2},$$

measuring the extent to which the average values of the simulated and actual series deviate from each other,

$$\text{Variance, } \text{U}^{\text{S}} = \frac{(\sigma_{\hat{y}} - \sigma_y)^2}{\frac{1}{T}\sum_{t=1}^{T}(y_t - \hat{y}_t)^2},$$

indicating the degree of variability in the series, and

Covariance, $\mathrm{U}^{\mathrm{C}} = \dfrac{2(1-\rho)\sigma_{\hat{y}}\sigma}{\frac{1}{T}\sum_{t=1}^{T}(y_t - \hat{y}_t)^2}$,

representing the remaining unsystematic error.

This is based on the fact that the mean squared error can be decomposed as:

$$\frac{1}{T}\sum_{t=1}^{T}(y_t - \hat{y}_t)^2 = (\bar{\hat{y}} - \bar{y})^2 + (\sigma_{\hat{y}} - \sigma_y)^2 + 2(1-\rho)\sigma_{\hat{y}}\sigma_y$$

where $\bar{\hat{y}}$, $\bar{y}$, $\sigma_{\hat{y}}$ and $\sigma_y$ are the means and standard deviations of the series $\hat{y}_t$ and $y_t$, respectively, and

$$\rho = (1/\sigma_y\sigma_y T)\sum_{t=1}^{T}(\hat{y}_t - \bar{\hat{y}})(y_t - \bar{y})$$

is the correlation coefficient
(Pindyck and Rubinfeld: 338-342).

## APPENDIX 3: FULL IDEAL PRINCIPLES

The process of model selection involves the following five criteria:

### (i) *Consistency*

The model should have logically possible signs and magnitudes of parameters and predictions. It should be consistent with existing long-run equilibria between the variables.

### (ii) *Significance*

The estimated model should exhibit economic and statistical significance of its parameters, as examined through a vast array of statistical indicators (significance tests) as well as economic theory (economic significance). The model must be economically as well as statistically meaningful.

### (iii) *Data adequacy*

Various indications of adequacy should suggest that the model provides an adequate representation of the data. This is where numerous statistical tests are applied, focusing on explanatory power as well as testing the adequacy of the underlying econometric assumptions. Tests of the latter can be classified into three groups (Likelihood ratio, Wald and Lagrange multipliers). These are asymptotically equivalent, but have different small-sample properties. The choice of tests is problem dependent. However, any given equation must be tested as thoroughly as possible.

### (iv) *Encompassing*

The model should encompass the characteristics of rival models, so that the latter contain no information that would be useful to improve the preferred model. Several econometric procedures have been suggested to examine whether, in some sense, any alternative model could be expected to deliver superior properties.

### (v) *Sensitivity*

Finally, the model should not display too much sensitivity to the sample size, the variable menu, or to other equations of the system. Sensitivity tests can be applied to individual equations and full systems.

The following table summarises the methods to test model selection criteria.

**Table A3.1: Model selection criteria**

| **Model selection criteria** | | |
|---|---|---|
| *Category* | *Property* | *Examples/Methods* |
| Consistency | a) Inadmissibility | Signs, magnitude of parameters and predictions |
| | b) Poor operating characteristics | No flow equilibria<br>Inconsistent with long-run equilibrium |
| Significance | a) Economic | Quantitative impact of unacceptable magnitude |
| | b) Statistical | |
| | i) Nominal significance levels | F-tests, t-tests, Wald tests, etc |
| | ii) Optimized significance levels | Various information criteria |
| Indices of inadequacy | a) For the conditional mean | RESET, LM-test for serial correlation |
| | b) For the conditional variance | Various heteroscedasticity tests |
| | c) For normality | Jarque-Bera test |
| Encompassing | a) The mean | F-test |
| | b) The variance | t-test |
| Sensitivity | a) To sample size | Chow-test |
| | b) To variable menu | Extreme bound analysis |
| | c) To equations of model | Simulation |

*Source*: Adrian Pagan's course Economics 517 Model Selection and Evaluation, taught at the University of Rochester in the Fall 1987.

## APPENDIX 4: IMPLICATIONS OF ADDITIVITY AND SEPARABILITY ON PRODUCTION FUNCTIONAL STRUCTURES

The notion of strong separability or strong additivity has major implications for the functional structure. In particular, a production function that is strongly separable must have a Cobb-Douglas or CES structure. Tests for strong separability are therefore equivalent to tests of flexible functional forms against restricted Cobb-Douglas or CES functions.

Given a function $y = f(x_1, x_2, \ldots\ldots, x_n)$, it is strongly additive if $\frac{\partial^2 y}{\partial x_i \partial x_j} = 0, (i \neq j)$ and strongly separable (from $x_k$) if $\frac{\partial[(\partial y / \partial x_i)/(\partial y / \partial x_j)]}{\partial x_k} = 0, (i \neq j \neq k)$.

If a monotonic transformation (e.g. taking the logarithmic form) of the function satisfies the additivity condition, it is referred to as being quasi-additive (Chung 1994: 112). Christensen *et al.* (1973) and Berndt and Christensen (1973) showed that a production function is homogeneous and strongly separable if and only if it can be represented as either a Cobb-Douglas or CES production function (Allen 1997: 20). If a function is additive and homothetic, the Allen-Uzuwa partial elasticities of substitution between any pair of inputs are equal and constant (Chung 1994: 189).

The notion of weak separability, on the other hand, is important because it is a necessary condition to enable aggregation, whether inputs (in the case of a cost function) or outputs (in the case of a production function). A production function, y = f(x), is said to be weakly separable if the marginal rate of substitution between any two inputs, $x_i$ and $x_j$, belonging to the same group, $N^s$, is independent of the quantities of inputs outside of $N^s$:

$$\frac{\partial[(\partial y / \partial x_i)/(\partial y / \partial x_j)]}{\partial x_k} = 0, (i \neq j \neq k; \forall i, j \in N^s, k \in N^t, s \neq t).$$

Berndt and Christensen (1973) showed that weak separability, combined with homotheticity, are necessary and sufficient for the equality of all Allen elasticities of substitution with respect to different subsets of partition, i.e. $\sigma_{ik}^A = \sigma_{jk}^A, (\forall i, j \in N^s, k \in N^t, s \neq t)$.

Berndt and Christensen (1973) derived conditions for weak separability in the Translog function:

$$lnQ = ln\alpha_0 + \sum_{k=1} \alpha_k \ln V_k + \frac{1}{2} \sum_{k=1} \sum_{l=1} \beta_{kl} \ln V_k \ln V_l \quad .$$

The necessary conditions for separability are:

$$(\beta_{ik}\alpha_j - \beta_{jk}\alpha_i) + \sum_{m=1} (\beta_{ik}\beta_{jm} - \beta_{jk}\beta_{im}) \ln V_m = 0, \forall i, j \in N^s, k \in N^t, s \neq t; m = 1, \ldots, n.$$

They showed that there are two possible sets of conditions under which these equations would be satisfied:

First, a set of linear restrictions:

$\beta_{ik} = \beta_{jk} = 0, \forall i, j \in N^s, k \in N^t, s \neq t$ .

Alternatively, a set of non-linear restrictions:

$$\frac{\alpha_i}{\alpha_j} = \frac{\beta_{ik}}{\beta_{jk}} = \frac{\beta_{im}}{\beta_{jm}} = 0, \forall i, j \in N^s, k \in N^t, s \neq t; m = 1,\ldots,n$$

(Allen 1997: 36-37)

In the case of the two-input Translog production function:

$$lnQ = ln\alpha_0 + \alpha_1 lnV_1 + \alpha_2 lnV_2 + \beta_{11}(lnV_1)^2 + \beta_{22}(lnV_2)^2 + \beta_{12} lnV_1 lnV_2 ,$$

the assumption of a constant elasticity of substitution (i.e. assumptions of homotheticity and separability) implies the parameter restrictions of:

$$\beta_{11} = \beta_{22} = -\frac{1}{2}\beta_{12}$$

(Thomas 1993: 331).

## APPENDIX 5: A REVIEW ON PRODUCTION FUNCTIONS

The production function, in traditional theory of the firm, expresses output (Q) as a function of inputs, that is:

$$Q = Q\,(V_1; V_2; \ldots\ldots V_n), \qquad \text{(A5.1)}$$

with

Q = Output / Level of production; and
$V_I$ = i'th production factor (i = 1,2,.....n).

The variables $Q$, and $V_i$ are flow variables so that the production function above expresses a flow of output as a function of the flow of services provided by the factor inputs. All the variables are assumed to be continuously variable, infinitely divisible and the inputs are assumed to be continuously substitutable at all levels of production. For given levels of inputs ($V_i$), equation A5.1 defines a maximum possible level of output, $Q$. This means that the technical problem of how to achieve the greatest output from given levels of inputs is assumed to be solved. However, because of factor substitutability, a given output can be produced by many alternative combinations of inputs. The problem of deciding which combinations of inputs provide the given level of output at minimum cost is therefore an economic problem. The production function is thus not confined to the least cost combinations of all the inputs utilised (Heathfield 1987: 45).

A production function exhibits the following economic properties:

(i) The marginal product of each input is always positive, that is:

$$\frac{\partial Q}{\partial V_n} > 0\,. \qquad \text{(A5.2)}$$

(ii) However, although the production function must be such that the marginal products of the inputs are always positive, they have to be diminishing, illustrating the law of diminishing marginal productivity, that is:

$$\frac{\partial^2 Q}{\partial V_n^2} < 0\,. \qquad \text{(A5.3)}$$

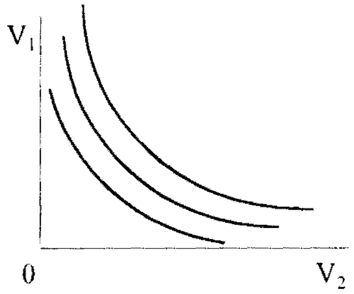
(iii) It exhibits increasing, decreasing or constant returns to scale. The returns to scale implied by a production function depend on the response of output to an equi-proportionate change in all the inputs. If equation A5.1 is homogenous of degree $n$, then depending on whether $n$ is less than, equal to, or greater than unity, equi-proportionate increases in the inputs will lead to less than proportionate, equi-proportionate, or more than proportionate increases in output. In terms of equation A5.1,

$$Q(\lambda V_n) = \lambda^n Q(V_n) \qquad \text{(A5.4)}$$

where λ is the equi-proportionate change in factor inputs. It must be remembered, however, that all production functions are not homogeneous and that some, while exhibiting increasing returns to scale at, for example, low levels of inputs, may show decreasing returns to scale at higher input and output levels.

(iv) The fact that inputs are assumed to be continuously substitutable means that there are an infinite number of possible combinations of factor inputs (implying a wide variety of alternative techniques) which may be used to produce a given output. The slope of an isoquant yields the rate at which one factor can be substituted for another without altering the level of output. (Isoquants for the two-input case are illustrated in Figure 1). The absolute value of this slope is known as the marginal (also known as technical) rate of substitution (MRS), with

**Figure 1: An isoquant map**



Source: Nicholson 1994: 317

$$MRS = -\frac{dV_1}{dV_2}. \qquad (A5.5)$$

Taking the total derivative of equation A5.5 and assuming output is constant along the isoquant, result in

$$dQ = \frac{\partial Q}{\partial V_1} dV_1 + \frac{\partial Q}{\partial V_2} dV_2 = 0. \qquad (A5.6)$$

Thus

$$MRS = -\frac{dV_1}{dV_2} = \frac{\partial Q}{\partial V_2} / \frac{\partial Q}{\partial V_1} \qquad (A5.7)$$

The MRS is therefore equal to the ratio of the two marginal products. The greater the ratio of $V_2$ inputs to $V_1$ inputs the greater the quantity of $V_2$ needed to replace one unit of $V_1$ without reducing output. This means that isoquants are convex to the origin. The more convex the isoquants, the more limited, generally, the substitution possibilities.

(v) The MRS and therefore also the degree of convexity or shape of the isoquants, influence the elasticity of substitution (σ), which serves as an independent measure of the substitution possibilities of the production function. The elasticity of substitution (σ), defined as

$$\sigma = -\frac{d(V_1/V_2)}{V_1/V_2} / \frac{d(MRS)}{MRS} \qquad (A5.8)$$

therefore measures the proportionate change in the marginal rate of technical substitution along an isoquant. Thus, if the isoquants are relatively flat (i.e. substitution is relatively easy), then movements along an isoquant (i.e. changes in the input ratio) are accompanied by little change in the MRS and hence the elasticity of substitution is high. However, if the isoquants have a pronounced curvature, implying that substitution possibilities are more limited, then $\sigma$ will be low.

Given, however, the marginal productivity conditions

$$\frac{\partial Q}{\partial V_1}=\frac{p_1}{p}\; and \;\frac{\partial Q}{\partial V_2}=\frac{p_2}{p} \qquad (A5.9)$$

with $p_1$, $p_2$ and $p$ the prices of input$_1$, input$_2$ and output respectively, the cost-minimising condition yields

$$MRS=\frac{\partial Q}{\partial V_2}/\frac{\partial Q}{\partial V_1}=\frac{p_2}{p_1}. \qquad (A5.10)$$

Redefining the elasticity of substitution ($\sigma$) as

$$\sigma=-\frac{d(V_1/V_2)}{V_1/V_2}/\frac{d(p_2/p_1)}{p_2/p_1}. \qquad (A5.11)$$

Thus $\sigma$ is given by the proportionate change in the input ratio divided by the proportionate change in the factor price ratio. When the price of input$_2$ rises relative to that of input$_1$, firms will attempt to substitute input$_1$ for input$_2$ and increase the input$_1$/input$_2$ ratio. When such substitution is possible only to a limited extent, a given proportionate change in $p_2/p_1$ will lead to only small changes in the input$_1$/ and the elasticity of substitution will be small. However, when considerable substitution is possible, $\sigma$ will be large.

At this point it is important to take note of the concept of homotheticity. A homothetic production function is a function where the technical (marginal) rate of substitution depends only on the ratio between the inputs utilised, and not on the level of total production. The slope of the curves depends only on the ratio of the inputs used, and does not depend on the distance from the origin. Isoquants representing higher levels of production are simply copies of those for lower production. Cobb-Douglas and CES production functions are homothetic functional forms. More specifically, the Cobb-Douglas technology may be defined as a homothetic, unitary elasticity of substitution production technology (Nicholson 1994: 98).

Several functional forms of production functions, which represent the technology of production, have evolved during the history of estimating production behaviour by means of mathematical and statistical modelling. Although there are many functional forms, the most commonly used are the Cobb-Douglas, constant elasticity of substitution (CES), variable elasticity of substitution (VES), Transcendental logarithmic (Translog) and the generalised Leontief functions. In order to

Solving equations A6.2 and A6.3 with respect to $x_1$ and $x_2$ gives:

$$x_1 = x_1(p_1, p_2, C) \tag{A6.4}$$
$$x_2 = x_2(p_1, p_2, C). \tag{A6.5}$$

Equations A6.4 and A6.5 can be substituted into equation A6.1 to give:

$$C = C(p_1, p_2, y). \tag{A6.6}$$

Compare equations A6.1 and A6.6. Normalising output ($y = 1$), there exits a duality between the production function and the corresponding cost function. The duality observed is called Shephard's duality (Chung 1994:201-202).

Given the relationship between a production and cost function, estimation of a production function can, therefore, be carried out directly or indirectly. The indirect approach is based upon the duality theory whereby a production function is derived from an estimated cost function. An alternative approach can be followed, by means of which the production function is estimated directly. The indirect approach is used in this study to overcome the obstacles posed by data constraints associated with the direct approach.

By evaluating different functional forms to estimate a production function and by using duality theory, the production function can be empirically estimated. This estimation will consist of an estimation of the Cobb-Douglas cost function. The cost function will then be used to derive the Cobb-Douglas production function. The validity of the Cobb-Douglas functional form, as representation of the production technology of the South African economy, is tested. The restrictive assumptions of a constant and unitary elasticity of substitution are tested by estimating a Translog production function, imposing the restrictions step-by-step and testing their validity to determine whether the Translog collapses to the Cobb-Douglas functional form.

# APPENDIX 7: AN EXPOSITION OF THE DATA UTILISED IN THE SUPPLY-SIDE MODEL

The necessary data was obtained from the South African Reserve Bank's Quarterly Bulletin, South African Statistics (SA Statistics) and the Development Bank of Southern Africa (DBSA). Annual, constant price data from 1970 to 1995 was used to estimate the parameters of the model. Where appropriate data was transformed, 1990 served as base year. Series affected by inflation were deflated by the appropriate price index.

All data, except the real capital stock[1] in the real fixed investment function and the technology index included in the cost/production function, was transformed into logarithmic form. Apart from the fact that the structure of the transcendental functional form requires that logarithmic variables be used, there are certain advantages to the estimation of logarithmic models. Logarithmic models transform non-linear models (relationships) into linear form, which allows the use of linear estimation procedures. The estimated regressors are coefficients of elasticity (partial multipliers), rather than coefficients of marginal effects. Logarithmic transformations also help to overcome problems due to non-stationarity.

The following time series had to be derived for the variables defined in the various theoretical models:

(i) *Real gross domestic cost of production at factor cost*

An investigation of the South African input-output table concluded that only 5 percent of the gross operating surplus, published by the South African Reserve Bank, relates to production (capital and entrepreneurial) costs. The definition for the real gross domestic cost of production at factor cost (c) can therefore be expressed as:

$$c = \frac{labour\ \ remuneration\ + \ 0.05 * gross\ \ operating\ \ surplus}{production\ \ price\ \ index}$$

with the series for nominal labour remuneration, nominal gross operating surplus and the production price index obtained from the SARB Quarterly Bulletin.

(ii) *Cost of labour*

The cost of labour represents the nominal wage bill of the country and is calculated by adding the wages of skilled workers and unskilled workers in South Africa. Unskilled workers are classified as those workers without matriculation or an equivalent

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[1] Investment decisions are made with the purpose of profit maximisation, i.e. investment decisions (the extent to which capital stock needs to be increased) are made to obtain an optimal level of capital, i.e. the point where the marginal product of capital ($\Delta Y/\Delta K$) equals real user-cost-of-capital. Therefore, in the empirical estimation of an investment function, although the natural logarithms of all relevant variables are used, capital stock must be used in its level-form. It implies that the relative change in investment is not dependent on the relative change in capital stock, but on its absolute level. Remember that the logarithmic form of any variable represents the relative change of that variable over time.

qualification. Skilled workers are classified as those workers with matriculation or a higher qualification. The cost of labour ($\ell$) can be represented by the following expression:

$$\ell = \frac{(wage\ \ rate\ \ of\ \ unskilled\ \ labour\ + \ wage\ \ rate\ \ of\ \ skilled\ \ labour)}{production\ \ price\ \ index}$$

Data for skilled and unskilled wage rates was obtained from the Development Bank of South Africa.

(iii) *User-cost-of-capital*

While the cost of labour can be calculated by adding directly observable series, the cost of capital has to be inferred. The neo-classical approach by Hall and Jorgenson's (1967) is used to derive a measure for the user-cost-of-capital ($r$). See Appendix 14 for a discussion of the theory. The measure for user-cost-of-capital ($r$) can be expressed as:

$$r = price\ of\ capital\left(\frac{(interest\ rate)-(inflation\ \ rate)+(rate\ of\ depreciation)}{1-tax\ ratio}\right)$$

with the price of capital approximated by the deflator for gross domestic fixed investment; the production price index is utilised as the appropriate inflation rate; the rate of depreciation is set at 20 percent per annum[2], and the tax ratio is defined as the direct tax rate of incorporated business enterprises relative to the gross domestic product at factor cost.

(iv) *Technical progress*

Instead of resorting to either the Hicks-neutral ($A = A_0$) or the more commonly used, although still restrictive, Harrod-neutral (labour-augmenting) technical progress specifications, an attempt was made to at least partially endogenise technical progress in the cost/production relation. See Appendix 12 for a discussion on the various kinds of technical progress. A technological index is included in the function to represent technical progress. With the construction of the index, recognition is given to work done by Budd and Hobbis (1989) by capturing the role of imported technical innovation, proxied by foreign investment relative to domestic investment. The index is extended to allow for human capital augmentation (through the inclusion of an education index), labour augmentation (through the inclusion of a productivity index) and exogenous factors such as once-off innovations. A time trend is also included to allow for a degree of neutrality.

The technological index ($t$) can therefore be represented by the following expression:

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[2] This rate is assumed to be 20 percent, based on the fact that firms write their capital stock off over a period of usually 5 years in an attempt to optimise the tax deductions based on the depreciation of capital goods.

$$t = \left(\frac{education\ \ index}{1.51}\right)*0.15 + \left(\frac{productivity}{100}\right)*0.15 + \left(\frac{relative\ \ foreign\ \ investment}{1.805383}\right)*0.05 + \left(\frac{time + technical\ \ innovation}{1}\right)*0.65$$

(v) *Financing of gross domestic investment*

The financial constraint variable (*fc*), i.e. the "financing of gross domestic investment" according to the system of national accounts, enters the system of equations as an identity, adding together private savings (sp), government savings (sg), corporate savings (sc), replacement investment or depreciation in real capital stock (*depr*), net foreign capital flow (*capflow*) and the change in gold and other foreign reserves (*reserv*):

$$fc = sp + sg + depr + sc + capflow + reserv\ .$$

However, since the financing of gross domestic investment equals total gross domestic investment in a general equilibrium framework such as the system of national accounts, data series for both these entities may be utilised. These series are only published in nominal terms and had to be deflated with the production price index to obtain the constant price values.

An explanatory list of all the variables encountered in the long-run cointegration relationship and the error correction model (ECM) is presented in Appendix 8.

Tests for non-stationarity (the presence of a unit root) were subsequently performed. Inferences concerning the stationarity properties of data were based on a range of evidence, of which the formal ADF test is merely one component. Economic theory, structural properties of the data, *a priori* information concerning political and other exogenous shocks to the economy over the sample period (more often than not resulting in structural breaks), data plots (Appendix 9), residual plots, plots of the autocorrelation function and spectral analysis all form part of the evidence used to draw conclusions on the stationarity of the data. This comprehensive set of inference guidelines prompted the conclusion that all relevant variables are integrated of order 1, i.e. stationary in first differences.

The results of the Augmented Dickey-Fuller tests as well as an exposition of the testing procedure are reported in Appendix 17.

Apart from the long-run explanatory variables also included in the ECM, a few dummy variables were included in several individual models to avoid a bias in the estimation which may arise if significant events in the South African economy are ignored. These variables smooth out the significant and substantial effects of the following incidents:

(i) *Economic sanctions (sanction_dum)*

During the latter half of the eighties and the early nineties, South Africa was heavily affected by sanctions as a result of growing international discontent with the country's political dispensation. Sanctions had an adverse effect on the domestic cost of production. A higher demand for local inputs increased the prices of these production factors, while imported inputs became increasingly scarce and expensive. It also affected production directly in that local producers no longer had access to several, more productive imported inputs.

(ii) *Drought (drought_dum)*

South Africa experienced a severe drought in 1983 and a prolonged one from 1992 to 1995. These droughts had a direct, negative effect on agricultural production and increased the production cost of the secondary industries dependent on agricultural inputs.

(iii) *IMF support (imf_dum)*

South Africa benefited from IMF assistance from 1975 to 1977. These contributions stimulated the demand side of the economy and, at least in theory, also production. These funds were also used to assist production in South Africa directly

(iv) *Opec oil shocks (opec_dum)*

The oil price shocks of the 1970s resulted in dramatic increases in domestic fuel prices and as a consequence activated a chain of price and cost surges in the economy. The economy in general and firms in particular could not escape the negative effects of increasing costs, decreasing profits and savings, and slumping economic growth.

(v) *Emigration of skilled labour (braindrain_dum)*

International sanctions and disinvestment during the mid-1980s and early 1990s, coupled with a new political dispensation endorsing labour acts of affirmative action, created an unstable and unprofitable environment for especially skilled labour in South Africa. This led to a substantial outflow of highly qualified and professional labour which the domestic economy is in serious need of.

## APPENDIX 8: VARIABLE LIST

| **series** | **natural logarithms** | **Variable names** | **Data source** |
|---|---|---|---|
| bbb_cp | | Gross domestic expenditure at current prices | KB6012jj |
| bbp_90p | ln_bbp_90p | Gross domestic product at market prices at constant 1990 prices | KB6006yj |
| bbp_cp | | Gross domestic product at market prices at current prices | KB6006jj |
| bbp_min_90p | ln_bbp_min_90p | Gross domestic product : mining and quarrying at constant 1990 prices | KB6032yj |
| bbpfact_90p | ln_bbpfact_90p | Gross domestic product at factor cost at constant 1990 prices | KB6003yj |
| bbpfact_cp | | Gross domestic product at factor cost at current prices | KB6003jj |
| bpppot_90p | ln_bbppot_90p | Potential gross domestic product at factor cost at constant 1990 prices | Solved by production function |
| braindrain_dum | | Dummy: emigration of skilled labour | *na* |
| c90p_lrem_gos5 | ln_c90p_lrem5 | Gross domestic cost of production at constant 1990 prices | cost_lrem_gos95/ppi |
| cost_lrem_gos5 | | Gross domestic cost of production at current prices | (lab_rem - 0.05*gos_cp) |
| crime_index | ln_crimeind | Crime index | crime incidents/total_pop/1990-number/1000 (South African survey) |
| cu | ln_cu | Percentage utilisation of production capacity : manufacturing sector | KB7078jj |
| de_cp | | Provision for depreciation at current prices | KB6002jj |
| depend_rat | | Dependency ratio | (total_pop - s*1000)/(s*1000) |
| dipi | | Deflator : gross domestic fixed investment | (if_cp/if_r_sarb) |
| dirinves_r | ln_dirinves_r | Total foreign direct investment at constant 1990 prices | dirinvest/ppi |
| dirinvest | | Total foreign direct investment at current prices | KB5162jj |
| drought_dum | | Dummy: periods of severe drought | *na* |
| educ_index | ln_educind | Education index | ((matrics passed/total_pop/1990-number)*100) |
| empl_rat | ln_empl_rat | Employment ratio | n/s |
| empl_rat_s | ln_empl_rat_s | Employment ratio : skilled labour sector | n_s/s_s |
| empl_rat_u | ln_empl_rat_u | Employment ratio : unskilled labour sector | n_u/s_u |
| energy_ind | ln_energy_ind | Energy index = electricity index | KB7068jj |
| excess_dem_cp | ln_exces_dem_cp | Excess demand at current prices | bbb_cp/bbp_cp |
| exchange_rate | | Dollar/rand exchange rate | 100/r_$ |

| series | natural logarithms | Variable names | Data source |
|---|---|---|---|
| fincond_cp | ln_fincond_cp | Financing of gross domestic investment at current prices | (sp_cp + sc_cp + sg_cp + de_cp + netcapfl + gold_reserv_cp) = totdomi_cp |
| fincond_ppi | ln_fincond_ppi | Financing of gross domestic investment at constant 1990 prices : PPI deflated | (sp_cp + sc_cp + sg_cp + de_cp - netcapfl - gold_reserv_cp)/ppi = totdomi_cp/ppi |
| gold_reserv_cp | | Change in gold and other foreign reserves at current prices | KB6205jj |
| gos_cp | | Gross operating surplus at current prices | KB6212jj |
| gostc_cp | ln_gostc_cp | After-taxed gross operating surplus at current prices | gos_cp – tc_cp |
| gprys_$ | ln_gprys_$ | London gold price in US dollar | KB5357jj*100 |
| gprys_r | ln_gprys_r | London gold price in SA rand | KB5356jj *100 (gprys_$*r_$) |
| h_transf_receiv | ln_h_transf | Net current transfers received by households from government, incorporated business enterprises and the rest of the world | h_tran_rec_c (KB6231jj)+ h_tran_rec_g (KB6257jj) + h_tran_rec_w (KB6243jj) - h_tran_pay_g (KB6252jj) - h_tran_pay_w (KB6248jj) |
| health_index | ln_healthind | Health index | (number of medical practisions / total_pop)/1990-number/1000 (SA Statistics, www.statssa.gov.za/ publications/ statistics_in_brief/ health) |
| if | ln_if | Gross domestic fixed investment at constant 1990 prices | if_cp/ppi |
| if_cp | | Gross domestic fixed investment at current prices | KB6009jj |
| if_r_sarb | | Gross domestic fixed investment at constant 1990 prices | KB6009yj |
| imf_dum | | Dummy: IMF contributions and loans | *na* |
| income_index | ln_incomeind | Income index : per capita personal disposable income at constant 1990 prices | KB6272yj |
| indinves_r | ln_indinves_r | Total foreign non-direct investment at constant 1990 prices | indinvest/ppi |
| indinvest | | Total foreign non-direct investment at current prices | KB5180jj |
| intern_comp | ln_intern_comp | International competitiveness of South African economy | domestic export prices relative to world export prices (IFS) |
| intern_posind | ln_interposind | International position index | ((exchange_rate/1990-number)*0.2 + (intern_comp/1990-number)*0.05 + (rel_diri_r/1990-number)*0.5 + (rel_indi_r/1990-number)*0.2 + (worldshare/1990-number)*0.05) |
| inv_cp | | Total change in inventories at current prices | KB6010jj |
| kap_lab_rat | ln_kap_lab_rat | Capital-labour ratio | kap_r/(lab_rem_cp/ppi)*1000 |

| **series** | **natural logarithms** | **Variable names** | **Data source** |
|---|---|---|---|
| kap_r | ln_kap_r | Capital stock at constant 1990 prices | KB6149yj |
| lab_rem_cp | | Remuneration of employees at current prices | KB6000jj |
| n | ln_n | Demand for labour (Employment) | SA Statistics, www.statssa.gov.za/ publications/ statistics_in_brief/ labour *or*<br>DBSA: Development Information Business Unit – standardised employment series |
| n_diff | | Difference between employment figures from SA Statistics and employment figures from sarb | n - n_sarb |
| n_ind_sarb | | Demand for labour in noon-agricultural sectors : 1990 = 100 | KB7009jj |
| n_informal | ln_n_informal | Labour participants in the informal sector | DBSA (n_informal (DBSA) + n (SA Statistics) + unempl (SA Statistics)= s (SA Statistics)) |
| n_pot | ln_n_pot | Potential demand for labour (employment) | (s_smooth*(1 - nawru_hpf)) |
| n_s | ln_ns | Demand for skilled labour (skilled employment) | (percentages of DBSA applied to n of SA Statistics)/100 |
| n_sarb | | Demand for labour (excluding agricultural sector) | (n_ind_sarb)*1990-number/100 000 000 |
| n_u | ln_nu | Demand for unskilled labour (unskilled employment) | (percentages of DBSA applied to n of SA Statistics)/100 |
| nawru | | Non-accelerating wage rate of unemployment | unempl_rat - (d(unempl_rat)/d$^3$(ln_wtot_vpi))*d$^2$(ln_wtot_vpi) |
| nawru_hpf | | Hodrick-Prescott filter used to smooth nawru | *na* |
| netcapfl | | Net capital flow at current prices | KB5024jj |
| netcapfl_r | | Net capital flow at constant 1990 prices | netcapfl/ppi |
| opec_dum | | Dummy: OPEC oil price shocks | *na* |
| p_manuf | ln_p_manuf | Production prices : manufacturing (1990 = 100) | KB7046jj/63.6 |
| pk | | Price of capital | KB2004jj (escom stock) |
| pk_ppi | | Price of capital at constant 1990 prices : PPI deflated | pk - ppigrowth |
| pnettx | | Deflator : net indirect taxes | (txind - subs)/(bbp_90p - bbpfact_90p) (vpigrowth in future) |
| ppi | ln_ppi | Production prices : total (1990 = 100) | KB7048jj/65.4 |

| **series** | **natural logarithms** | **Variable names** | **Data source** |
|---|---|---|---|
| ppigrowth | ln_ppigrowth | Production inflation | ((ppi - ppi(-1)/ppi(-1))*100 |
| prime_rate | ln_prime_rate | Predominant prime overdraft rate of clearing banks at current prices | KB1403g |
| product_sarb | ln_product_sarb | Labour productivity according to SARB statistics, excluding agricultural sector | (bbp_90p/n_sarb)/1990-number |
| product | ln_product | Labour productivity | (bbp_90p/n/1990-number |
| px | ln_px | Deflator : exports of goods and non-factor services | xgnfd_cp/xgnfd_90p |
| px_sa_$ | | Deflator : South African exports in US dollar prices | IFS: 19974...DZF; WT028 |
| px_world_$ | | Deflator : World exports in US dollar prices | IFS: 00174...DZF; WT028 |
| pz | ln_pz | Deflator : imports of goods and non-factor services | zgnfd_cp/zgnfd_90p |
| pz_$ | ln_pz$ | Import prices in US dollar | pz*exchange_rate |
| r_$ | ln_r$ | Rand-dollar exchange rate | KB5339jj |
| rel_diri_r | ln_rel_diri_r | Direct foreign investment relative to gross domestic investment at constant prices | (dirinvest/if_cp)/ppi |
| rel_i_r | ln_rel_i_r | Total foreign investment relative to gross domestic investment at constant 1990 prices | ((dirinvest + indinvest)/if_cp)/ppi |
| rel_indi_r | ln_rel_indi_r | Indirect foreign investment relative to gross domestic investment at constant 1990 prices | (indinvest/if_cp)/ppi |
| rel_wscost_ucc | ln_rel_wscost_u | Skilled labour cost relative to user-cost-of-capital | ws_cost_ppi/ucc2_90p |
| rel_wsu | ln_rel_wsu | Skilled wages relative to unskilled wages | w_s/w_u |
| rel_wsu_rat | ln_rel_wsu_rat | Skilled wage rate relative to the unskilled wage rate | (w_s/n_s)/(w_u/n_u) |
| rel_wucost_ucc | ln_rel_wucost_u | Unskilled labour cost relative to user-cost-of-capital | wu_cost_ppi/ucc2_90p |
| s | ln_s | Total labour supply | SA Statistics, www.statssa.gov.za/ publications/ statistics_in_brief/ labour |
| s_rat | ln_srat | Total labour supply ratio | s/total_pop |
| s_rat_hpf | | Hodrick-Prescott filter used to smooth total supply of labour | *na* |
| s_s | ln_ss | Skilled labour supply | SA Statistics (www.statssa.gov.za/ publications/ statistics_in_brief/ labour) data for s, but ratio according to DBSA |
| s_smooth | | Smoothed labour supply | *na* |

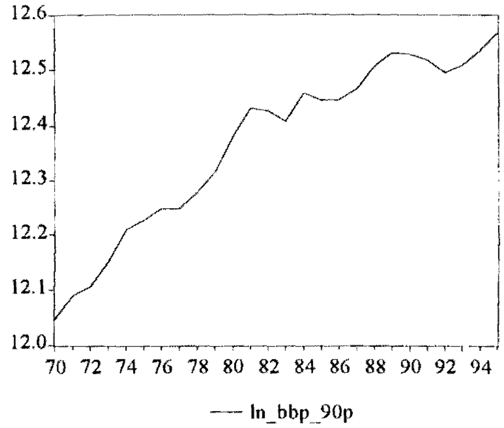
| **series** | **natural logarithms** | **Variable names** | **Data source** |
|---|---|---|---|
| s_u | ln_su | Unskilled labour supply | SA Statistics (www.statssa.gov.za/ publications/ statistics_in_brief/ labour) data for s, but ratio according to DBSA |
| sanction_dum | | Dummy : sanctions | *na* |
| sc_cp | ln_sc_cp | Corporate saving at current prices | KB6201jj |
| sc_cp_rat | | Corporate savings rate at current prices | sc_cp/bbp_cp |
| sg_cp | | Saving of the general government at current prices | KB6202jj |
| share_ns | | Demand for labour share of skilled workers | OHS: Workers by level of education (grade 10/NTC I + grade 11/NTC II + grade 12/NTC III + diplomas + degrees), SA Statistics (www.statssa.gov.za/ publications/ statistics_in_brief/ labour) |
| share_nu | | Demand for labour share of unskilled workers | (1 – share_ns) |
| share_ss | | Labour supply share of skilled workers | OHS: Level of education (grade 10/NTC I + grade 11/NTC II + grade 12/NTC III + diplomas + degrees), SA Statistics (www.statssa.gov.za/ publications/ statistics_in_brief/ labour) |
| share_su | | Labour supply share of unskilled workers | (1 – share_ss) |
| share_ws | | Wage share of skilled labour | DBSA: high level + mid level |
| share_wu | | Wage share of unskilled labour | DBSA: semi-level + unskilled |
| soc_index | ln_socind | Socio-economic index | (educ_index/1990-number)*0.20 + (energy_ind/1990-number)*0.15 + (health_index/1990-number)*0.15 + (1/(crime_index/1990-number))*0.1 + (income_index/1990-number)*0.2 + (h_transf_receiv/1990-number)*0.1 + (unpl_ben/1990-number)*0.1 |
| sp_cp | | Personal saving at current prices | KB6200jj |
| ss_rat | ln_ssrat | Skilled labour supply ratio | s_s/s |
| subs | | Subsidies at current prices | KB6005jj |
| tc_cp | | Direct taxes of incorporated business enterprises at current prices | KB6230jj |
| tc_ppi | | Direct taxes of incorporated business enterprises at constant 1990 prices: PPI deflated | tc_cp/ppi |

| series | natural logarithms | Variable names | Data source |
|---|---|---|---|
| tc_rate_cp | | Direct tax rate of incorporated business enterprises at current prices | tc_cp/bbpfact_cp |
| tc_rate_ppi | ln_tcrate_ppi | Direct tax rate of incorporated business enterprises at constant 1990 prices : PPI deflated | tc_ppi/bbpfact_90p |
| tecno_hpf | | Hodrick-Prescott filter used to smooth technology index | *na* |
| tecno_index | | Technology index | (educ_index/1990-number)*0.15 + (product/1990-number)*0.15 + (rel_i_r/1990-number)*0.05 + (time/10 + tecno_innov)*0.65 |
| tecno_innov | | Dummy: technology innovation | *na* |
| total_pop | ln_total_pop | Total population | SA Statistics, www.statssa.gov.za/ publications/ statistics_in_brief/ demography |
| totdomi_cp | | Gross domestic investment at current prices | KB6180jj |
| txind | ln_txind | Indirect taxes at current prices | KB6004jj |
| ucc2_90p | ln_ucc2_90p | User-cost-of-capital at constant 1990 prices | dipi*((pk_ppi/100) + 0.2)/(1 - tc_rate_ppi) |
| ucc2_nom | ln_ucc2_nom | User-cost-of-capital at current prices | dipi*((pk/100) + 0.2)/(1 - tc_rate_cp) |
| unempl | | Total unemployment | unempl_rat*s |
| unempl_rat | ln_unempl_rat | Unemployment rate | SA Statistics, www.statssa.gov.za/ publications/ statistics_in_brief/ labour |
| unempl_rat_s | ln_unemplrat_s | Unemployment rate : skilled labour | unempl_s/n_s |
| unempl_rat_u | ln_unemplrat_u | Unemployment rate : unskilled labour | unempl_u/n_u |
| unempl_s | | Skilled labour force unemployment | s_s – n_s |
| unempl_u | | Unskilled labour force unemployment | s_u – n_u |
| union_members | | Union members | ILO Review *or* NMC, Department of labour *or* South African Institute of Race Relations Survey |
| union_mil | ln_unionmil | Union militancy | union_work_lost/n |
| union_power | ln_unionpower | Union power | union_members/n |
| union_pres_ind | ln_uniopresind | Union pressure index | ((union_power/1990-number)*0.60 + (union_mil/1990-number)*0.10 + (depend_rat/1990-number)*0.30) |
| union_work_lost | | Strikes and stoppages : man-days lost | KB7018jj |

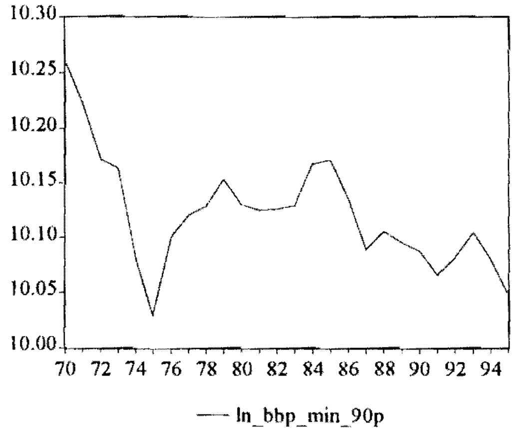
| **series** | **natural logarithms** | **Variable names** | **Data source** |
|---|---|---|---|
| unpl_ben | | Unemployment benefit | SA Statistics : SA labour statistics, table 4.2.1.1 (SA Statistics, www.statssa.gov.za/ publications/ statistics_in_brief/ labour) |
| vpi | ln_vpi | Consumer price index | KB7032jj |
| vpigrowth | ln_vpigrowth | Consumption inflation | (vpi - vpi(-1))/vpi(-1)*100 |
| w_cost_cp | | Cost of labour at current prices | ((wtot_rate)*(1 + 0.16))/(1 - (tc_rate_cp)*(1 + 0.3))<br>*with*<br>*pension contribution = 0.06 (6%)*<br>*medical contribution = 0.1 (10%)*<br>*non-wage contributions = medical + pension = 0.16 (16%)*<br>*corporate income tax rate = 0.3 (30%)* |
| w_prod | ln_w_prod | Wage productivity | (w_tot/product)/100 |
| w_s | | Skilled wages at current prices | w_tot*share_ws |
| w_tot | | Total wages at current prices | (w_s + w_u) *or* KB6000jj |
| w_u | | Unskilled wages at current prices | w_tot*share_wu |
| worldshare | ln_worldshare | World market share | (x_sa_$/x_world_$)/10 (IFS) |
| ws_cost_cp | | Cost of skilled labour at current prices | w_cost_cp*share_ws |
| ws_cost_ppi | ln_wscost_ppi | Cost of skilled labour at constant 1990 prices : PPI deflated | ws_cost_cp/ppi |
| ws_rate | ln_ws_rate | Skilled wage rate at current prices | w_s/n_s |
| ws_vpi | | Skilled wages at constant 1990 prices : CPI deflated | w_s/vpi |
| ws_vpi_rate | ln_wsvpi_rat | Skilled wage rate at constant 1990 prices : CPI deflated | ws_vpi/n_s |
| wtot_ppi_rat | ln_wtot_ppi_rat | Total wage rate at constant 1990 prices : PPI deflated | (wtot_rate/ppi)/n |
| wtot_rate | ln_wtot_rate | Total wage rate at current prices | w_tot/n |
| wtot_vpi | ln_wtot_vpi | Total wages at constant 1990 prices : CPI deflated | (w_tot)/vpi |
| wtot_vpi_rat | ln_wtot_vpi_rat | Total wage rate at constant 1990 prices : CPI deflated | (wtot_rate/vpi)/n |
| wu_cost_cp | | Cost of unskilled labour at current prices | w_cost_cp*share_wu |
| wu_cost_ppi | ln_wucost_ppi | Cost of unskilled labour at constant 1990 prices : PPI deflated | wu_cost_cp/ppi |
| wu_ppi | | Unskilled wages at constant 1990 prices : PPI deflated | w_u/ppi |

| **series** | **natural logarithms** | **Variable names** | **Data source** |
|---|---|---|---|
| wu_ppi_rate | ln_wuppi_rat | Unskilled wage rate at constant 1990 prices : PPI deflated | wu_ppi/n_u |
| wu_rate | | Unskilled wage rate at current prices | w_u/n_u |
| wu_vpi | | Unskilled wages at constant 1990 prices : CPI deflated | w_u/vpi |
| wu_vpi_rate | ln_wuvpi_rat | Unskilled wage rate at constant 1990 prices : CPI deflated | wu_vpi/n_u |
| x_sa_$ | | South African exports at US dollar prices | IFS: 19970...DZF; WT025 |
| x_world_$ | | World exports at US dollar prices | IFS: 00170...DZF; WT025 |
| xgnfd_90p | | Exports of goods and non-factor services at constant 1990 prices | KB6013yj |
| xgnfd_cp | | Exports of goods and non-factor services at current prices | KB6013jj |
| xgoud_cp | | Net gold exports at current prices | KB5001jj |
| xgoud_ppi | ln_xgoud_ppi | Net gold exports at constant 1990 prices : PPI deflated | xgoud_cp/ppi |
| xgoud_px | ln_xgoud_px | Net gold exports at constant 1990 prices : deflated by export prices | xgoud_cp/px |
| zgnfd_90p | | Imports of goods and non-factor services at constant 1990 prices | KB6014yj |
| zgnfd_cp | | Imports of goods and non-factor services at current prices | KB6014jj |

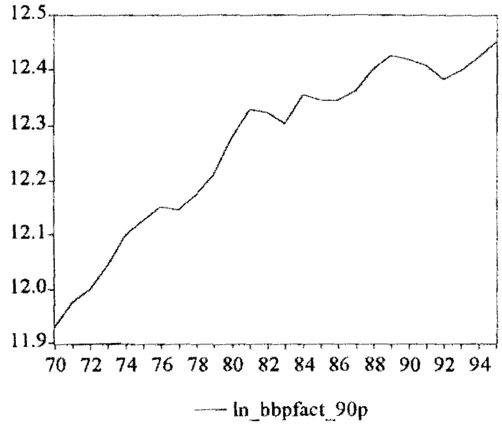
# APPENDIX 9: GRAPHICAL REPRESENTATION OF THE DATA



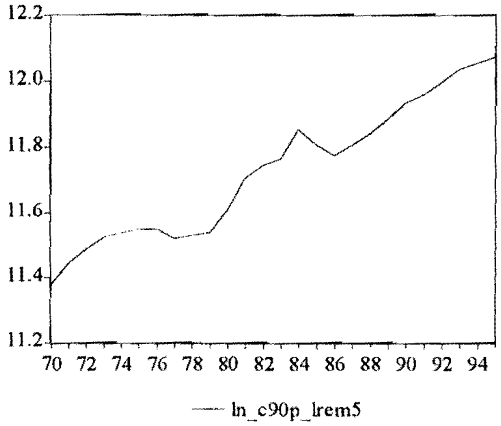
Real GDP at market prices



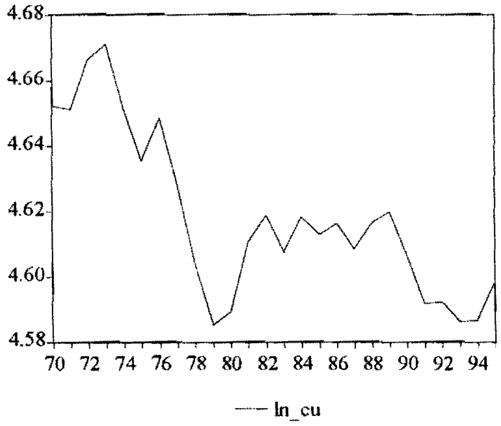
Real GDP: mining and quarrying



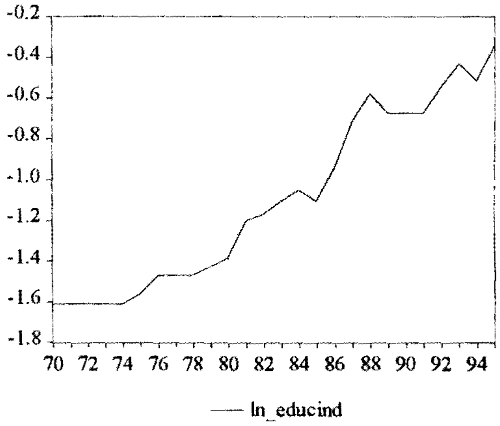
Real GDP at factor cost



Real gross domestic cost of production

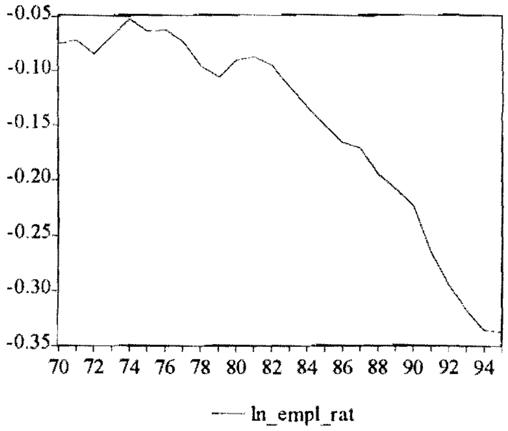


Capacity utilisation

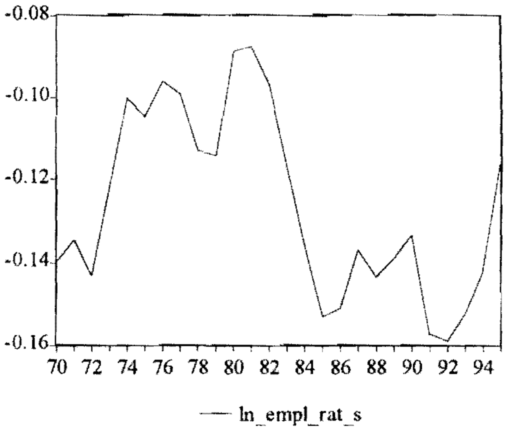


Education index

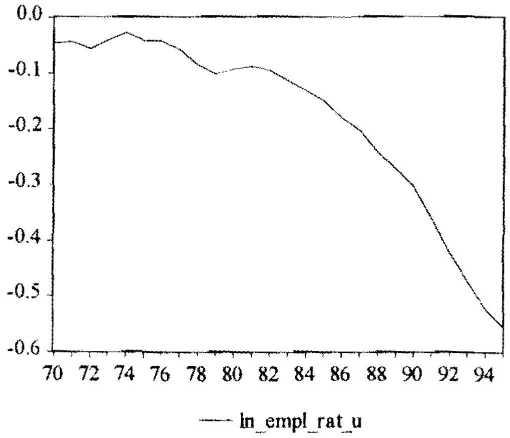
Employment ratio



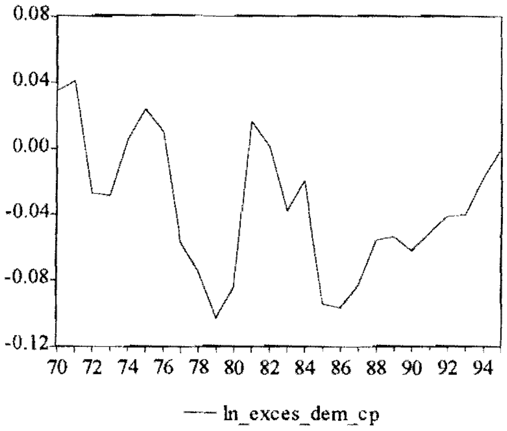
Skilled employment ratio



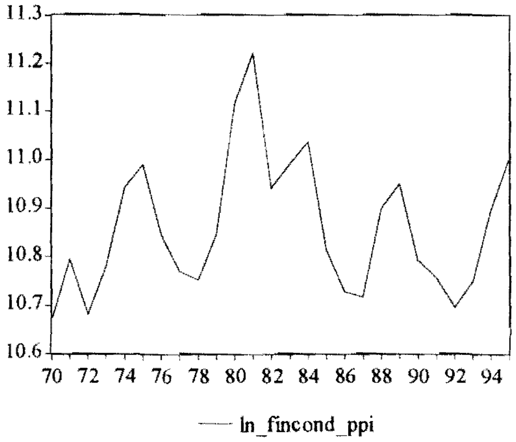
Unskilled employment ratio



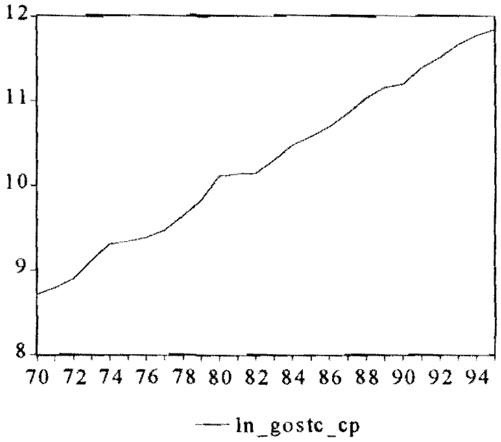
Nominal excess demand



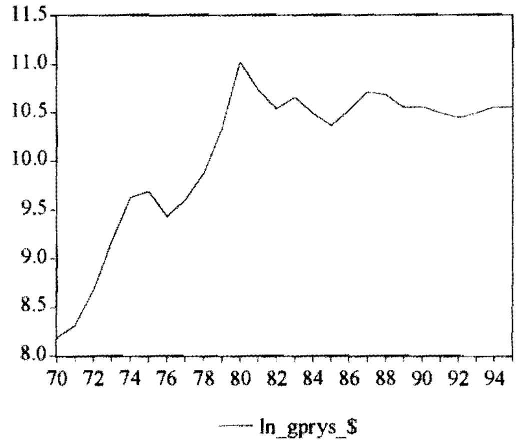
Real financing of gross domestic investment



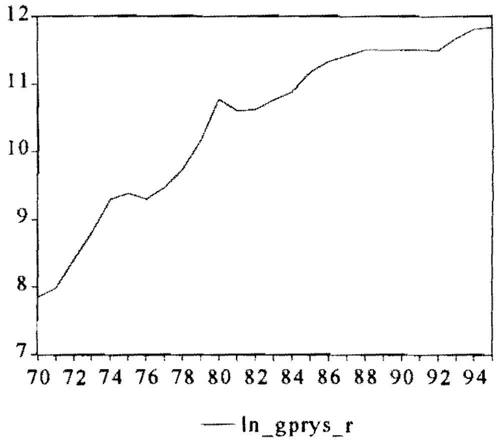
Nominal after-taxed operating surplus



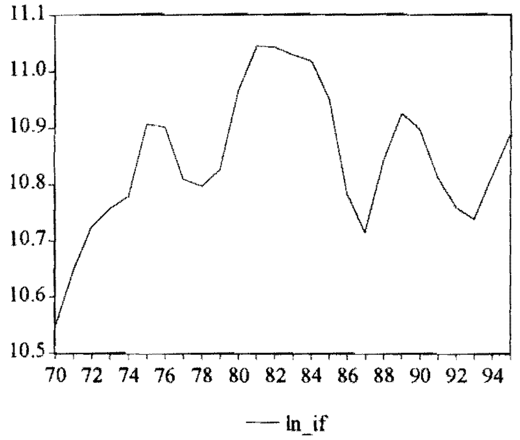
Gold price in US dollar



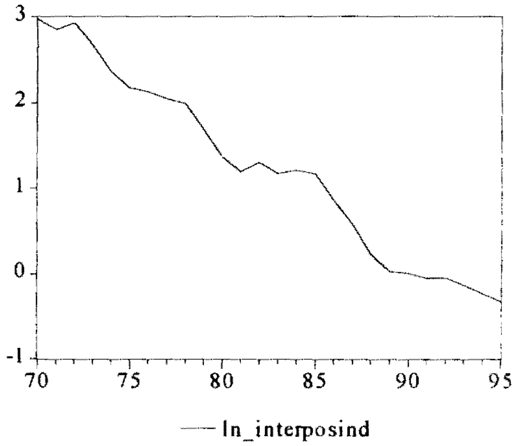
Gold price in SA rand



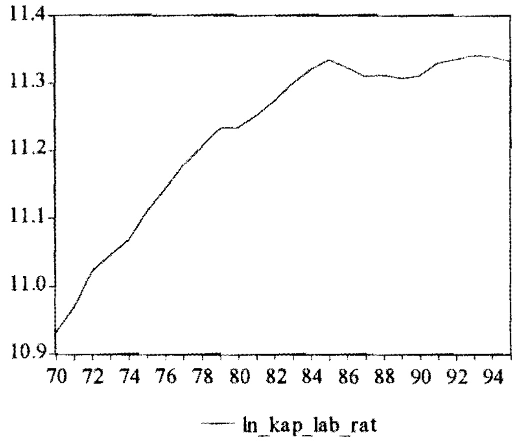
Real domestic fixed investment



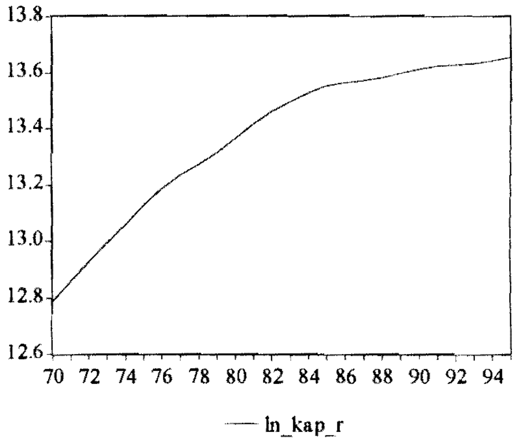
International position index



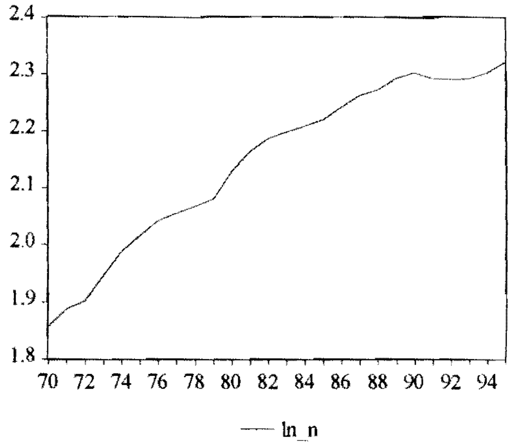
Capital-labour ratio



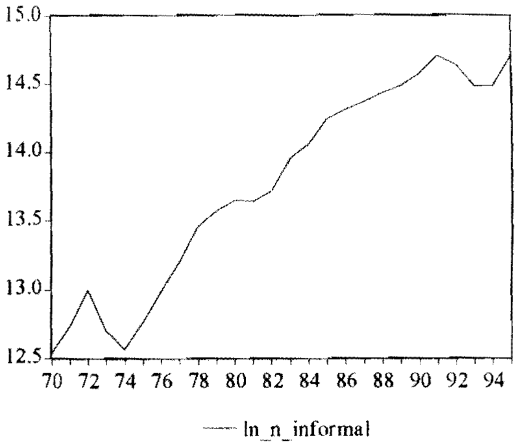
Real capital stock



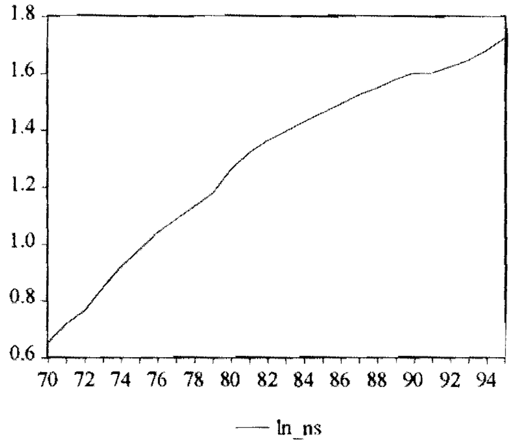
Demand for labour



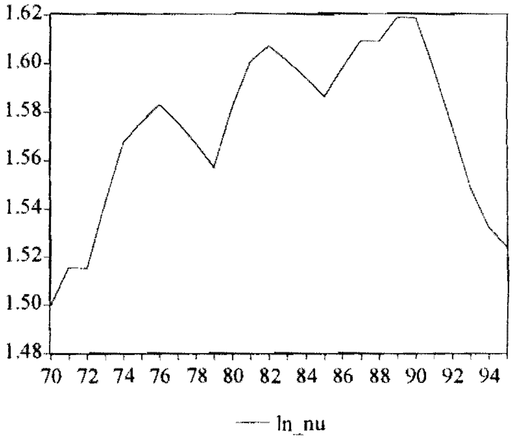
Labour participants in the informal sector



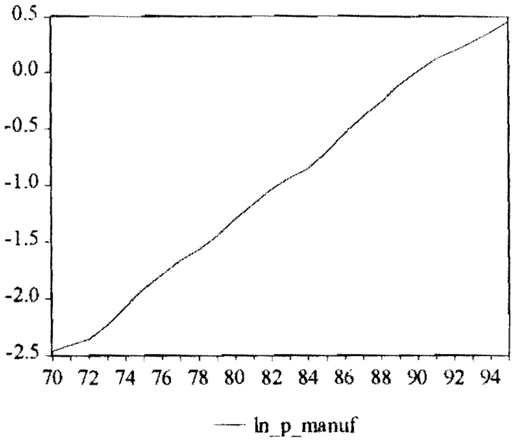
Demand for skilled labour



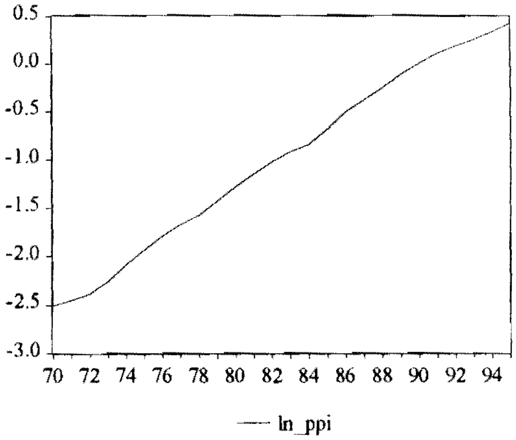
Demand for unskilled labour



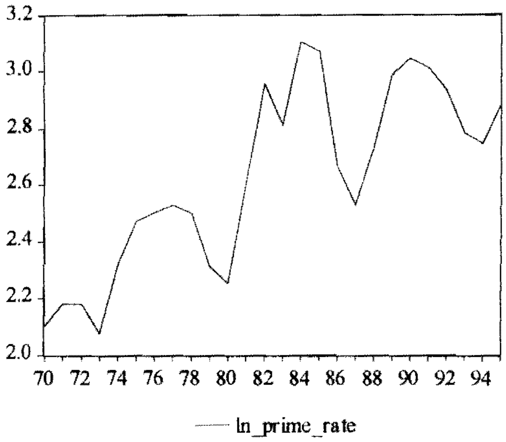
Production prices: manufacturing



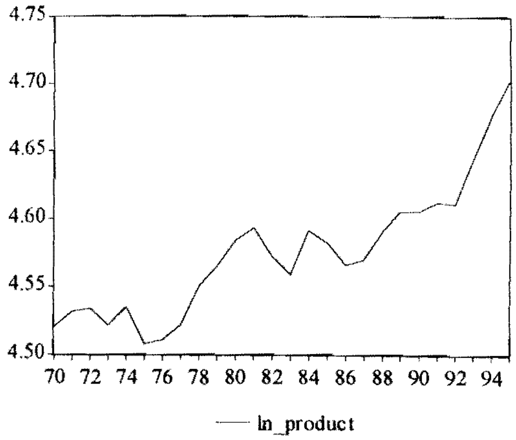
Production price index



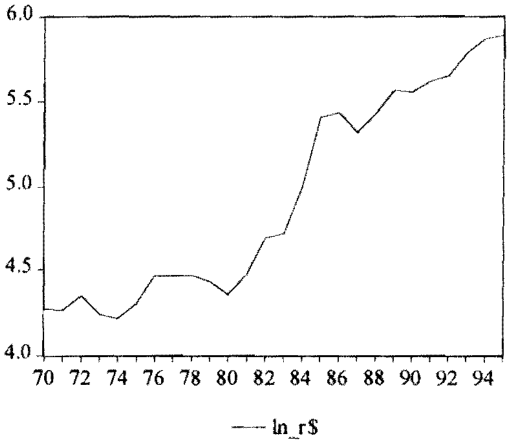
Predominant prime overdraft rate of clearing banks



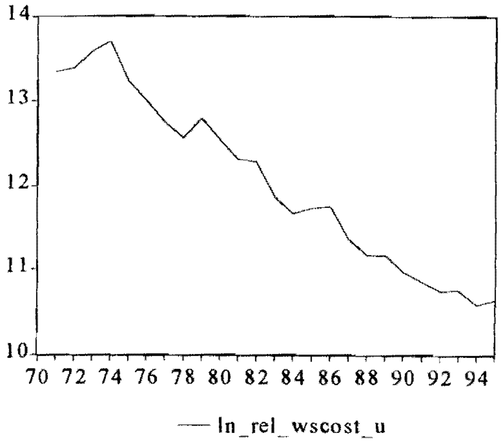
Productivity



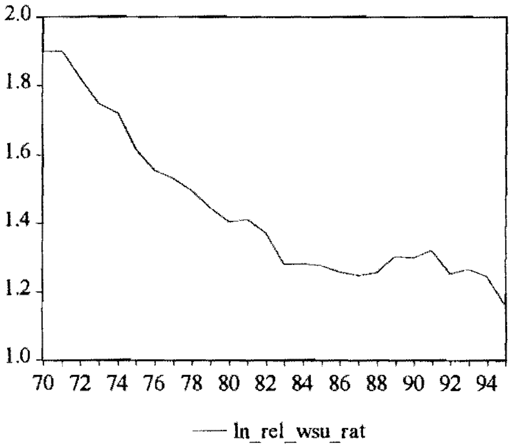
Rand-dollar exchange rate



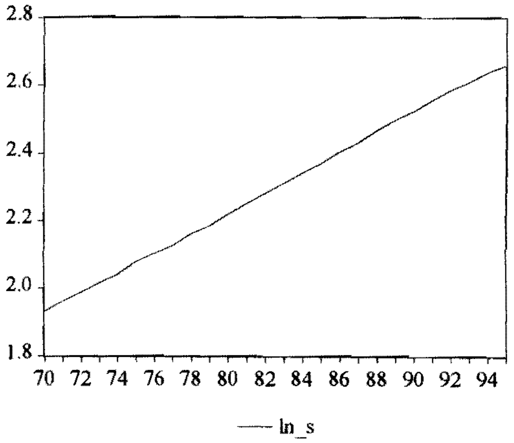
Skilled labour cost relative to user-cost-of-capital

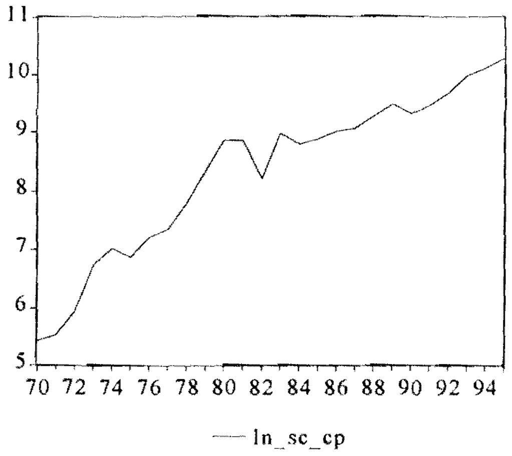


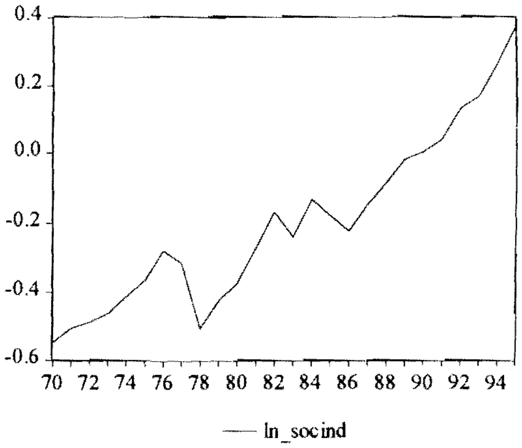
Skilled/Unskilled wate rate

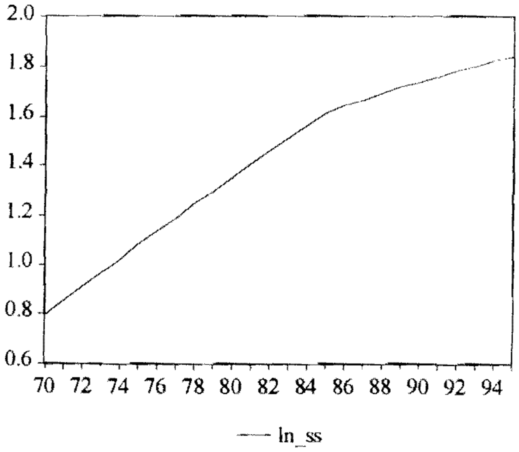


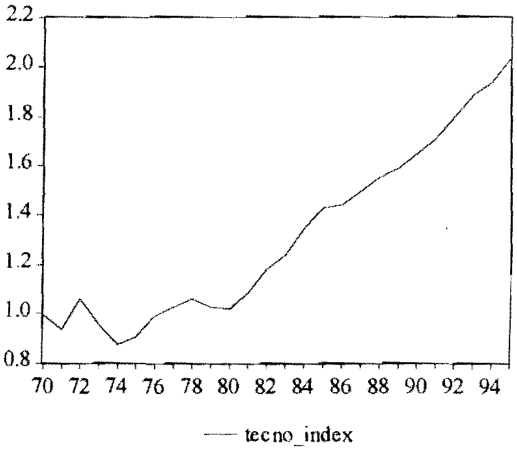
Labour supply

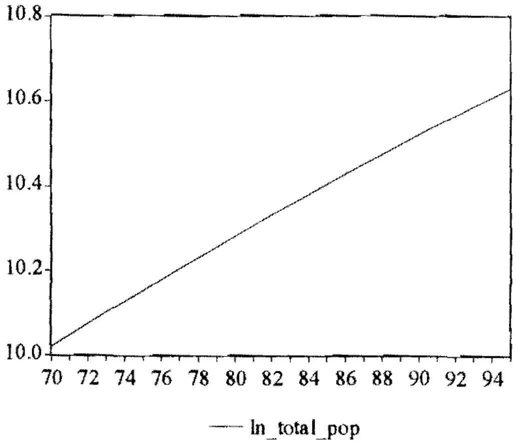


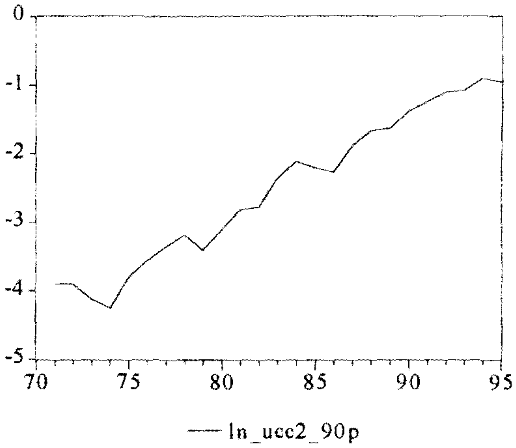

Nominal corporate savings

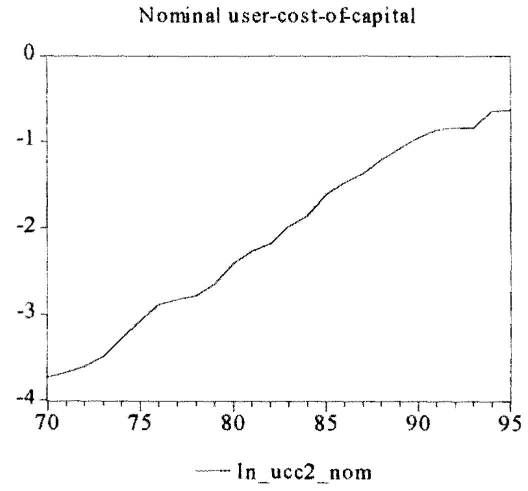

Socio-economic index

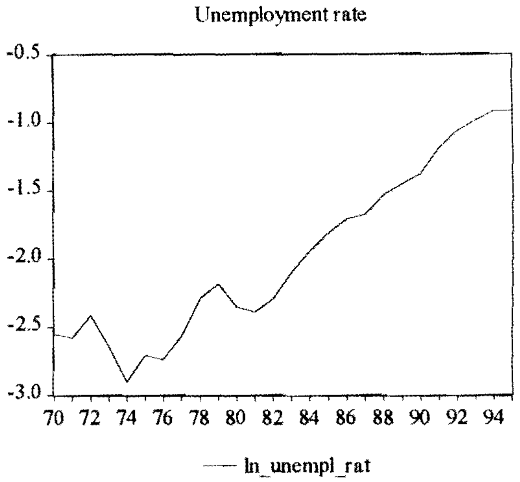

Skilled labour supply

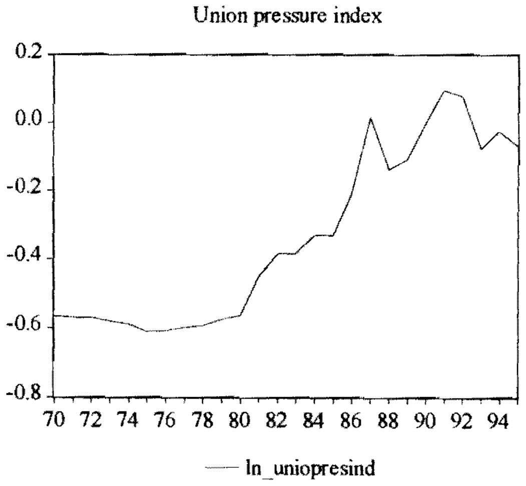

Technology index

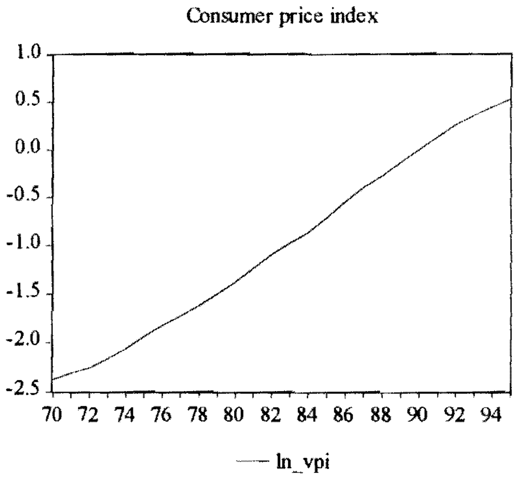

Total population

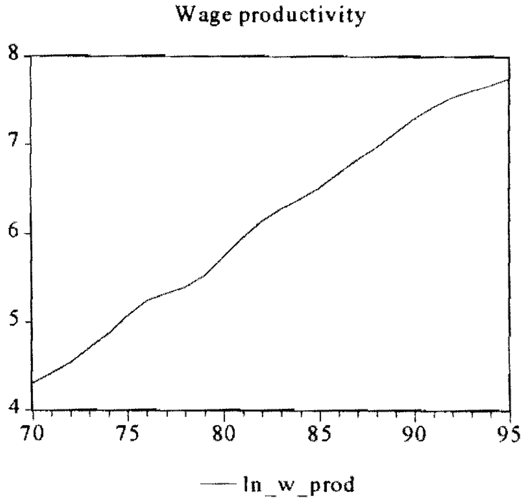

Real user-cost-of-capital


Nominal user-cost-of-capital


Unemployment rate


Union pressure index


Consumer price index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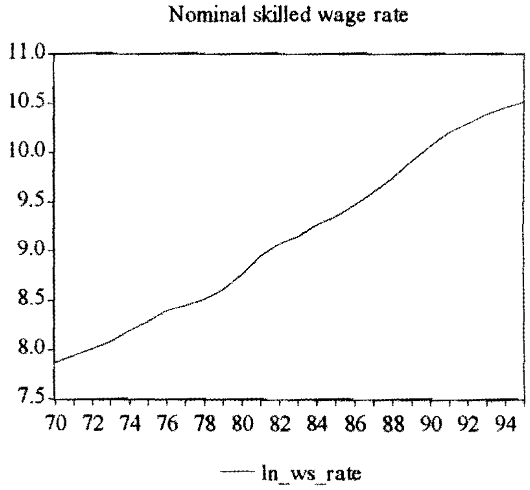
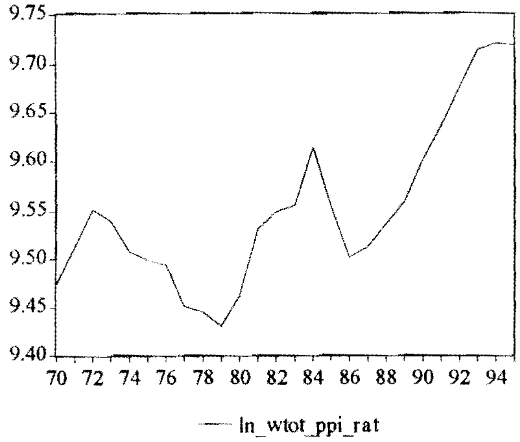
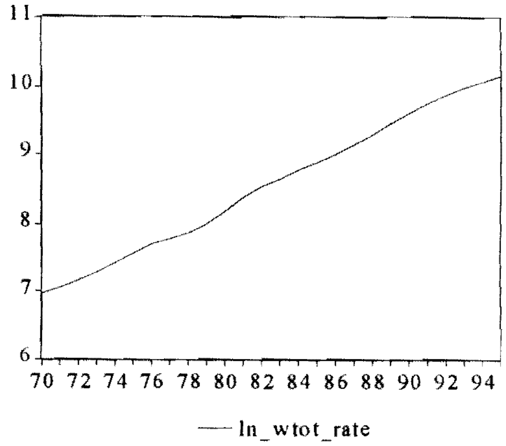
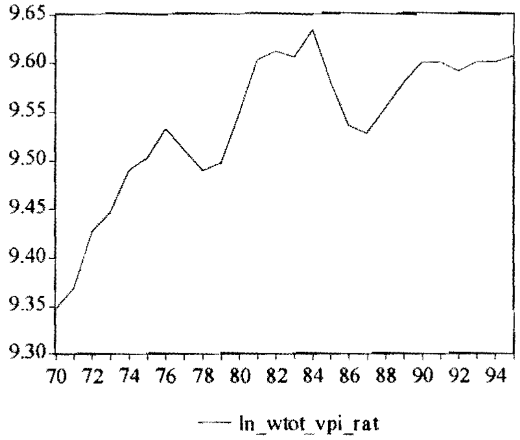
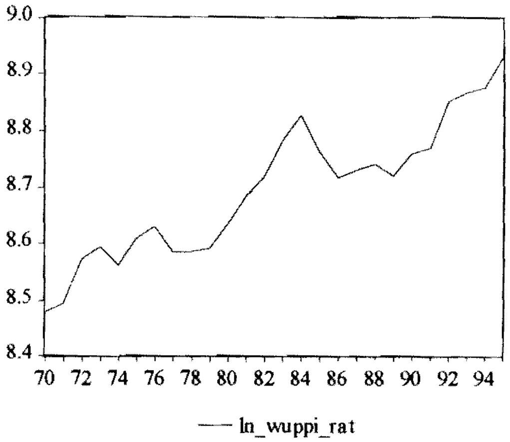
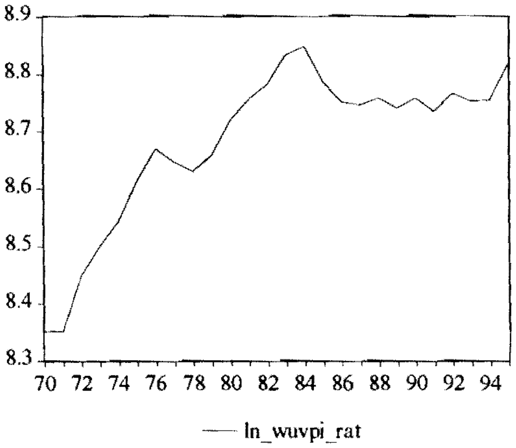

Nominal skilled wage rate

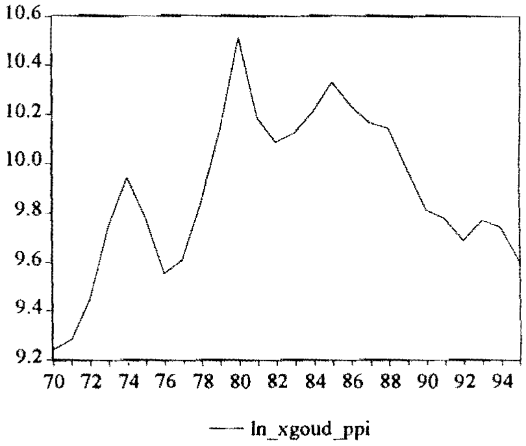

Real total wage rate : PPI deflated

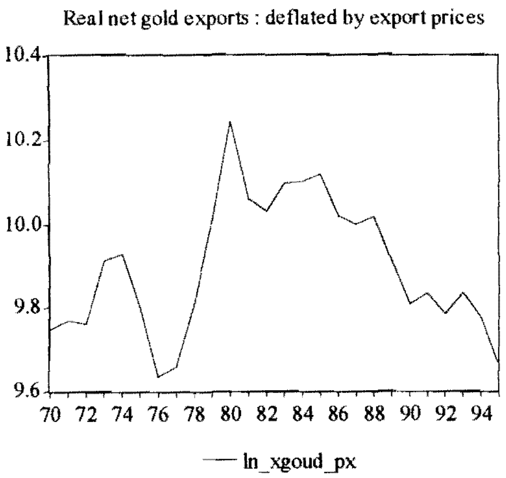

Nominal total wage rate

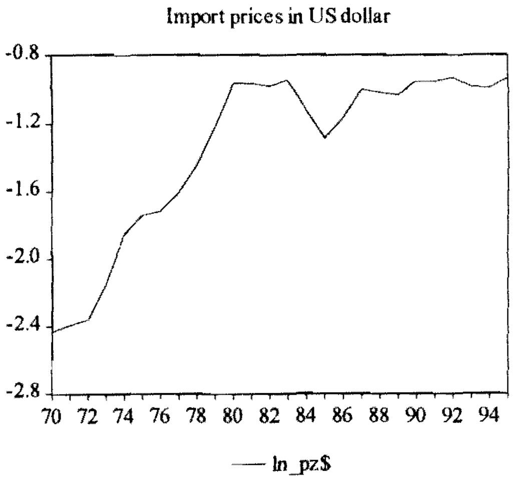

Real total wage rate : CPI deflated


Real unskilled wage rate : PPI deflated


Real unskilled wage rate : CPI deflated


Real net gold exports : PPI deflated


Real net gold exports : deflated by export prices
10.4
10.2
10.0
9.8
9.6
70 72 74 76 78 80 82 84 86 88 90 92 94
— ln_xgoud_px


Import prices in US dollar
-0.8
-1.2
-1.6
-2.0
-2.4
-2.8
70 72 74 76 78 80 82 84 86 88 90 92 94
— ln_pz$

# APPENDIX 10: EVALUATING THE RESPONSE PROPERTIES OF THE MODEL: METHODOLOGY

The dynamic simulation properties of every individual model are investigated and it is tested for stability and robustness simultaneously.

For this purpose, dynamic, *ex-post* and partial simulations are performed on the estimated production function. Two types of dynamic simulations are performed: first, an *ex-post* dynamic simulation on the production function (without any shocks applied) and second, *ex-post* dynamic simulations where each of the explanatory variables are independently increased (shocked).

The initial dynamic simulation (without applying any shocks) is carried out as an indication of the goodness of fit of the model. The response characteristics of the model are evaluated by subsequently subjecting the model to sensitivity testing by changing (shocking) each of the explanatory variables (one at a time). This is done by increasing them by 10 percent. For a model to be stable and robust, shocks applied to it should result in consistent long-run multiplier effects. A consistent long-run multiplier effect means that the difference between the shocked simulated value and the simulated value without a shock must ideally result in approximately 10 percent of the original coefficient of the shocked variable (i.e. the multiplier effect). A shock in short-term explanatory variables should cause an initial movement away from the long-run equilibrium growth path, but eventually the model should converge to the original equilibrium growth path.

Having applied a 10 percent shock to each of the explanatory variable, the dependent variable converged around a new equilibrium, with the adjustment equal to 10 percent of the estimated coefficient of the shocked long-run explanatory variable. In the case of shocked short-run explanatory variables, the dependent variable converged to the original equilibrium growth path.

The results of the adjustment process towards either a new long-run equilibrium (in accordance with the elasticities of the respective cointegration relationships) or the baseline equilibrium (in the case of short-run explanatory variables) are both tabled and graphically illustrated. Vertical axes measure the difference between the outcome of the baseline estimation and the estimation subjected to the exogenous shock, as a percentage of the level of the dependent variable. The speed of adjustment in respective cases is apparent from the graphs. In all instances the adjustment process is completed within the sample range.

# APPENDIX 11: KMENTA'S TAYLOR APPROXIMATION OF THE EXPANSION OF THE CES FUNCTIONAL FORM INTO THE TRANSLOG FUNCTIONAL FORM

By using a Taylor series, the CES functional form can be expanded into the Translog functional form. This expansion was first suggested by Kmenta (1967), and has been utilised by Sargan (1971) and Griliches and Ringstad (1971).

Kmenta based his research on the CES function, which was first introduced by Arrow, Chenery, Minhas and Solow in 1961:

$$Q = \gamma \; (\delta V_1^{-\theta} + (1-\delta)V_2^{-\theta})^{\frac{-\nu}{\theta}} \qquad \text{(A1)}$$

where Q = production; $\gamma$ = efficiency parameter ($\gamma > 0$); $V_i$ = production factors (inputs) with $i$ = 1,2 ; $\theta$ = substitution parameter ($-1 < \theta < \propto$); and $\delta$ = distribution (capital intensity) parameter ($0 < \delta < 1$).

By assuming a Taylor series expansion of about $\theta = 0$, Kmenta obtains a linear approximation of the CES function, which can be written as:

$$\ln Q = \ln \gamma + \nu\delta \ln V_1 + \nu(1-\delta)\ln V_2 - \frac{1}{2}\nu\theta\delta(1-\delta)[\ln(V_1 / V_2)]^2 \qquad \text{(A2)}$$

Provided $\theta$ is near zero (i.e. provided the elasticity of substitution, $\sigma = 1/(1 + \theta)$, is near unity), equation A2 provides a close and convenient approximation of equation A1.[1] This assumption has to be tested in practice.

Kmenta's Taylor approximation to the CES function (equation A2) is, however, of the same form as the Translog production function with imposed restrictions of homotheticity and separability, i.e. a Translog production function exhibiting a constant elasticity of substitution.

The Translog production function of Christensen, Jorgenson and Lau approximates the logarithm of output by a quadratic in the logarithms of the inputs:

$$\begin{aligned} \mathit{lnQ} &= \mathit{ln}\alpha_0 + \sum_{i=1}^{2} \alpha_i \ln V_i + \frac{1}{2}\sum_{i=1}^{2}\sum_{j=1}^{2} \beta_{ij} \ln V_i \ln V_j \\ &= \mathit{ln}\alpha_0 + \alpha_1 \ln V_1 + \alpha_2 \ln V_2 + \beta_{11}(\ln V_1)^2 + \beta_{22}(\ln V_2)^2 + \beta_{12} \ln V_1 \ln V_2 \; . \end{aligned} \qquad \text{(A3)}$$

Restricting the Translog production function to homotheticity and a constant elasticity of substitution, i.e. imposing the restrictions of $\sum \beta_{ij} = \sum \beta_{ji} = 0$ and $\beta_{11} = \beta_{22} = -\frac{1}{2}\beta_{12}$, the equation becomes:

---

[1] If $\theta = 0$ and $\sigma = 1$, then the Translog production function of the form:

$$\ln Q = \ln\alpha_0 + \alpha_1 \ln V_1 + \alpha_2 \ln V_2 + \beta_{11}(\ln V_1)^2 + \beta_{22}(\ln V_2)^2 + \beta_{12} \ln V_1 \ln V_2 ,$$

reduces to the Cobb-Douglas production function of the form:

$$\ln Q = \ln\alpha_0 + \alpha_1 \ln V_1 + \alpha_2 \ln V_2 .$$

$$lnQ = ln\alpha_0 + \alpha_1 \ln V_1 + \alpha_2 \ln V_2 - \frac{1}{2}\beta_{12}(\ln V_1 - \ln V_2)^2 \tag{A4}$$

which is of the same form as Kmenta's Taylor approximation to the CES function[2].

Hence, if the Translog production function (equation A3) is estimated, the hypothesis of a CES may be tested by checking whether the estimated coefficients obey the restrictions: $\beta_{11} = \beta_{22} = -\frac{1}{2}\beta_{12}$ (Thomas 1993: 329-331).

Griliches and Ringstad (1971) performed this test by using cross-sectional inter-firm data for different Norwegian industries. In order to address the problem of a high degree of multicollinearity between the variables $lnV_1$, $lnV_2$ and $[ln(V_1/V_2)]^2$, they rearranged Kmenta's Taylor approximation as:

$$ln\left(\frac{Q}{V_2}\right) = ln\,\gamma + (\nu - 1)lnV_2 + (\nu\delta)\ln\left(\frac{V_1}{V_2}\right) - \frac{1}{2}\nu\theta\delta(1-\delta)\left[\ln\left(\frac{V_1}{V_2}\right)\right]^2 . \tag{A5}$$

Estimation of equation A5 resulted in estimates for $\gamma$, $\nu$, $\delta$ and $\theta$ and therefore provides information on the properties such as the returns to scale ($\nu$), capital intensity of production ($\delta$) and elasticity of substitution ($\sigma = 1/(1 + \theta)$). The closeness of $\theta$ to zero serves as a test whether the Kmenta approximation to the CES function is valid (see equation A2).

As mentioned above this transformation of the CES functional form into the Translog functional form, will be used to test the validity of the Cobb-Douglas functional form as a representation of production technology in South Africa.

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[2] Fuss, McFadden and Mundlak (1979: 239) give the following general derivation of the Kmenta Taylor expansion from the Translog function.

Consider the CES equation originally formulated by Arrow in 1961:

$$y^\rho = \alpha_0 + \sum_{i=1}^{n} \alpha_i x_i^\rho$$

with x a vector of inputs or prices, depending on whether a direct or dual form is being considered, y is output, cost or profit.

If $\alpha_0 = 0$ and $\Sigma\alpha_i = 1$ in the CES formula, then a first order expansion in $\rho$, provides a linear-in-parameters Translog form

$$\ln y = \Sigma\alpha_i \ln x_i + \frac{\rho}{2}[\Sigma\alpha_i(\ln x_i)^2 - \Sigma\alpha_i \ln x_i]^2$$

with second-order terms $\alpha_{ii} = \frac{\rho}{2}\alpha_i(1-\alpha_i)$ and $\alpha_{ij} = \frac{\rho}{2}\alpha_i\alpha_j \quad i \neq j$.

## APPENDIX 12: REPRESENTATIONS OF TECHNICAL PROGRESS

Consider a two-factor Cobb-Douglas production structure:

$$Q_t = AK_t^{\alpha} L_t^{B}$$

with $Q$ output, $K$ capital and $L$ labour.

Production models have to allow technology to improve over time in order to explain growth in output with stable populations and growth in the presence of diminishing returns to scale production structures.

A number of alternative representations of technical progress have been proposed.

### A12.1 Neutral technical progress

One way of handling technical progress is to make the efficiency parameter $A$, vary over time so that:

$$Q_t = A(t)K_t^{\alpha} L_t^{B} . \qquad \text{(A12.1)}$$

Before equation A12.1 can be estimated, some form has to be given to the function $A(t)$. The form most frequently used in practice is:

$$A(t) = Ae^{gt}$$

where $A$ and $g$ are constants, so that equation A12.1[1] becomes

$$Q_t = Ae^{gt} K_t^{\alpha} L_t^{B} . \qquad \text{(A12.2)}$$

$A$, also known as Hicks-neutral productivity, represents the value of $A(t)$ at time = 0. Partially differentiating equation A12.2 with respect to $t$ yields

$$\frac{\partial Q_t}{\partial t} = gQ_t .$$

Hence,

$$\frac{\partial Q_t}{\partial t} \Big/ Q_t = g .$$

---

[1] A popular alternative application of this is the labour-augmenting or Harrod-neutral technical progress where $L_t = A(t)L_{at}$, with $L_{at}$ actual labour input. In its simplest case $A(t) = Ae^{gt}$, reflecting an exponential time trend (Hall and Nixon 1997; Turner, Richardson and Rauffet 1993). An extension of this where labour is set to be human capital-augmented, i.e. $A(t) = Ae^{\varphi(S)}$ with $\phi(S)$ reflecting the efficiency of a unit of labour with S years of schooling relative to one with no schooling ($\phi(S) = 0$) (Hall and Jones 1996).

Thus $g$ measures the proportionate change in output per time period when input levels are held constant. Put differently, $g$ is the proportionate change in output that results from technical progress.

It is convenient to estimate equation A12.2 in logarithmic form as it simply requires the inclusion of a time trend in the usual Cobb-Douglas estimation equation:

$$\log Q_t = \log A + gt + \alpha \log K_t + \beta \log L_t . \qquad \text{(A12.3)}$$

Although production functions with neutral specifications of technical progress are most commonly used in practice, they have definite limitations.

(i) *Constancy of g*

The implication of a constant g that technical progress occurs at a constant rate may not be realistic.

(ii) *Neutrality of the technical progress*

The neutrality of the technical progress implies that it has no effect on the marginal rate of substitution of capital for labour[2] and hence for a given ratio of factor prices does not influence the proportions in which capital and labour inputs are combined.[3] Thus, such technical progress does not affect the capital or labour intensity of the productive process, while it is most probable that technical innovations will either be labour-saving or capital-saving.

A non-neutral technical progress will permit the $\alpha/\beta$-ratio to vary over time.

(iii) *Technical progress exogenous and disembodied*

Technical progress in this case is exogenous because it has been superimposed on the system. ($A$ is simply assumed to grow over time for no stated reason.)[4]

Disembodied technical progress is a form of exogenous technical progress, implying that all existing factors of production are transformed, no matter how long these factors have

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[2] For equation A12.2 it is still true that $\partial Q_t / \partial K_t = \alpha(Q_t / K_t)$ and $\partial Q_t / \partial L_t = \beta(Q_t / L_t)$ so that

$$MRS = \left(\frac{\beta}{\alpha}\right)\left(\frac{K_t}{L_t}\right)$$

The MRS remains constant for any $K/L$ ratio. This occurrence is known as the Hicks-neutral technical progress. It is also Harrod-neutral, since for any $Q/K$ ratio, the marginal product of capital is left unchanged.

[3] This form of technical progress means that the isoquants are all shifted towards the origin, but their slopes at the point where they meet any ray from the origin (i.e. for any $K/L$ ratio) remain unchanged.

[4] Extensions of this, such as the modelling of effects of learning and of research and development expenditure, have been developed.

been in existence. This is clearly unrealistic, certainly as far as capital inputs are concerned. The occurrence of some new invention does not normally mean that all existing capital machinery, no matter of what age, can now be fully adapted to take advantage of the new technique (Thomas 1993).

### A12.2 Alternative representations of technical progress

(i) *Vintage models*

The estimation of the so-called vintage models was an attempt to deal with the disembodied nature of production functions with a neutral technical progress specification.

The first rigorous attempt to formulate a model of embodied technical progress was that of Solow (1960). In the Solow model, technical progress proceeds at a constant rate $g$, but affects only newly produced capital goods. Separate production functions exist for machines of different vintages. Thus, if $Q_v$ is the output produced by machines of vintage $v$ (i.e. constructed in year $v$), $K_v$ is the number of machines of that vintage, and $L_v$ is the labour employed on such machines. Then (assuming a basic Cobb-Douglas form) the production function for machines of vintage $v$ is

$$Q_v = Ae^{gv}K_v^{\alpha}L_v^{B} \qquad \text{(A12.4)}$$

where $g$ is the rate of technical progress. Capital stock of vintage $v$, $K_v$, is dependent on investment in machines in the year $v$ and the rate (assumed constant) at which machines depreciate. Total output is the sum of all outputs obtained from machines of all vintages and Solow was able to derive an aggregate production function in which the normal capital stock variable was replace by an index of "effective capital stock". This index was a weighted sum of all machines with weights declining with age.

(ii) *Developments based on cointegration*

Budd and Hobbis (1989) have applied cointegration analysis to the UK production function and in particular to address the problem of how best to represent technical progress. They argue that there are two main sources of technical advance. First, it may come through domestic research effort which they proxy by the number of new patents taken out in the US by UK residents. Secondly, new technology can be imported from abroad and this flow is proxied by imports of new machinery and by royalty payments to foreign countries. These flows are converted into "net stock of technology" variables by a simple cumulating process in which given depreciation rates are assumed.

Capital stock figures are adjusted to take into account that proportion which consists of recently imported machinery (which may be assumed to be technically superior, otherwise it would not have been imported). "Quality-adjusted" capital stock, $K$ is defined as $K^* = K(M/K)^{\gamma}$ where M is the net stock of recently imported machinery and $K$ is the unadjusted capital stock.

*A* technology index, $T$, is then defined as $T = aP^{\theta}R^{\phi}$ where $P$ and $R$ are the patents and royalties variables respectively.

A Cobb-Douglas production function of the kind $Q = A^*TK^{*\alpha}L^{B}$ is assumed which, after substitution becomes

$$Q = AL^{\beta}[K(M/K)^{\gamma}]^{\alpha}P^{\theta}R^{\phi} \text{ with } A = A^*a. \qquad \text{(A12.5)}$$

If the technology variables are unimportant, then $\gamma = \theta = \phi = 0$ and the function reduces to the standard Cobb-Douglas form:

$$Q = AK^{\alpha}L^{\beta}. \qquad \text{(A12.6)}$$

Budd and Hobbis tested standard forms based on equation A12.6 (with and without a time trend included to represent disembodied technical progress) for cointegration. These production functions invariably failed the cointegration tests and frequently had implausible coefficients. It was possible to find a cointegrating vector only when the technology variables were added to the equations. Hence Budd and Hobbis conclude that the long-run production function is of the form (A12.5) rather than (A12.6) and that technical progress is better represented by their proxy variables than by the traditional time trend.

# APPENDIX 13: THE NAIRU/NAWRU CONCEPT: THEORETICAL AND MEASUREMENT ISSUES

## A13.1 Basic concept and theoretical model

According to modern labour market literature, NAIRU is defined as the rate of unemployment at which inflation stabilises in the absence of wage-price surprises. Conventional thinking about the equilibrium unemployment rate assumes that, in the long-run NAIRU, is determined solely by supply-side factors of the labour market. However, Pichelmann and Schuh introduced an alternative hypothesis where hysteresis-mechanisms could lead to permanent shifts of equilibrium unemployment over time, implying that an unique long-run NAIRU may not even exist.

Consider the following simple formal exposition of equilibrium unemployment given by Pichelmann and Schuh (1997):

Firms set prices as a mark-up over expected wages:

$$p - w^e = \beta_0 - \beta_1 u \qquad \text{(A13.1)}$$

with $\beta_0$ denoting "price-push" factors (e.g. oil shocks, productivity slowdown) and with the mark-up depending (at least in the short-run) upon the state in the labour market.

Workers demand wages in relation to existing prices:

$$w - p^e = \gamma_0 - \gamma_1 u \qquad \text{(A13.2)}$$

with $\gamma_1 > 0$ because of union bargaining or efficiency wage considerations, and with $\gamma_0$ denoting "wage-push" factors (e.g. unemployment benefits, union power).

Solving for $u$ yields

$$u = (\beta_0 - \gamma_0)/(\beta_1 + \gamma_1) - 1/(\beta_1 + \gamma_1)[p - p^e + w - w^e]. \qquad \text{(A13.3)}$$

When there are no wage-price surprises

$$u = (\beta_0 - \gamma_0)/(\beta_1 + \gamma_1) = u^*]$$

with $u^*$ denoting the no-surprise equilibrium rate of unemployment.

Assuming real wages to equal expected real wages and expected inflation equals last year's inflation, give the underlying inflation-unemployment trade-off (standard Phillips-Curve):

$$\Delta\pi = \theta_1 (u^* - u). \qquad \text{(A13.4)}$$

Inflation will only remain unchanged in this setting, when actual unemployment equals $u^*$. Thus, the effects of aggregate monetary and fiscal policy, as well as of other types of demand shocks, are in the long-run constrained by this fundamental supply-side relationship. From this perspective, the only sustainable way to bring down unemployment is to reduce $u^*$.

The model is usually closed by introducing a conventional downward sloping aggregate demand schedule whereby lower prices elicit higher demand via real balance effects (and/or lower interest rates, improved competitiveness). Thus, demand disturbances may lead to cyclical unemployment, i.e., deviations of actual unemployment from its equilibrium level as defined above.

In the simple framework outlined above, movements in unemployment can be caused by shifts in aggregate demand giving rise to cyclical unemployment, and by shifts in the price or wage-setting schedules which change equilibrium unemployment.

The textbook theory claims that negative (positive) demand disturbances may temporarily push actual unemployment above (below) its equilibrium level, but over the medium term the ensuing process of disinflation (inflation) will inevitably drive unemployment back to equilibrium. The conventional approach then continues to argue that the degree of nominal inertia is simply not high enough to explain the sustained increase in unemployment in Europe. Thus, the theory concluded there must have been unfavourable shifts in the fundamental supply-side determinants of the NAIRU. The policy implication then, of course, is to press for supply-side reform.

However, despite considerable efforts, it has been hard to identify changes in the basic determinants of equilibrium unemployment large enough to account for the observed trend increase in actual unemployment. Consequently, the alternative hypothesis has been put forward that unemployment may be strongly dependent on its own history (hysteresis). According to this view, current equilibrium unemployment is not independent of past actual unemployment, because of endogenous mechanisms that tend to translate movements in actual unemployment into changes of equilibrium unemployment. The presence of such mechanisms blurs the simple-minded distinction between demand and supply factors because demand shocks eventually have longer-term supply-side consequences.

The distinguishing feature of a process characterised by hysteresis is that the behaviour of the process cannot be described by reference to state variables alone. Instead, in addition to state variables the past history of the process has to be invoked in order to explain its behaviour.

The following simple technical exposition is used to show how traditional economic thinking about the trade-off between unemployment and inflation is altered when the evolution of unemployment is subject to hysteresis effects. As a starting point, consider the following general formulation of the Phillips curve:

$$\pi = \pi^e + \theta_1 (u^* - u) \qquad \text{(A13.5)}$$

where $\pi$ and $\pi^e$ denote, respectively, the actual and expected rates of inflation and $u$ is the rate of unemployment. Equilibrium unemployment (NAIRU) corresponds to the steady-state situation when actual inflation is equal to expected inflation, so that $u = u^*$. Then, $u^*$ itself is usually assumed to be determined by a set of structural factors affecting the demand and supply-side of the labour market, but to be invariant with respect to business cycle conditions. Thus, denoting the relevant explanatory variables by $X$:

$$u^* = bX . \qquad \text{(A13.6)}$$

The possibility of hysteresis arises when equilibrium unemployment in a given period also depends on actual unemployment in the past, as e.g. in

$$u_t^* = \alpha u_{t-1} + bX . \qquad \text{(A13.7)}$$

In a steady state, where actual inflation is equal to expected inflation and unemployment is constant, equilibrium unemployment is now given by:

$$u^* = bX/(1-\alpha) . \qquad \text{(A13.8)}$$

Therefore, when last period's actual unemployment is fully translated into equilibrium unemployment in the next period $(\alpha = 1)$, then steady-state equilibrium is no longer uniquely defined. Any change in actual unemployment, e.g. brought about by macroeconomic policies, would also alter the NAIRU by the same amount; such a situation has been labelled as pure hysteresis. When actual unemployment feeds only partly into future equilibrium unemployment $(0 < \alpha < 1)$ there is persistence in unemployment in the sense that the NAIRU evolves only slowly towards its steady state (long-run) level ("speed-limits").

The conventional way to introduce hysteresis mechanisms[1] into the analysis is by adding into the wage equation an additional term denoting the change in unemployment:

$$w - p^e = \gamma_0 - \gamma_1 u - \gamma_2 \Delta u \qquad \text{(A13.9)}$$

where in the case of pure hysteresis it is only the change term that matters. Thus, most explanations for hysteresis generating mechanisms focus on the behaviour of labour market participants, changes in their productive capacity caused by unemployment, and on the resulting consequences for wage bargaining and the matching process between workers and jobs.

### A13.2 Measurement issues

The general consensus among economists is that there exists, at least in the long-run, a unique "equilibrium unemployment rate" (i.e. the "NAIRU") which is consistent with stable inflation. In practice, rules for the conduct of monetary policy or programs to reduce unemployment are guided by empirical estimates of the NAIRU. The construction of estimates of the NAIRU,

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[1] See Pichelmann and Schuh (1997) for a survey on hysteresis mechanisms.

however, suffers from the fundamental problem that the NAIRU is an unobserved variable, so that there exist leeway for a broad range of plausible methodological approaches for the estimation of the equilibrium unemployment rate.

### A13.2.1 Time-series approaches

A widely used method to construct estimates of the NAIRU relies on time-series methods, which are based solely on data of the unemployment rate. Univariate methods proceed by decomposing the unemployment rate into a deterministic and a stochastic component. The deterministic component of the series is then interpreted as the equilibrium unemployment rate whereas the stochastic component represents the cyclical development of the unemployment rate. In order to obtain an estimate of the NAIRU, it has to be ensured that the deterministic part of the unemployment rate is uncorrelated to inflation. This approach has various advantages: it is easy to construct estimates of the NAIRU and theoretical issues (i.e. misspecification of the "model") can be avoided to a large extent.

The simplest univariate specification assumes that the unemployment rate is a realisation of a stationary process, with its expectations being the (time-constant) NAIRU:

$$u_t = \sum_{i=1}^{p} \phi_i u_{t-i} + e_t \qquad \text{(A13.10)}$$

where the random variable $e_t \approx iid$ with mean 0, satisfying:

$$E[u_t] = \bar{u} \qquad \text{(A13.11)}$$

$$E[u_t - u_{t-1}] = 0\,. \qquad \text{(A13.12)}$$

This specification is in accordance to the basic model specified in section 1, which would, in the absence of any change of structural factors of the labour market, imply that the equilibrium unemployment rate is constant over time. A look at various countries' unemployment rates reveals, however, that actual unemployment rates exhibit considerable deviations from the long-run mean over time. According to the previous discussion this could be due to changes in the structural factors of the labour market, so that the equilibrium rate shifts from time to time. This possibility is taken into account when constructing estimates of the NAIRU which allow for "breaks" in the series, so that (A13.11) becomes:

$$E[u_t] = u_i \quad \text{if} \quad t_{i-1} < t \le t_i; \qquad i = 1,\ldots,I\,. \qquad \text{(A13.13)}$$

A problem arises within this model as the breaks are treated as being known with certainty. In practice however, it is difficult to determine the exact timing when the NAIRU might switch from one regime to another, so that an additional source of imprecision is added to these estimates.

However, since the 1980s a growing number of empirical studies suggest that the equilibrium unemployment rates may be described by non-stationary time-series, i.e. that they follow a stochastic trend so that:

$$E[u_t] = E[u_{i-1}] + \eta_t \tag{A13.14a}$$

or

$$u_t - u_{i-1} = a + \eta_t \tag{A13.14b}$$

with the parameter $a$ representing the deterministic and $\eta$ the stochastic component of the trend.

This implies that an "equilibrium" value to which the unemployment reverts in the long-run does not exist. This specification of the NAIRU concurs with the theoretical view, described in section 1, that hysteresis factors are at work in the labour market, i.e. that the NAIRU depends on the historical evolution of actual unemployment.

Structural Time Series Models as proposed by Harvey (1989) represent an appropriate methodological tool to construct estimates of the (unobserved) stochastic components of unemployment rates. The models assume that the NAIRU may be driven by simple but flexible stochastic processes. A standard specification of a univariate structural time-series model of the NAIRU is:

$$u_t = u_t^* + uc_t + i_t \tag{A13.15a}$$
$$u_t^* - u_{t-1}^* = a_{t-1} + e_t \tag{A13.15b}$$
$$a_t = a_{t-1} + \eta_t \tag{A13.15c}$$

where $u$ is actual unemployment, $u^*$ represents the trend unemployment rate, which may then be interpreted as the NAIRU, $uc$ is the cyclical unemployment rate, which follows a stochastic cycle.

### A13.2.2 Wage-price models

The fundamental drawback of the time-series approach for the estimation of the NAIRU is that it does not provide causal explanations for the development of the "equilibrium" unemployment rate. Estimates based on the univariate time-series methodology therefore form no sound basis for policy interventions as they leave the interactions between the economic variables indeterminate.

Econometric models based on the theoretical model describe in section 1 take the interdependence between economic variables into account. Empirical results obtained form these models thus allow for causal interpretations of the NAIRU estimates. In contrast to time-series models, movements of the NAIRU are explained by various labour market variables (i.e. wage or price pressure elements) which are inserted into the empirical models.

One commonly applied method to estimate the equilibrium unemployment rate is based on the wage equation described in section 1(A13.9), written in log-linear form:

$$\Delta(\log(w_t)-\log(p_t))=\beta_0+\beta_1(L)(\log(\pi_t)-\log(\pi_t^e))-\beta_2(U_t-NAWRU_t)+\beta_3\Delta U_t+\beta_4\log(x_t)+\beta_5\log(A_w)+\omega_t \tag{A13.16}$$

where NAWRU represents the equilibrium unemployment rate, $x$ depicts productivity and $Z_w$ are variables representing wage pressure elements (such as unemployment benefits, taxation, labour market mismatch, employment protection, etc.) and the change of the unemployment rate is inserted to capture possible hysteresis effects. Thus, the NAWRU may move over time due to changes in wage pressure elements or as a consequence of hysteresis effects. As this specification relates wage inflation rather than price inflation to movements of the unemployment rate, corresponding estimates of the equilibrium unemployment rate are referred to as the NAWRU (non-accelerating wage rate of unemployment). By imposing the long-run homogeneity restriction, namely that real wage growth must be proportional to productivity growth, this specification implies that it is possible to analyse the long-run equilibrium properties of the equilibrium unemployment rate.

In order to construct an estimate of the NAWRU, a model for inflationary expectations has to be developed for the estimation of the equation. A commonly used approach is to use lagged inflation rates as a proxy for "price surprises". Alternatively, some consensus or median forecast of inflation can be used in order to depict "expected inflation". Another commonly used possibility to construct estimates of the NAIRU is to use the standard Phillips-curve relation (A13.4):

$$\pi_t-\pi_t^e=\beta(L)(u_{t-1}-NAIRU_t)+\delta(L)(\pi_{t-1}-\pi_{t-1}^e)+\gamma(L)X_t+e_t \tag{A13.17}$$

where $\pi^e$ represents expected inflation, $L$ is the lag operator and $X$ represents additional regressors included in some empirical specifications. As in the case of the NAWRU-estimates described above, the need for a model of inflationary expectations arises. This specification forces the equilibrium unemployment rate, the NAIRU, to satisfy the steady-state condition that expected inflation must equal actual inflation. A drawback of the Phillips-Curve formulation is that "surprises" of nominal wage inflation (deviations of actual wages from their expected values) have to be treated as non-existent.

The discussion in section 1 indicated that both price setting and wage formation incorporate important information on the development of the NAIRU. It should thus be expected that estimates of the NAIRU can be improved by analysing both price and wage setting. This can be achieved by combining the wage setting curve (A13.16) with the price setting schedule (A13.17):

$$D(\log(p_t)-\log(w_t))=a_0-a_1(L)D(\log(w_t-\log(w_t^e))+a_3\log(y_t)-a_4\log(Z_{p_t})+e_t \tag{A13.18}$$

where $y$ is the level of output market activity and $Z_p$ captures "price pressure" variables as describe in section 1.

The NAIRU is then estimated by simultaneous estimation of equations (A13.16) and (A13.18) and solving for unemployment. This method allows the imposition of homogeneity restrictions both on price setting and on wage formation and thus implies that the estimate of the NAIRU satisfies the necessary conditions for the labour market equilibrium as described in section 1. The estimation of a wage-price system allows for the distinction between the impact of structural factors on wage formation and price setting respectively.

Although there exists a great number of empirical estimates of the NAIRU, there is an apparent lack of discussion about the precision of these estimates. In fact, two fundamental types of uncertainty may contribute to the imprecise measurement of the equilibrium unemployment rate. The first source of uncertainty arises from the fact that the NAIRU is an unobserved variable that leaves room for a number of plausible empirical models for its measurement. Different specifications generally lead to different point-estimates of the level of the NAIRU. The exposition above provided an overview of different possible approaches to the measurement of the equilibrium unemployment, all of which concur with the theoretical model of the NAIRU. The most important difficulty in this context arises from the possibility that in the long-run, the level of the NAIRU may be indeterminate, rendering the NAIRU stochastic in nature. Examples are presented by Pichelmann and Schuh (1997).

## APPENDIX 14: COST OF CAPITAL: A NEOCLASSICAL APPROACH

The pioneer of neoclassical theory, Jorgenson (1963), defines the cost of capital as the cost which the firm incurs as a consequence of owning an asset. The cost of capital transforms the acquisition price of an asset into an appropriate rental price. This cost depends on the rates of return and depreciation. The rate of return is the opportunity cost of holding capital goods rather than financial assets. Depreciation arises from the decline in the price of capital goods with age (Jorgenson 1993: 4).

The neoclassical theory of capital accumulation is formulated in two alternative yet equivalent ways. First, the firm may accumulate capital to supply the service to itself. The objective of the firm is to maximise its value, subject to its technical limitations. Secondly, the firm may rent the assets in order to obtain a capital service. In this case the objective of the firm is to maximise its current profit, defined as gross revenue less the cost of inputs less the rental value of capital. The rental can be calculated from the relationship between the price of new capital goods and the discounted value of future services received from these goods (Jorgenson 1993: 4).

According to Jorgenson (1993), in the absence of direct taxes, this relationship takes the form:
$q_t = \int e^{(-r)(s-t)c(s)-\delta(\theta - t)} ds$;
where $r$ is the discount rate, $q$ the price of capital goods, $c$ the cost of capital services and $\delta$ the rate of replacement (depreciation). The time of acquisition is given by $t$ and time $s$ is the time during which capital services are supplied (Jorgenson 1993: 4).

Differentiating this with respect to t gives $c = q(r+\delta) - q$, which is the rental price of capital services supplied by the firm to itself. Under static expectations about the price of investment goods, the rental price reduces to $c = q(r+\delta.)$.

To extend the formula to allow for taxation, Jorgenson (1993) defines a depreciation formula $D(s)$ to calculate the proportion of the original cost of an asset of age $s$, which may be deducted from taxes. Jorgenson also assumes a tax credit $k$ that may be deducted from investment expenditure. If the tax rate is constant over time at rate $u$, the equality between the price of investment goods and the discounted value of capital services is:

$$q_t = \int e^{(-r)(s-t)} [(1-u)c(s)e^{-\delta(\vartheta - t)} + u(1-k)q(t)D(s)]ds + k\, q_t .$$

Allowing the present value of depreciation on one rand's worth of investment to be denoted by $z$ gives:

$$z = \int e^{-rs} D(s)ds .$$

The rental value of capital under static expectations then becomes:

$$c = q(r+\delta) \times \frac{(1-k)(1-uz)}{(1-u)} .$$

There are at least three depreciation formulae, which can be applied when calculating *z*. After calculating the cost of capital, it can be used as one of the most important determinants in a neoclassical investment function and subsequently a production function. By including this variable, any effect of a change in tax, interest rates or depreciation can be investigated. Through this variable, a tax reduction will, for example, influence investment behaviour and eventually aggregate supply (Jorgenson 1993: 4).

The effect of tax policy on investment behaviour enters the investment function through the rental value of capital. This results in a change in the desired level of capital. Such a change leads to net investment (or disinvestment), increasing (or decreasing) capital stock to its new desired level (Jorgenson 1993: 4).

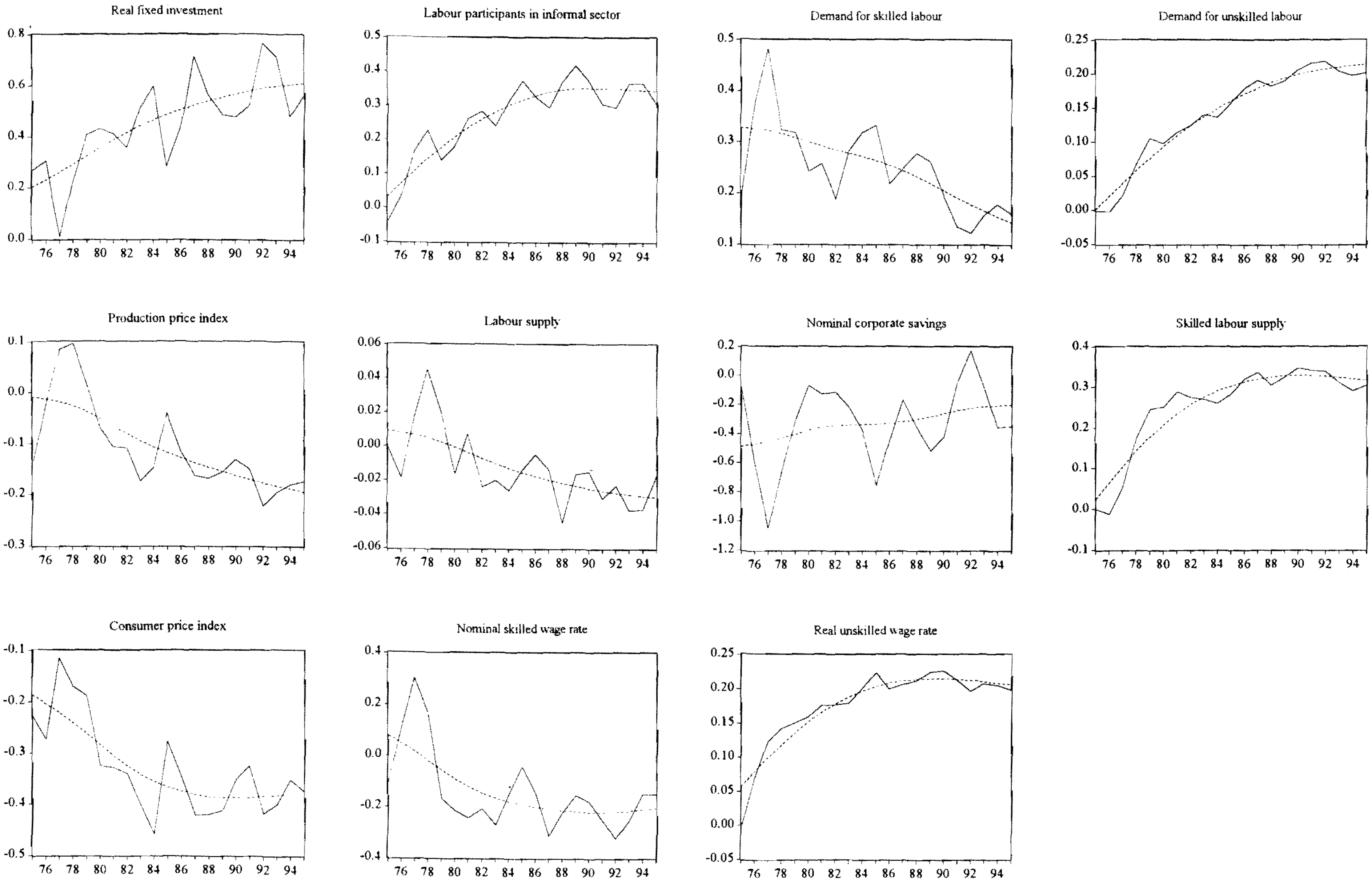
The user-cost-of-capital (*r*) can be expressed as:

$$r = price\ of\, capital\left(\frac{(interest\ rate)-(inflation\ rate)+(rate\ of\ depreciation)}{1-tax\ ratio}\right)$$

To summarise: this measure for user-cost-of-capital combines four effects. The first relates to an opportunity cost to invest and, based on the long-run nature of investment, is approximated by the yield on long-term government bonds. Second, fluctuations in the price of capital may lead to losses or gains for a firm when it sells its capital at the end of a period. A capital gain (loss) would reduce (increase) the user-cost-of-capital. These gains/losses can be approximated by the rate of inflation times the price of capital. A third cost for the owner of capital stems from the depreciation of capital, while the fourth component is taxes, resulting in a difference between the pre-tax and after-tax rates of return on capital.

## APPENDIX 15: LONG-RUN RESPONSE PROPERTIES

**Figure A15.1(a)** Long-run elasticities of the full supply-side model : 10% shock to real GDP at factor cost (actual and smoothed)



Real fixed investment

Labour participants in informal sector

Demand for skilled labour

Demand for unskilled labour

Production price index

Labour supply

Nominal corporate savings

Skilled labour supply

Consumer price index

Nominal skilled wage rate

Real unskilled wage rate

**Figure A15.1(b) Long-run multipliers of the full supply-side model : 10 % shock to real GDP at factor cost in 1975 (actual and smoothed)**

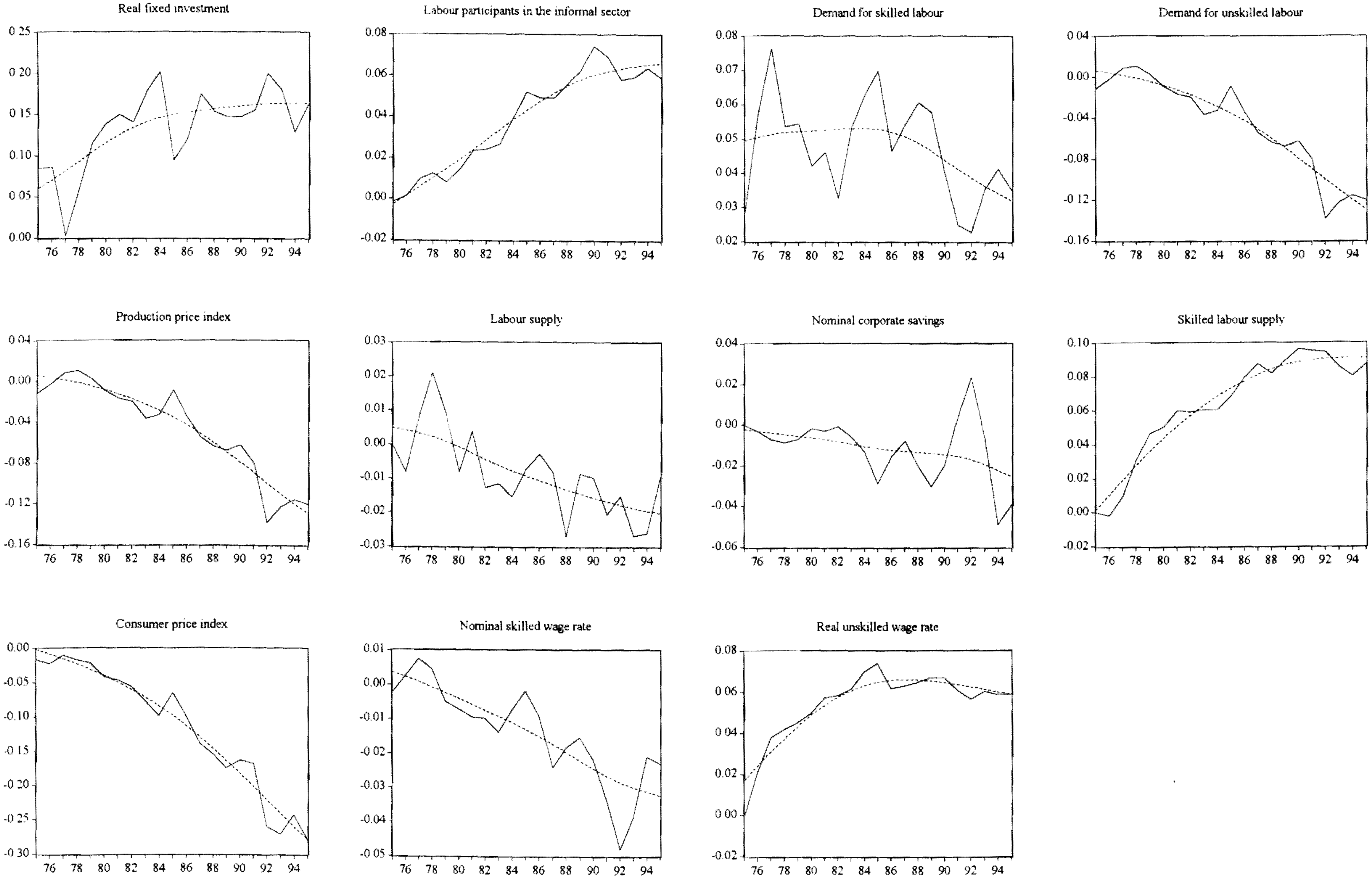


**Figure A15.2(a)** Long-run elasticities of the full supply-side model : 10% shock to real fixed investment (actual and smoothed)

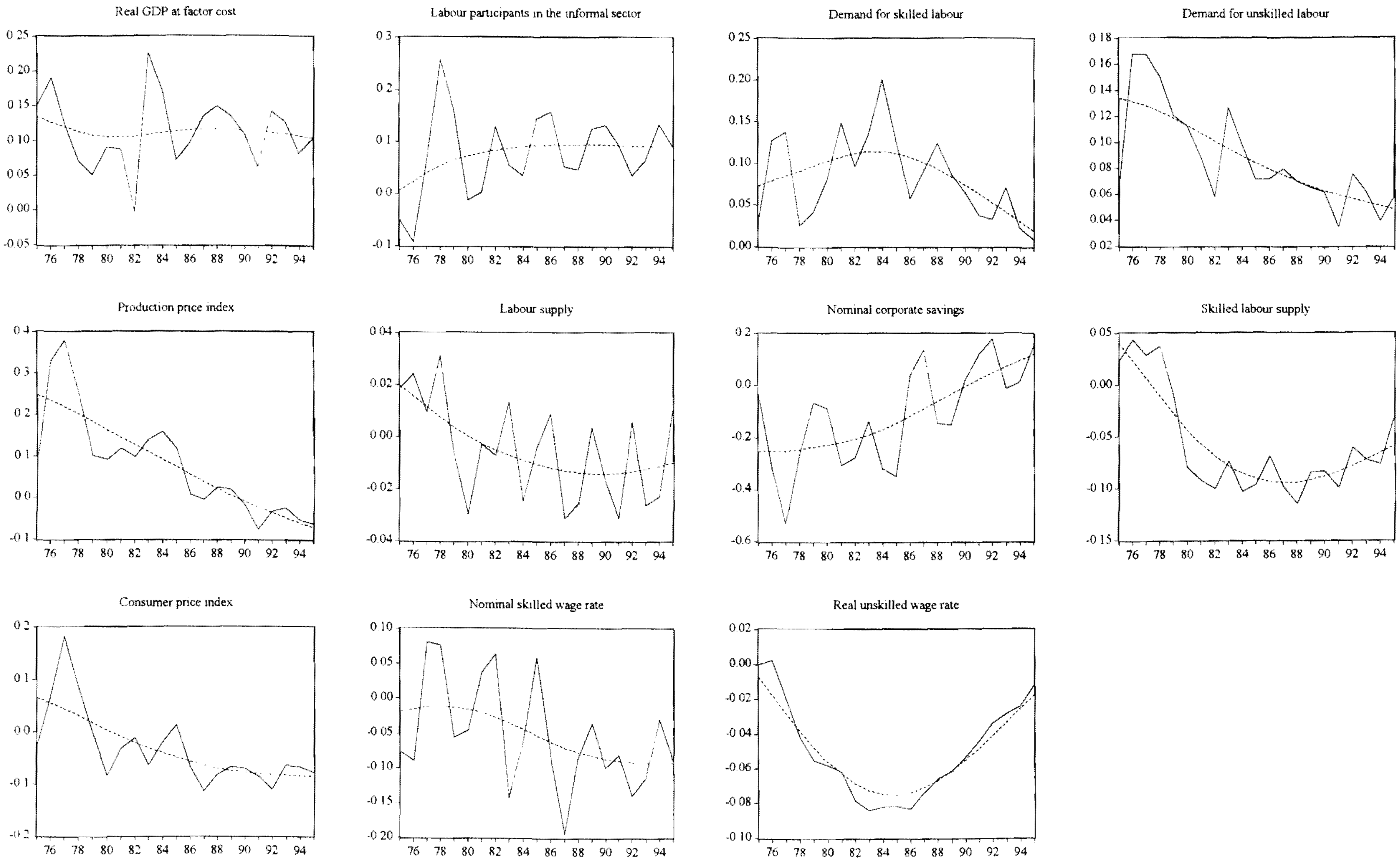
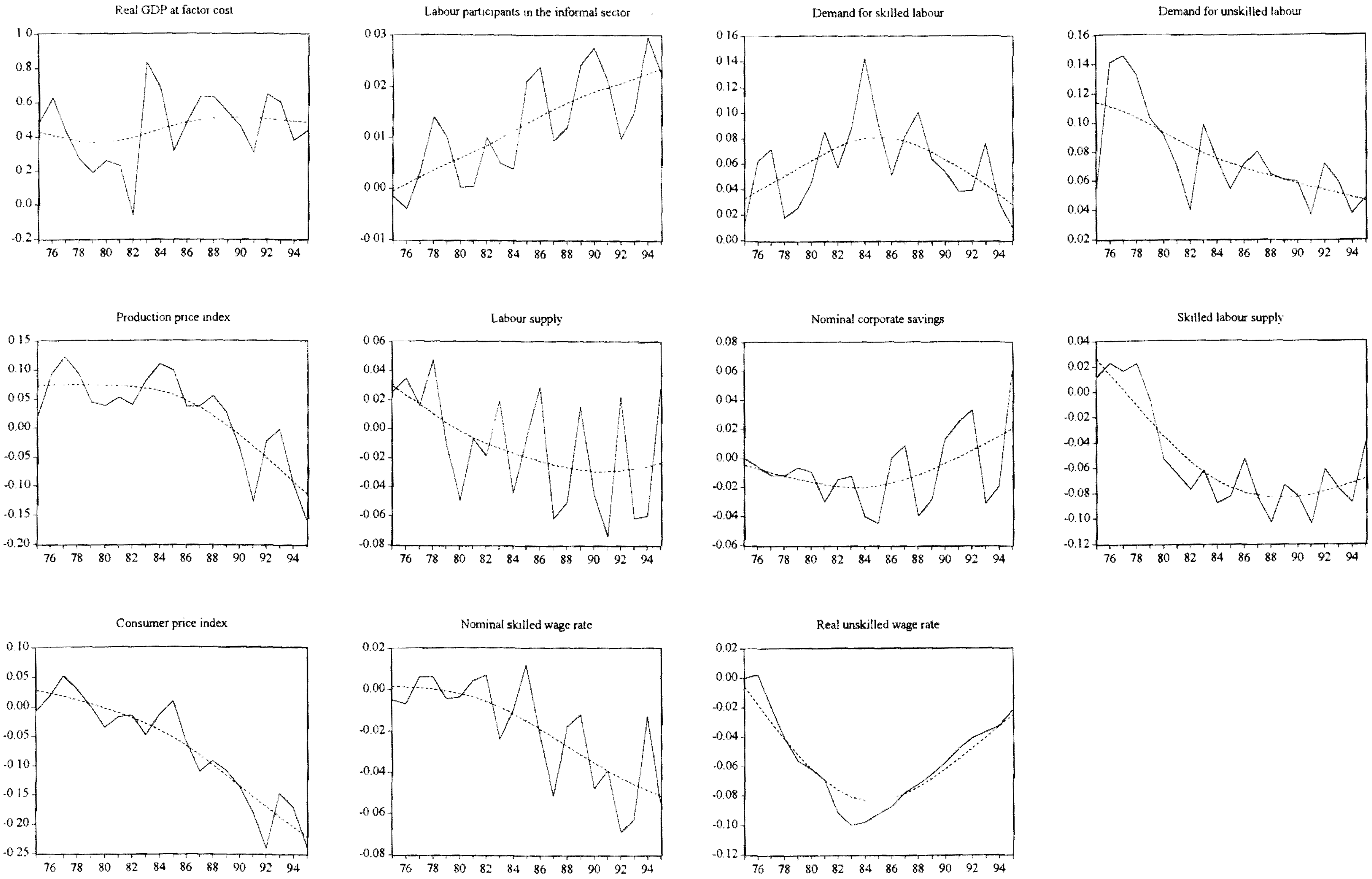


Figure A15.2(b) Long-run multipliers of the full supply-side model : 10% shock to real fixed investment in 1975 (actual and smoothed)


Real GDP at factor cost

Labour participants in the informal sector

Demand for skilled labour

Demand for unskilled labour

Production price index

Labour supply

Nominal corporate savings

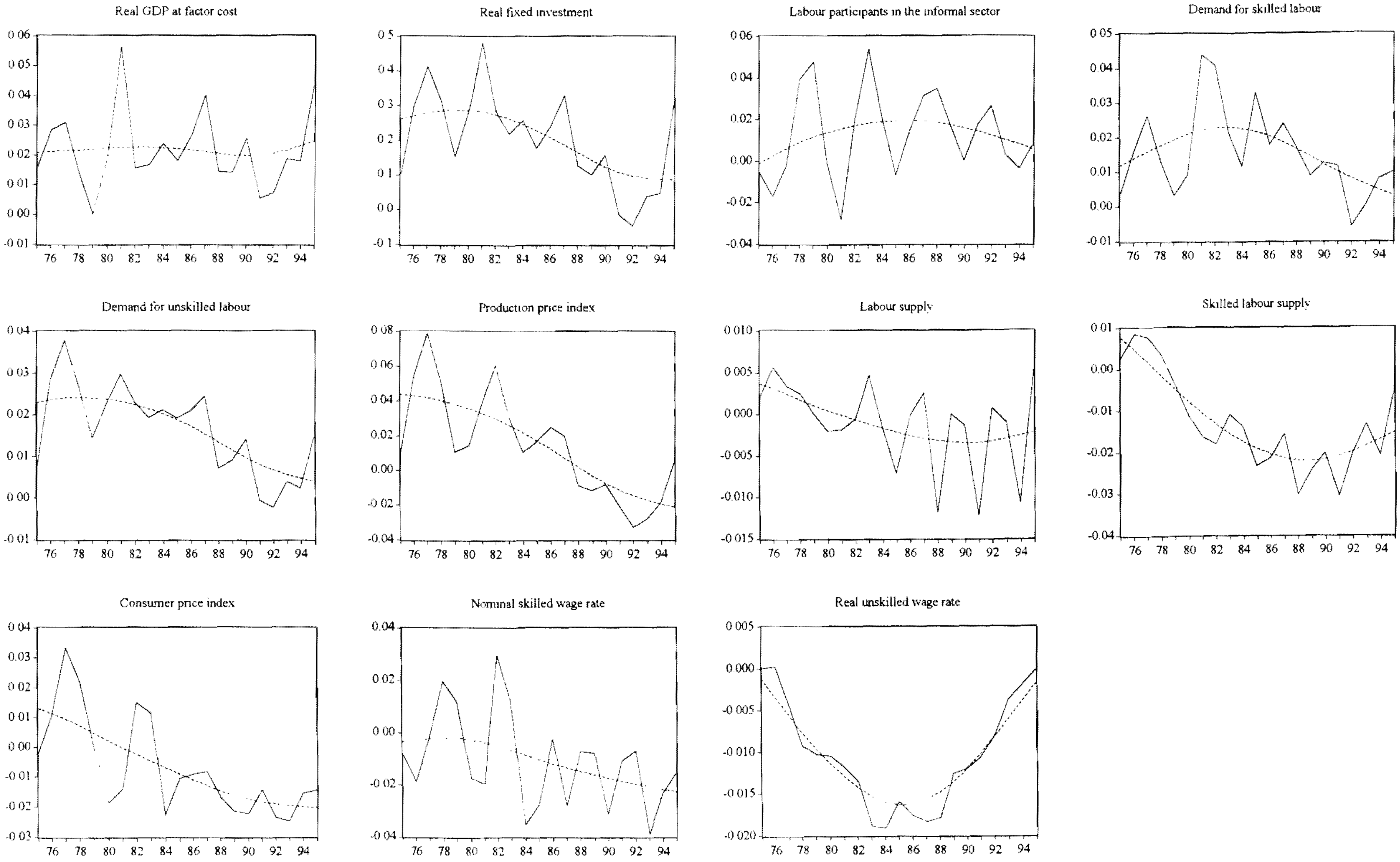
Skilled labour supply

Consumer price index

Nominal skilled wage rate

Real unskilled wage rate

**Figure A15.3(a)** Long-run elasticities of the full supply-side model : 10% shock to nominal corporate savings (actual and smoothed)



Real GDP at factor cost

Real fixed investment

Labour participants in the informal sector

Demand for skilled labour

Demand for unskilled labour

Production price index

Labour supply

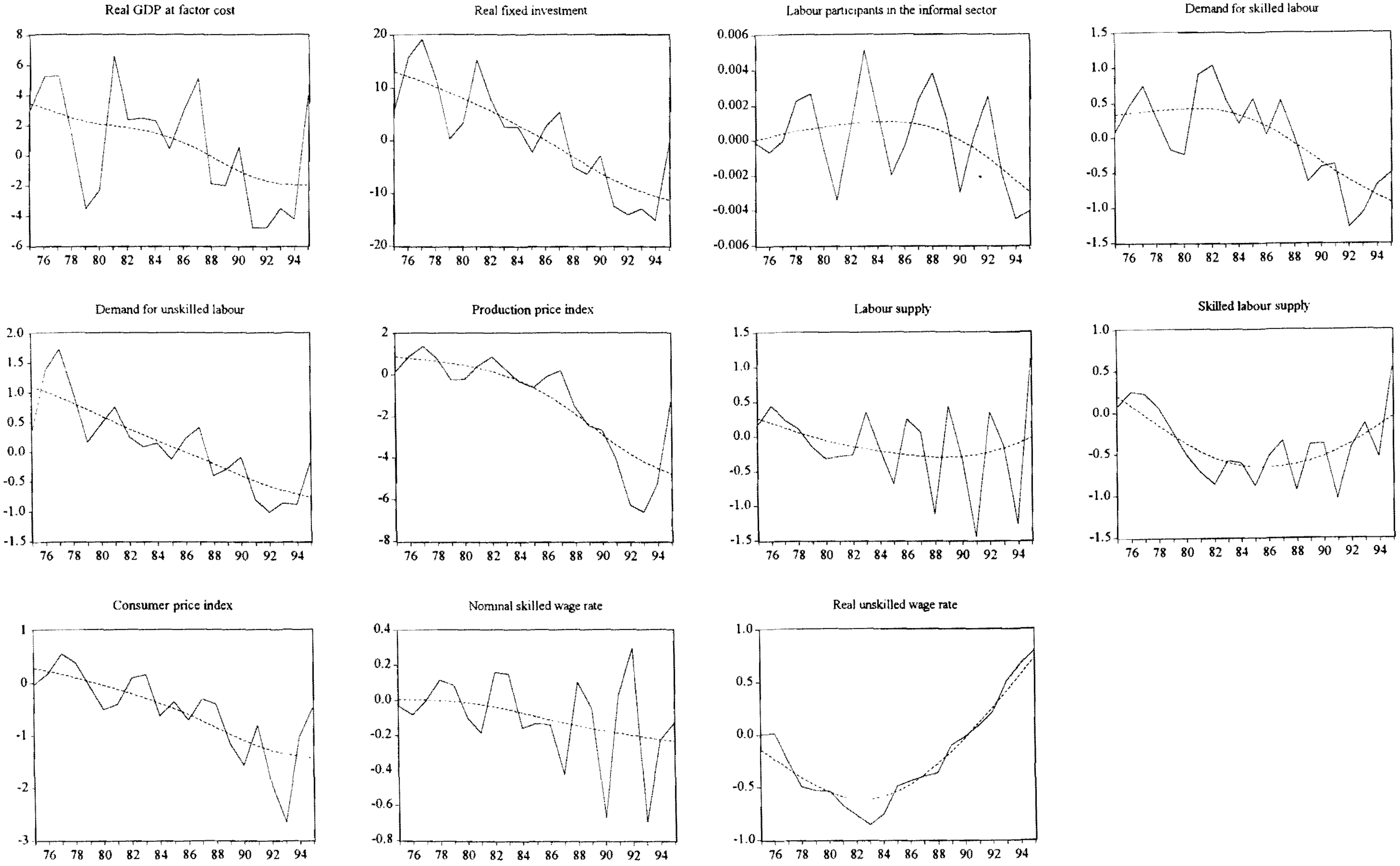
Skilled labour supply

Consumer price index

Nominal skilled wage rate

Real unskilled wage rate

**Figure A15.3(b)** Long-run multipliers of the full supply-side model : 10% shock to nominal corporate savings in 1975 (actual and smoothed)



Real GDP at factor cost

Real fixed investment

Labour participants in the informal sector

Demand for skilled labour

Demand for unskilled labour

Production price index

Labour supply

Skilled labour supply

Consumer price index

Nominal skilled wage rate

Real unskilled wage rate

Figure A15.4(a) Long-run elasticities of the full supply-side model : 10% shock to demand for skilled labour (actual and smoothed)

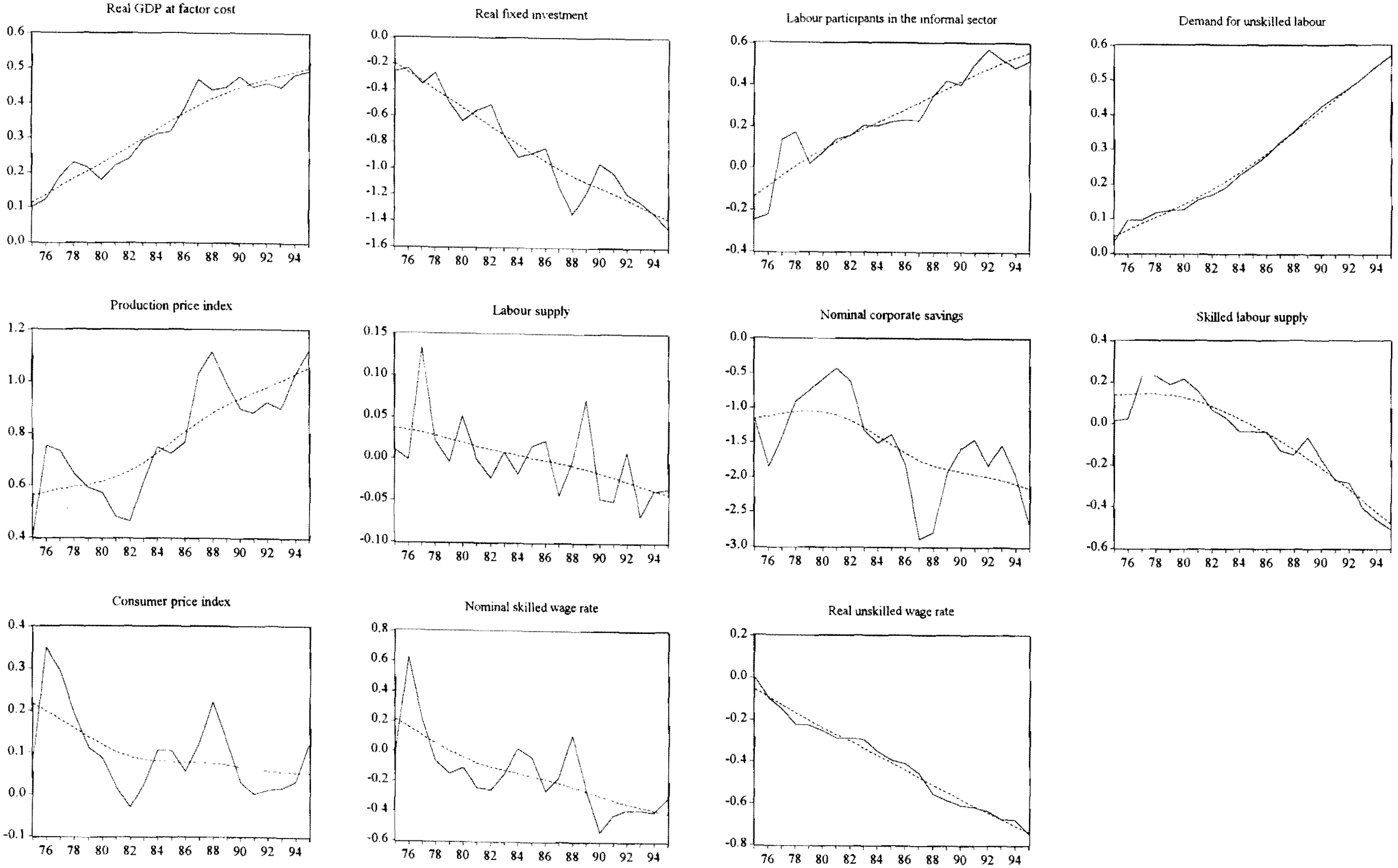


**Figure A15.4(b)** **Long-run multipliers of the full supply-side model : 10% shock to demand for skilled labour in 1975 (actual and smoothed)**

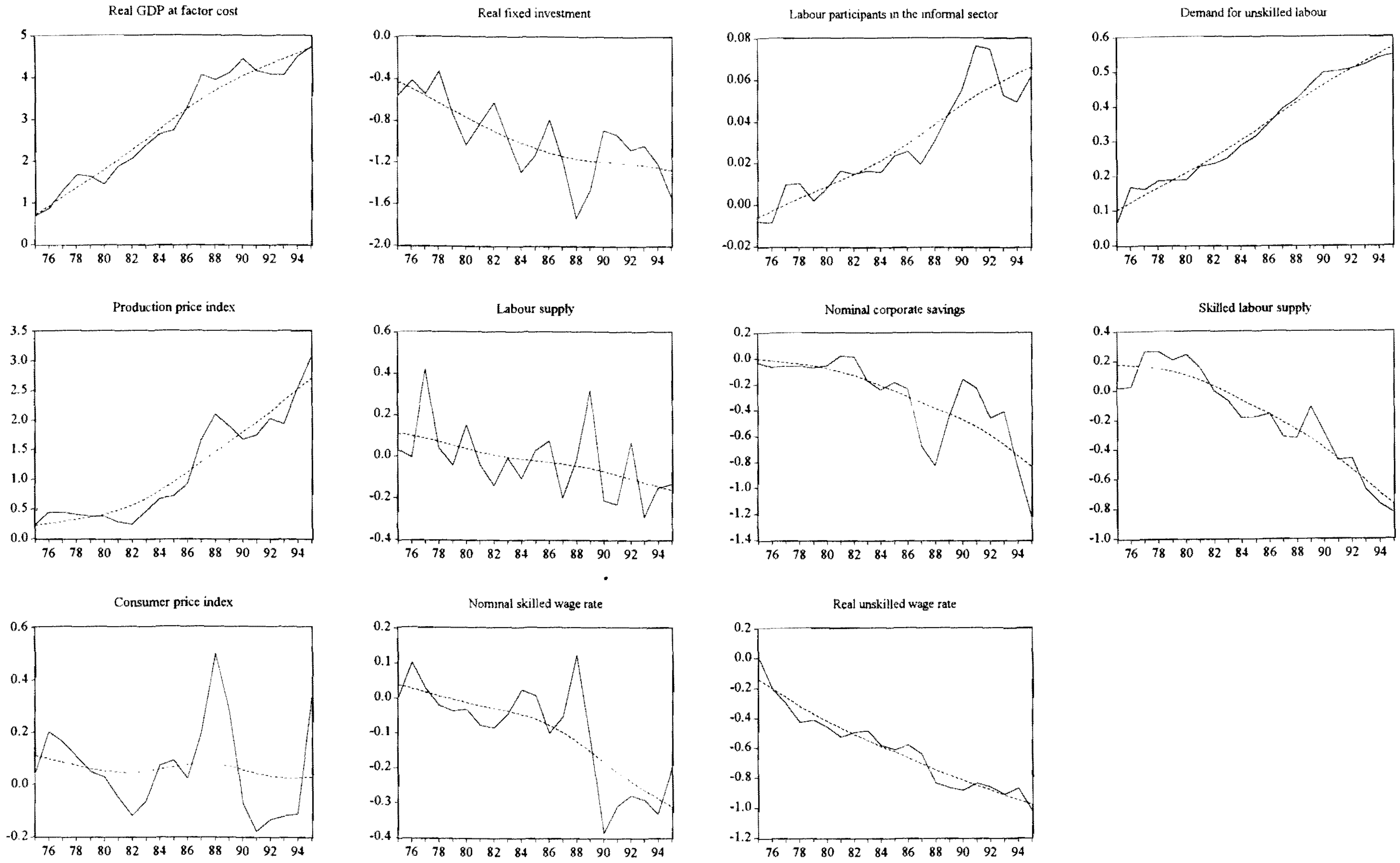


Figure A15.5(a) Long-run elasticities of the full supply-side model : 1% shock to demand for unskilled labour (actual and smoothed)

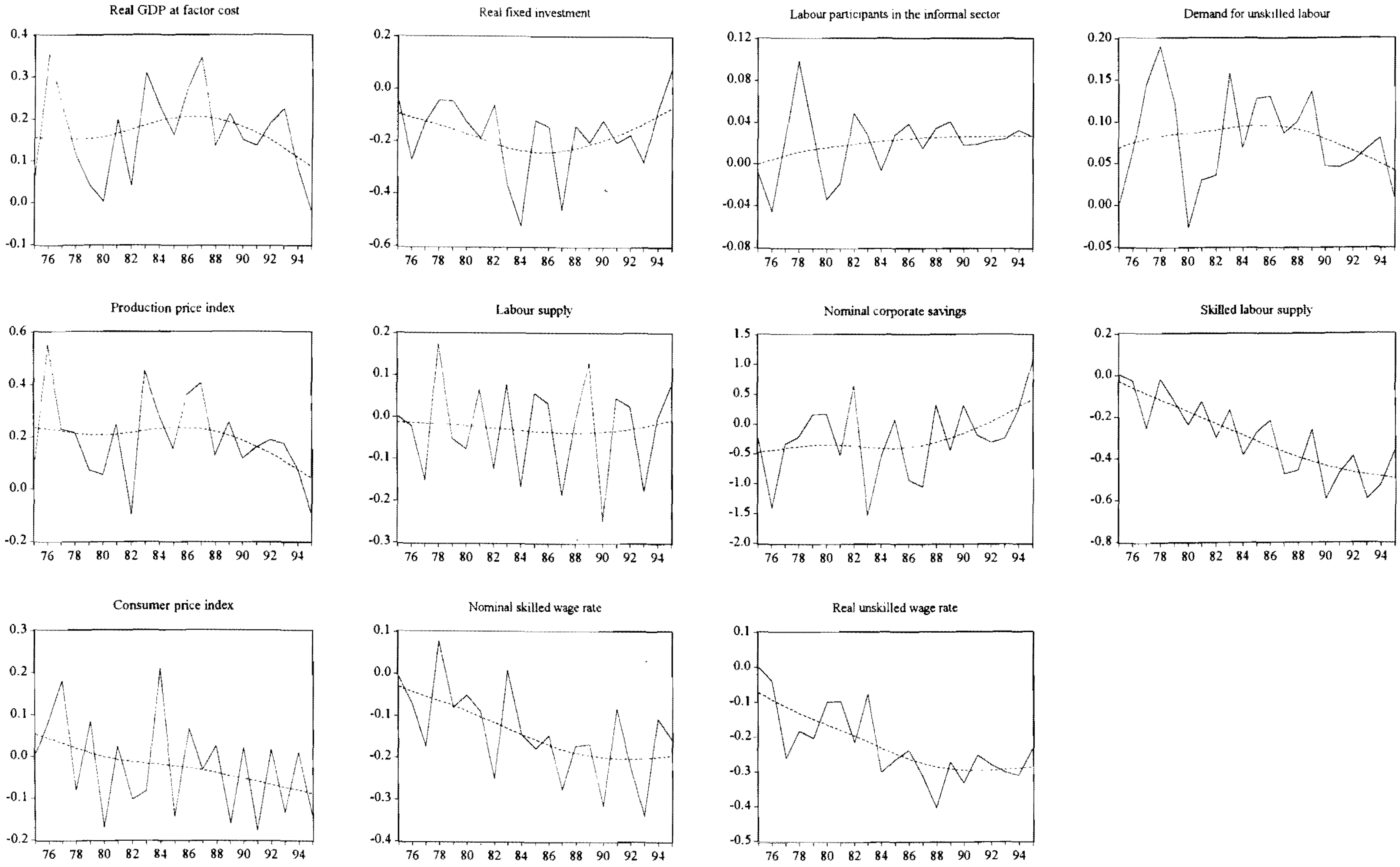
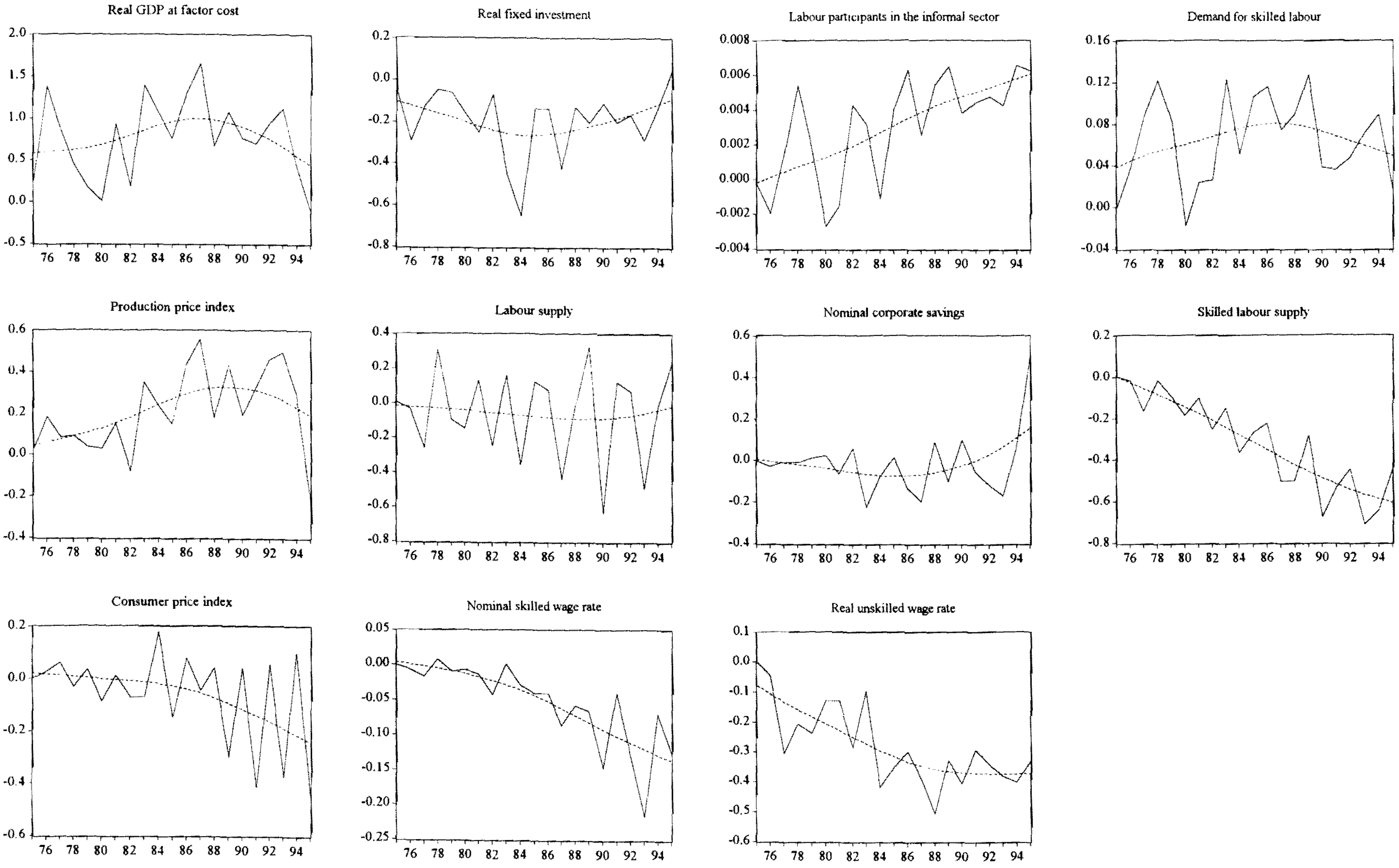


**Figure A15.5(b)** Long-run multipliers of the ful supply-side model : 1% shock to demand for unskilled labour in 1975 (actual and smoothed)


Real GDP at factor cost

Real fixed investment

Labour participants in the informal sector

Demand for skilled labour

Production price index

Labour supply

Nominal corporate savings

Skilled labour supply

Consumer price index

Nominal skilled wage rate

Real unskilled wage rate

**Figure A15.6(a) Long-run elasticities of the full supply-side model : 10% shock to labour supply (actual and smoothed)**

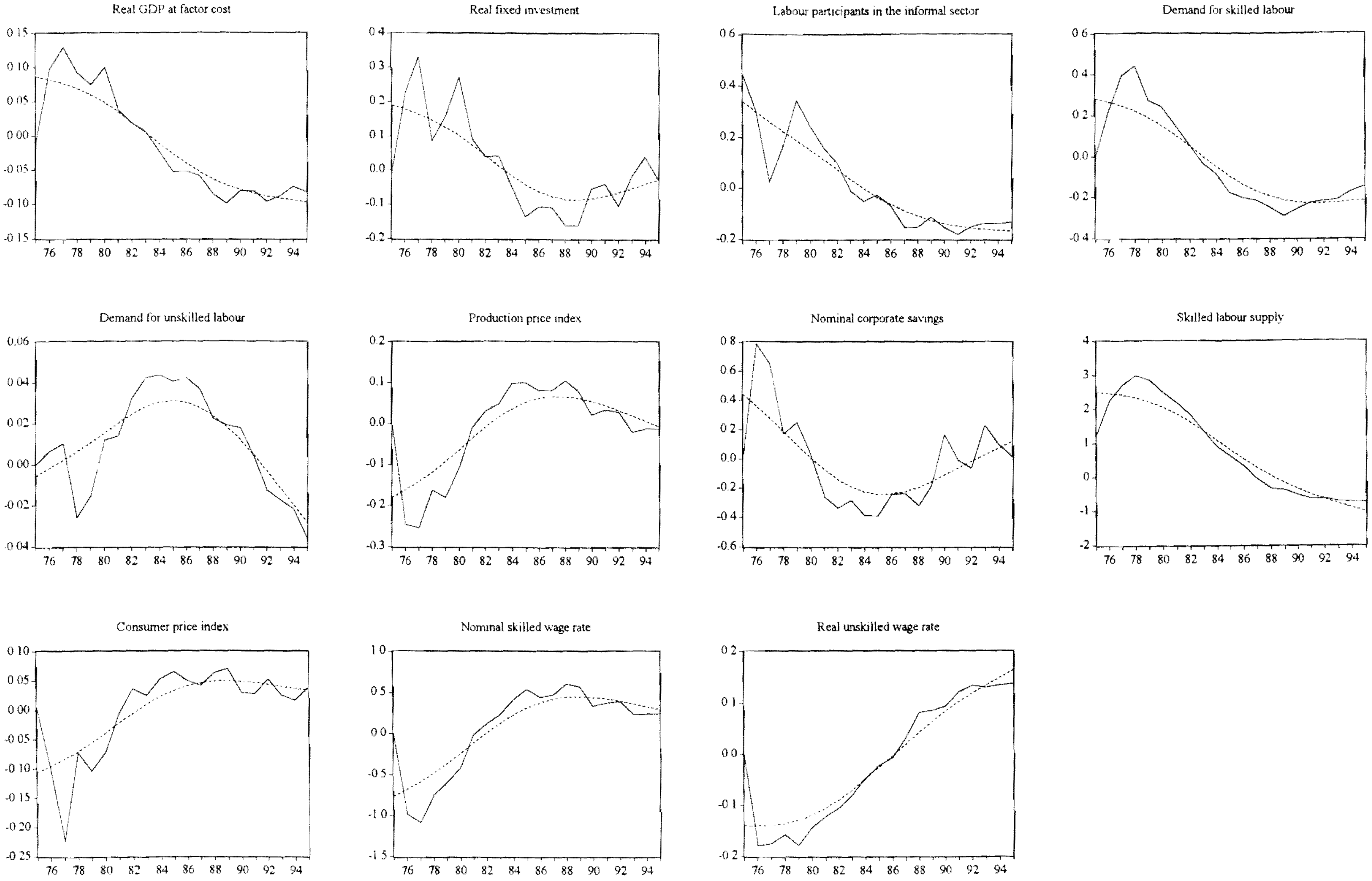


**Figure A15.6(b) Long-run multipliers of the full supply-side model : 10% shock to labour supply in 1975 (actual and smoothed)**

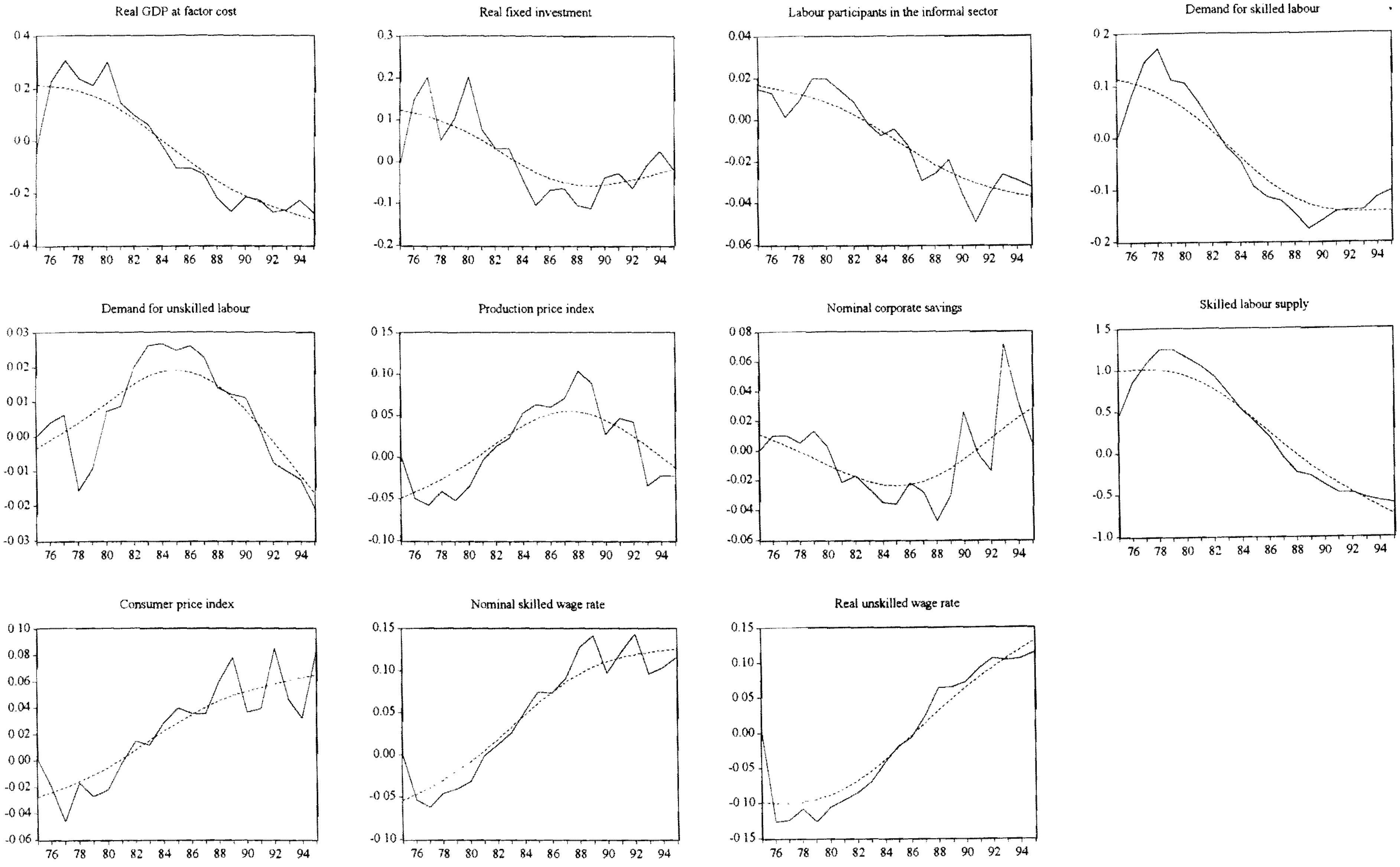


Figure 15.7(a) Long-run elasticities of the full supply-side model : 10% shock to skilled labour supply (actual and smoothed)

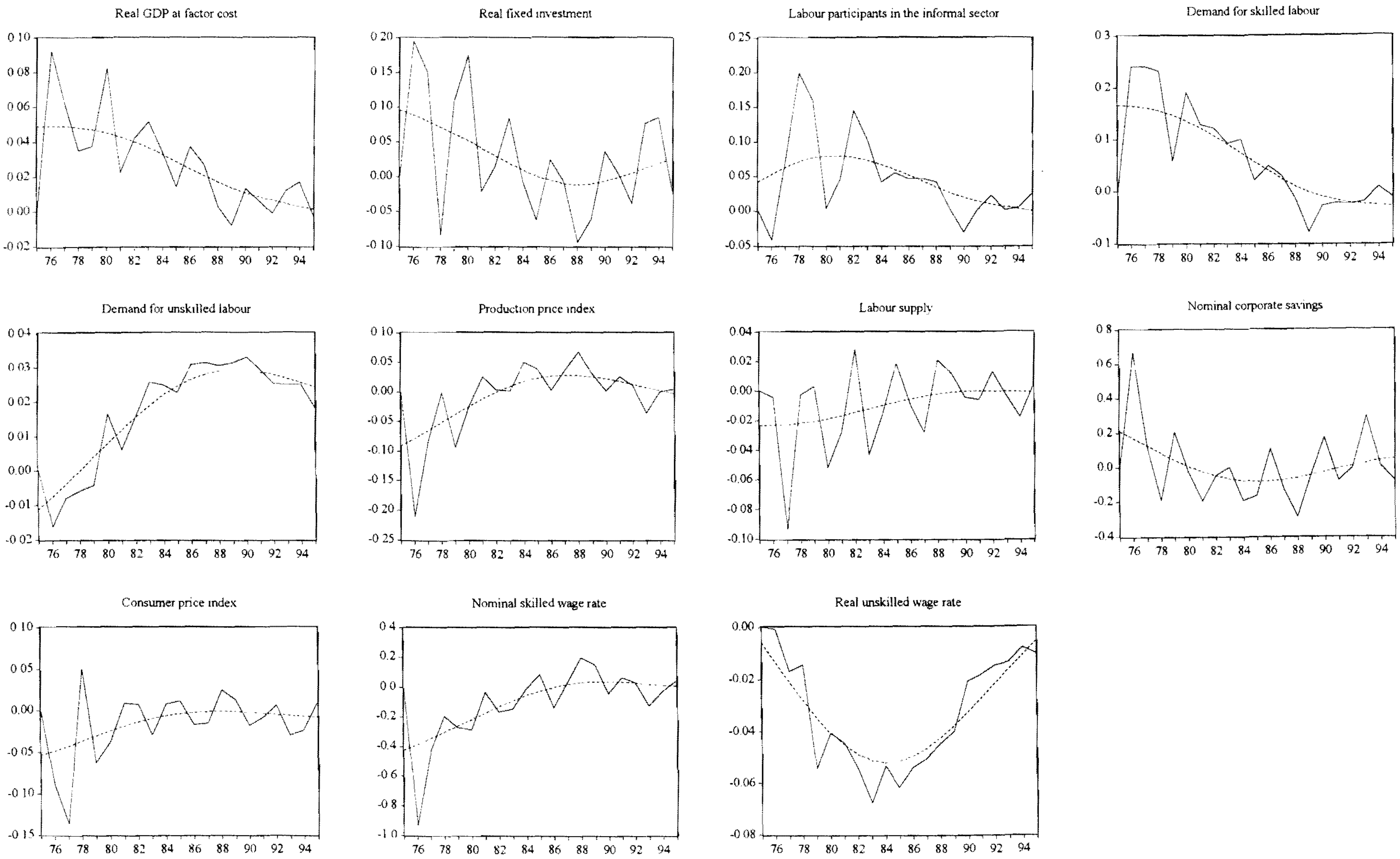
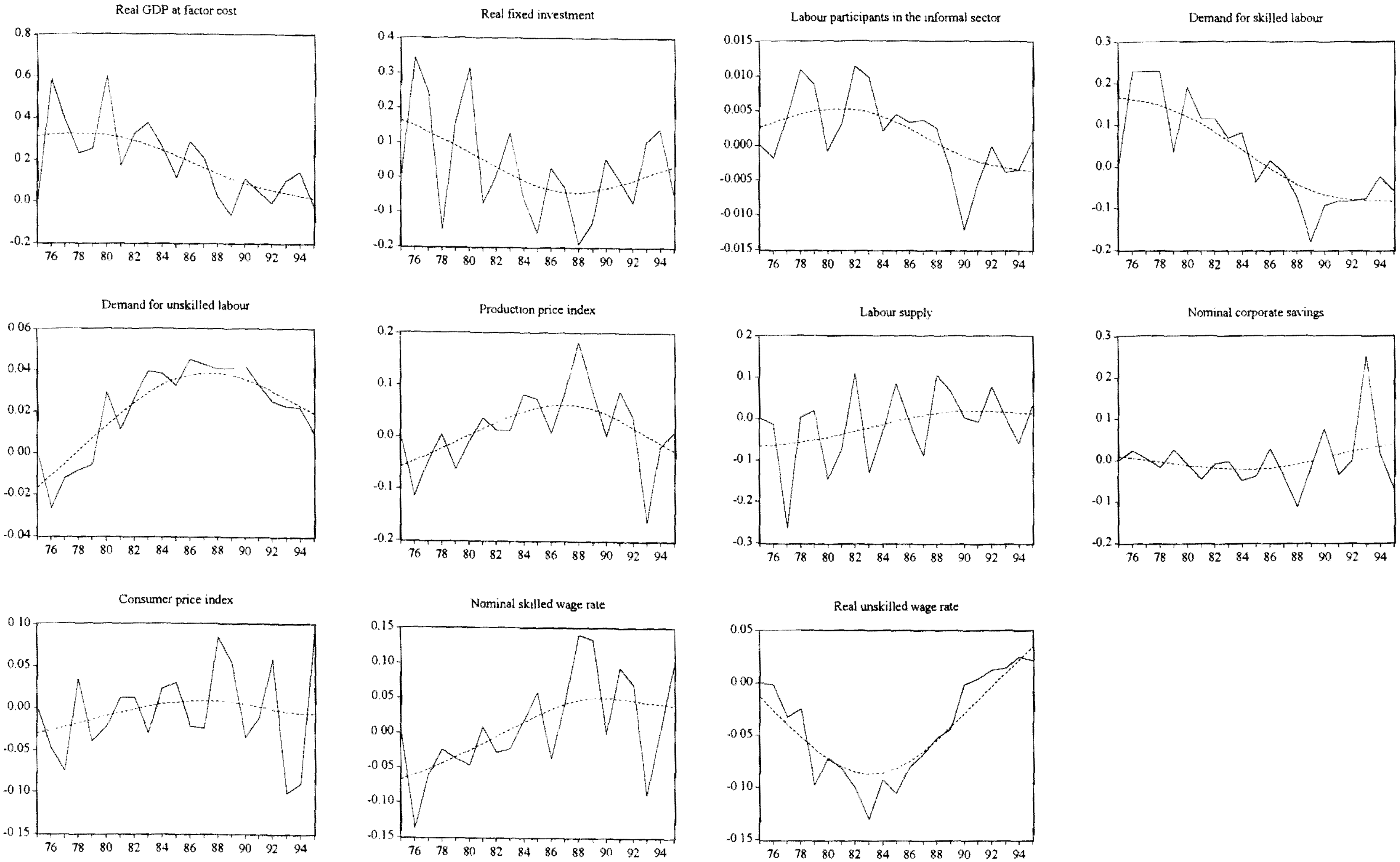


**Figure A15.7(b)** **Long-run multipliers of the full supply-side model : 10% shock to skilled labour supply in 1975 (actual and smoothed)**



Real GDP at factor cost

Real fixed investment

Labour participants in the informal sector

Demand for skilled labour

Demand for unskilled labour

Production price index

Labour supply

Nominal corporate savings

Consumer price index

Nominal skilled wage rate

Real unskilled wage rate

Figure 15.8(a) Long-run elasticities of the full supply-side model : 10% shock to nominal skilled wage rate (acutal and smoothed)

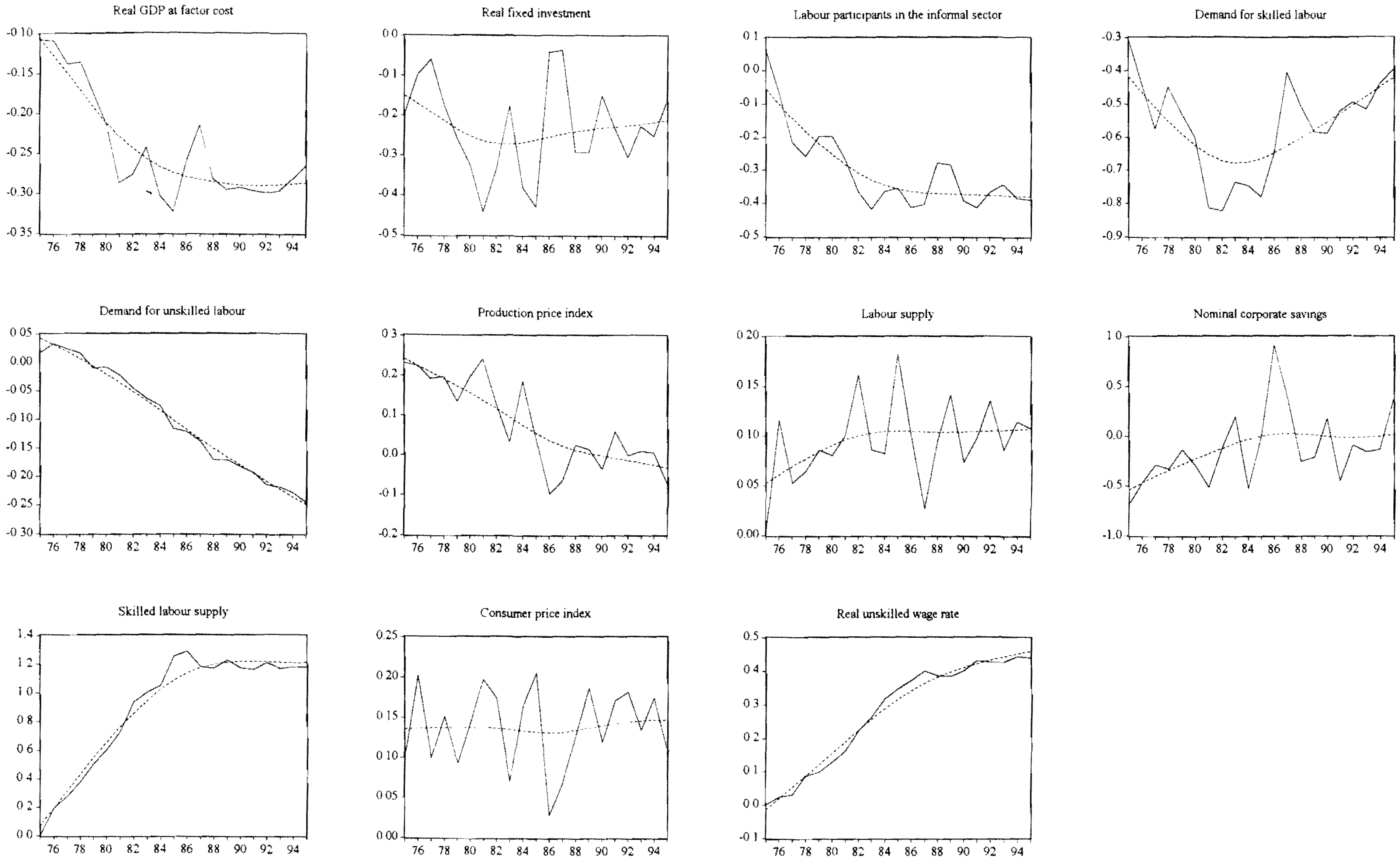


**Figure A15.8(b)** Long-run multipliers of the full supply-side model : 10% shock to nominal skilled wage rate in 1975 (actual and smoothed)

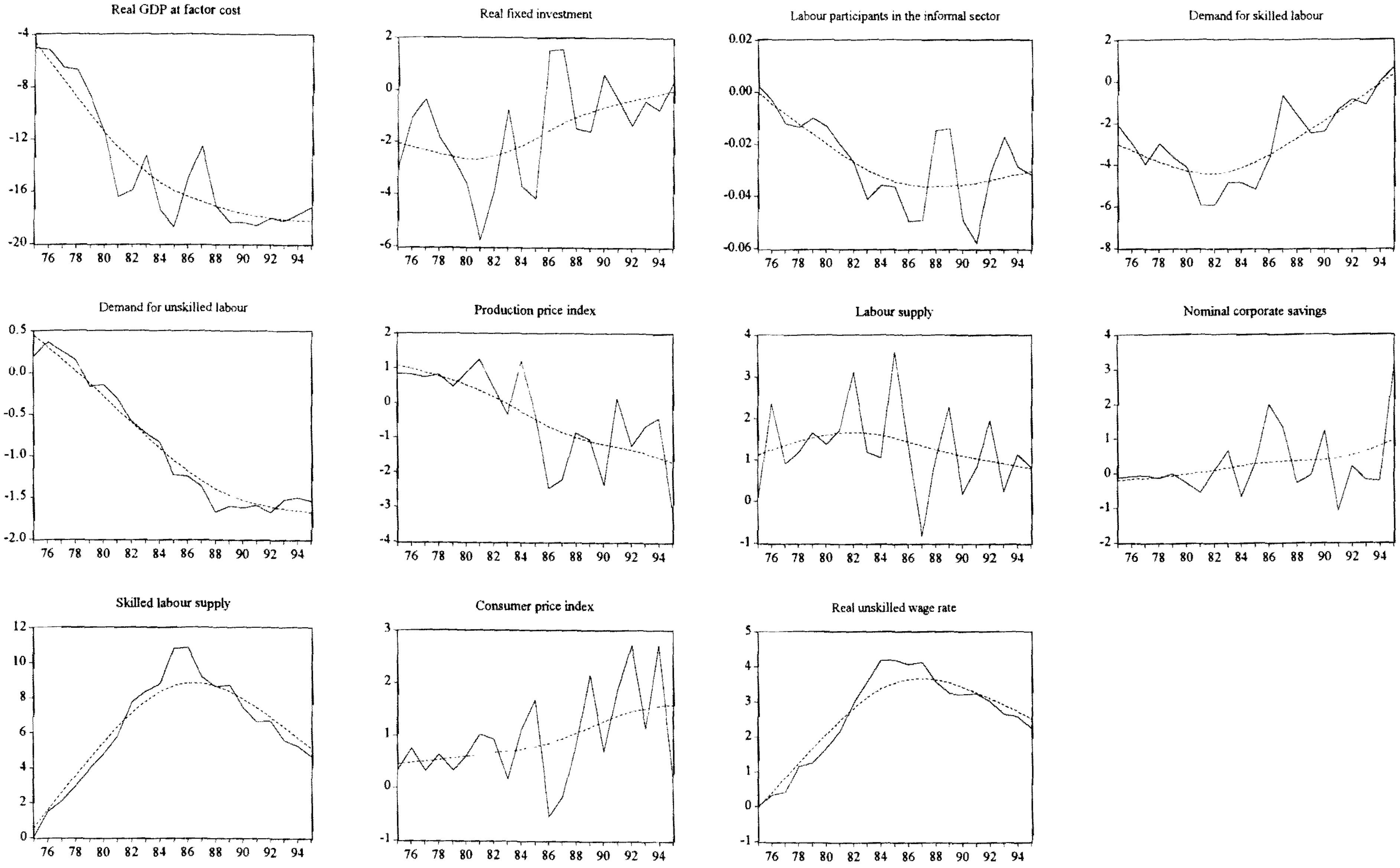


**Figure 15.9(a)** **Long-run elasticities of the full supply-side model : 1% shock to real unskilled wage rate (actual and smoothed)**

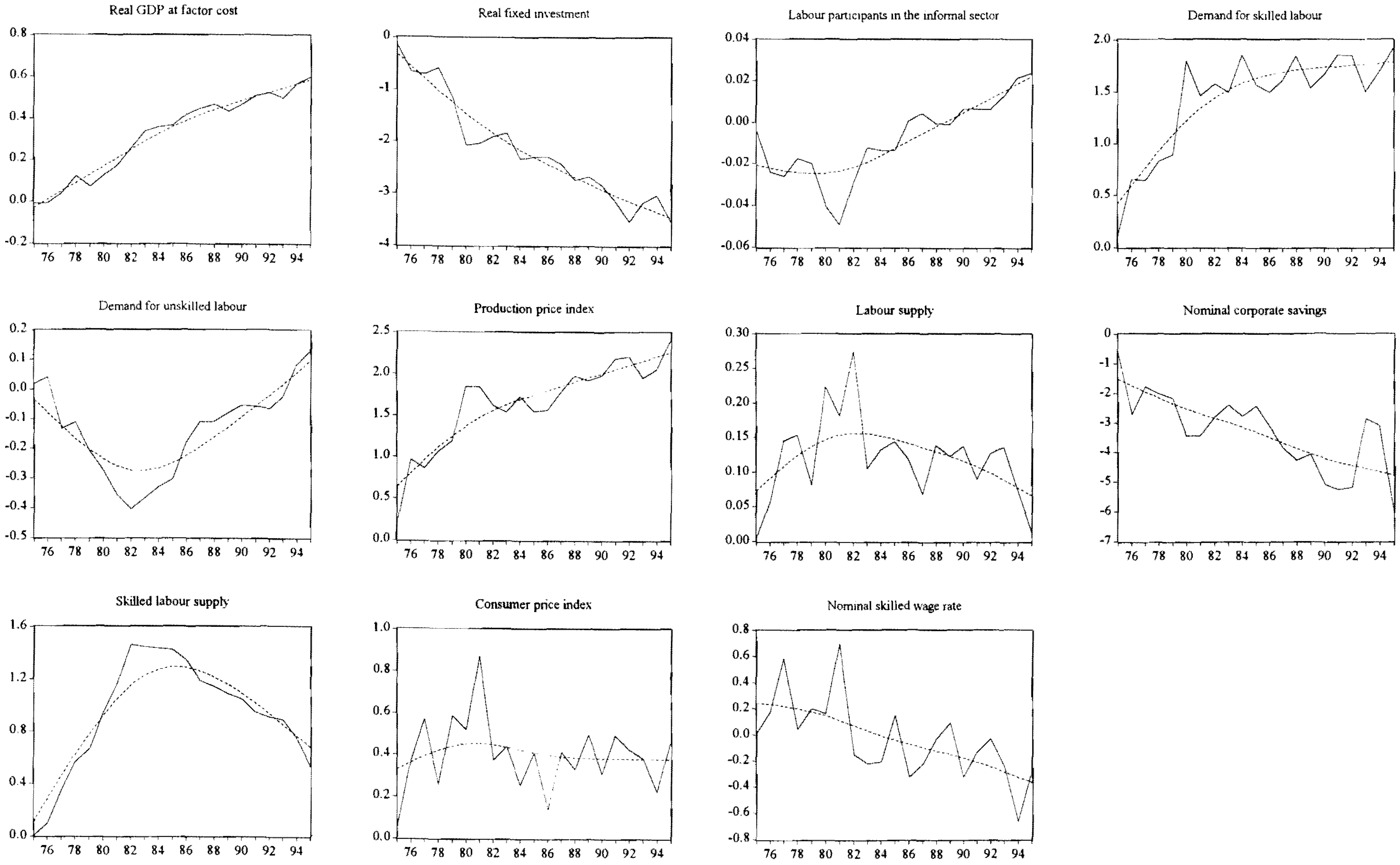


**Figure A15.9(b)** Long-run multipliers of the full supply-side model : 1% shock to real unskilled wage rate in 1975 (actual and smoothed)

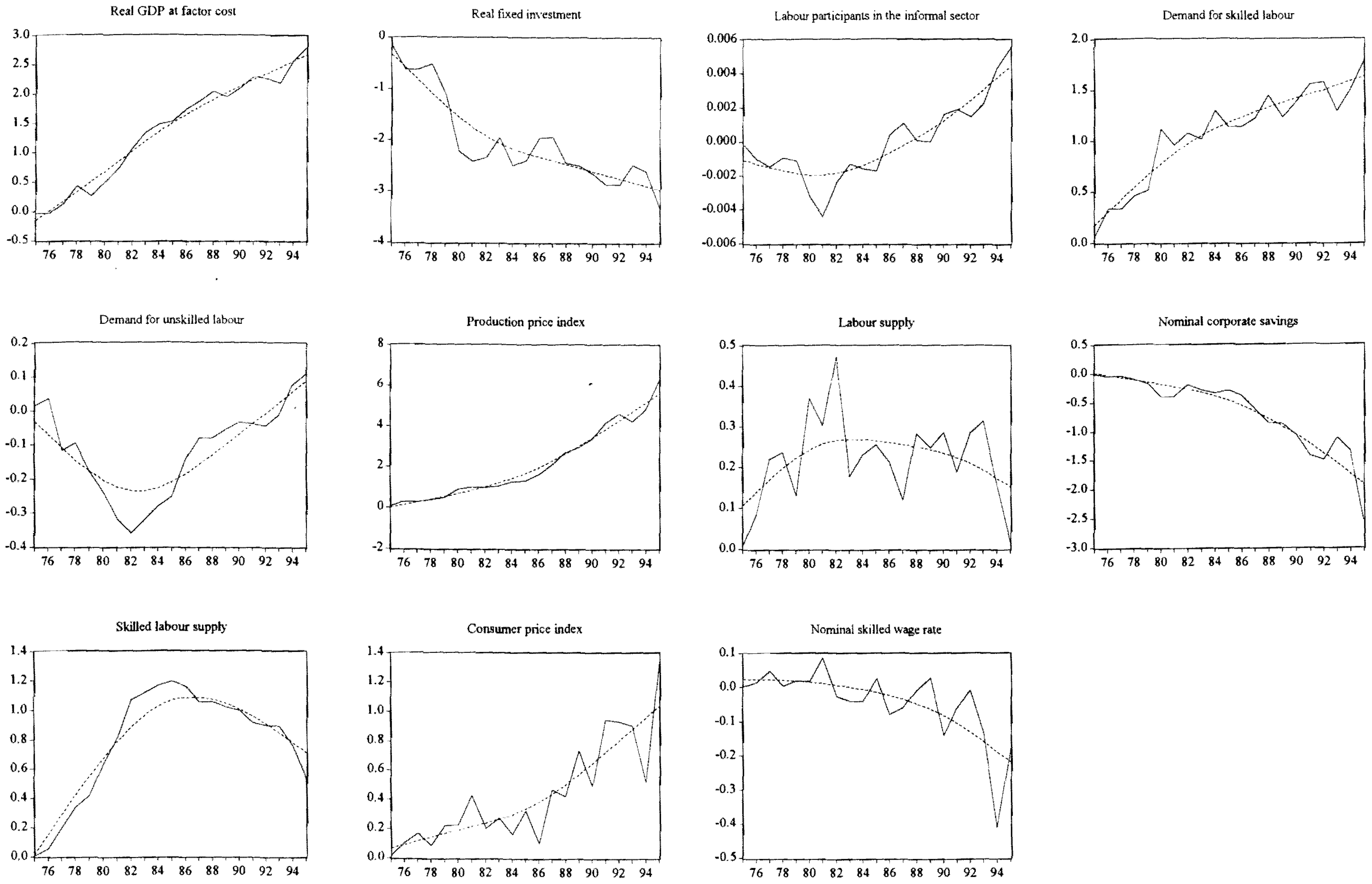


Figure A15.10(a) Long-run elasticities of the full supply-side model : 10% shock to production price-index (actual and smoothed)

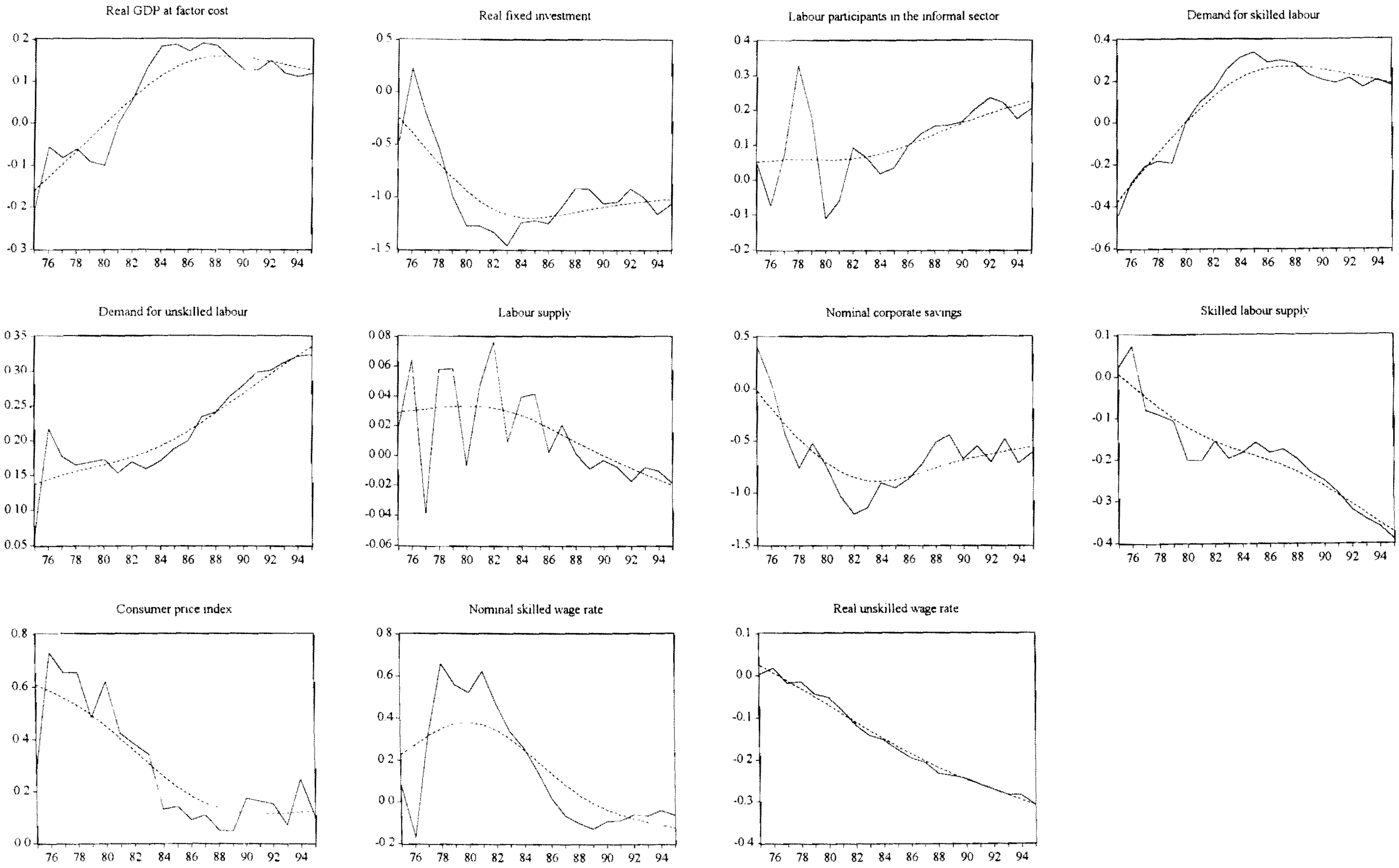


Figure A15.10(b) Long-run multipliers of the full supply-side model : 10% shock to production price index in 1975 (actual and smoothed)

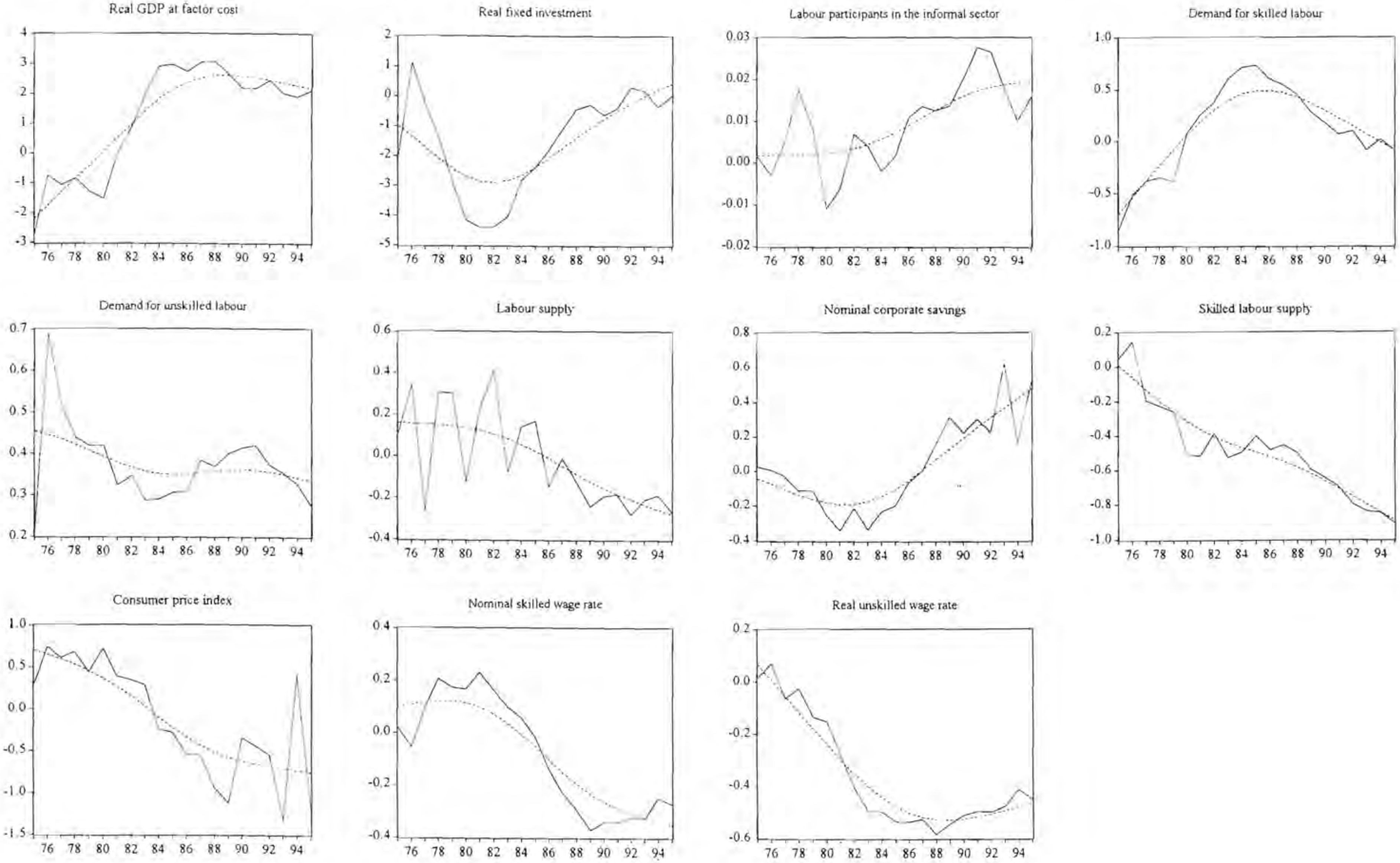


Figure 15.11(a) Long-run elasticities of the full supply-side model : 10% shock to consumer price index (actual and smoothed)

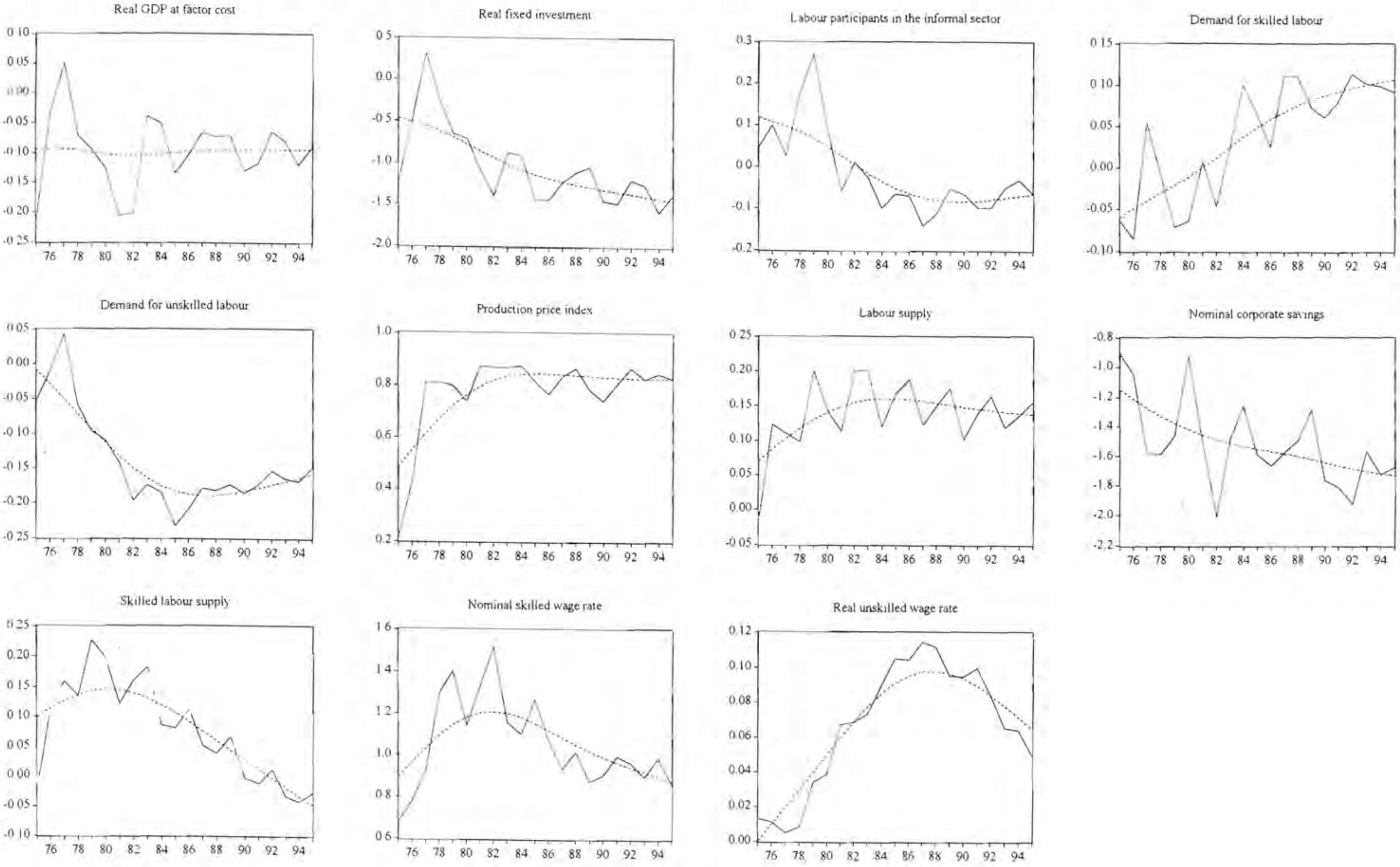


**Figure A15.11(b)** Long-run multipliers of the full supply-side model : 10% shock to consumer price index in 1975 (actual and smoothed)

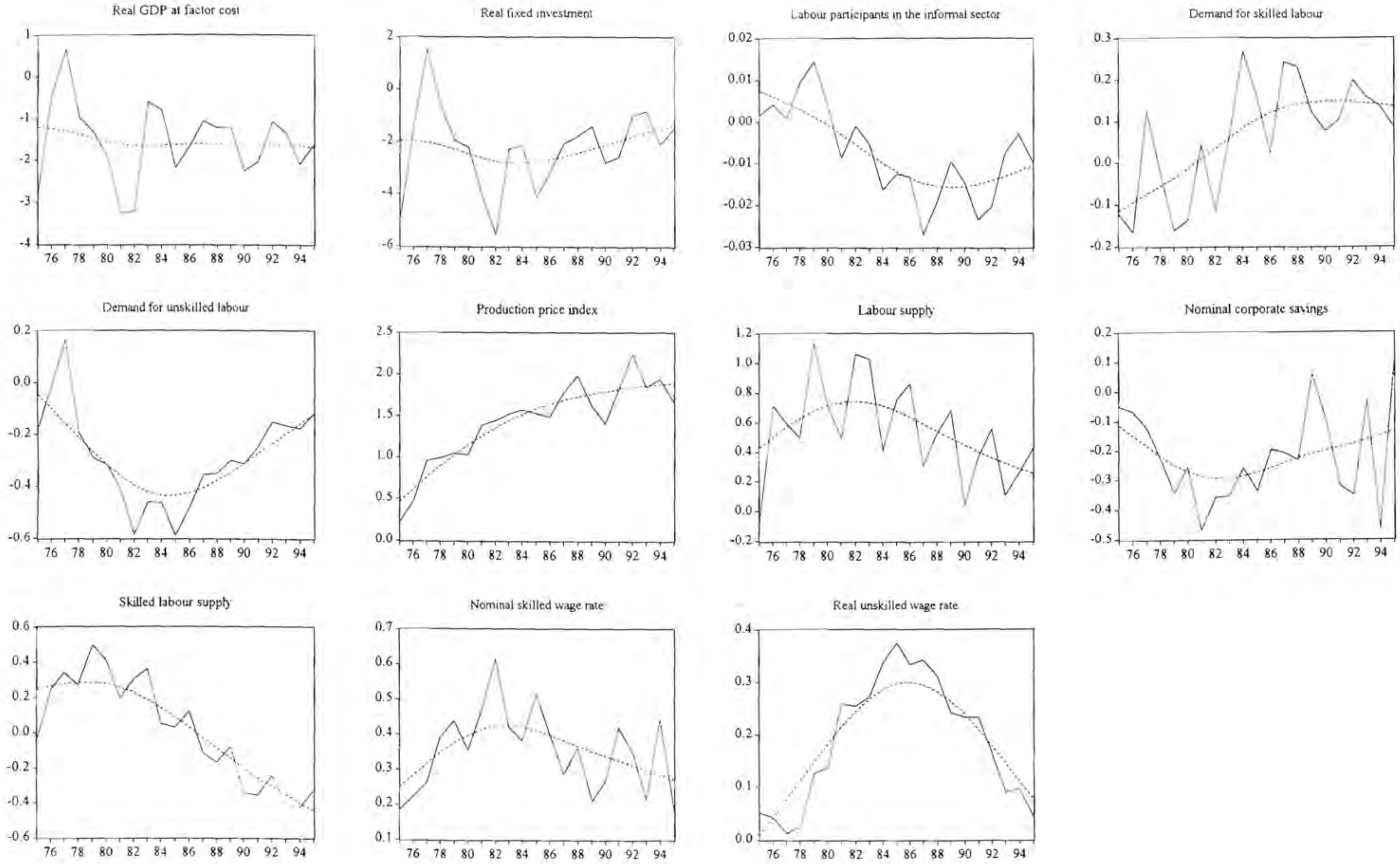


Figure A15.10(b) Long-run multipliers of the full supply-side model : 10% shock to production price index in 1975 (actual and smoothed)

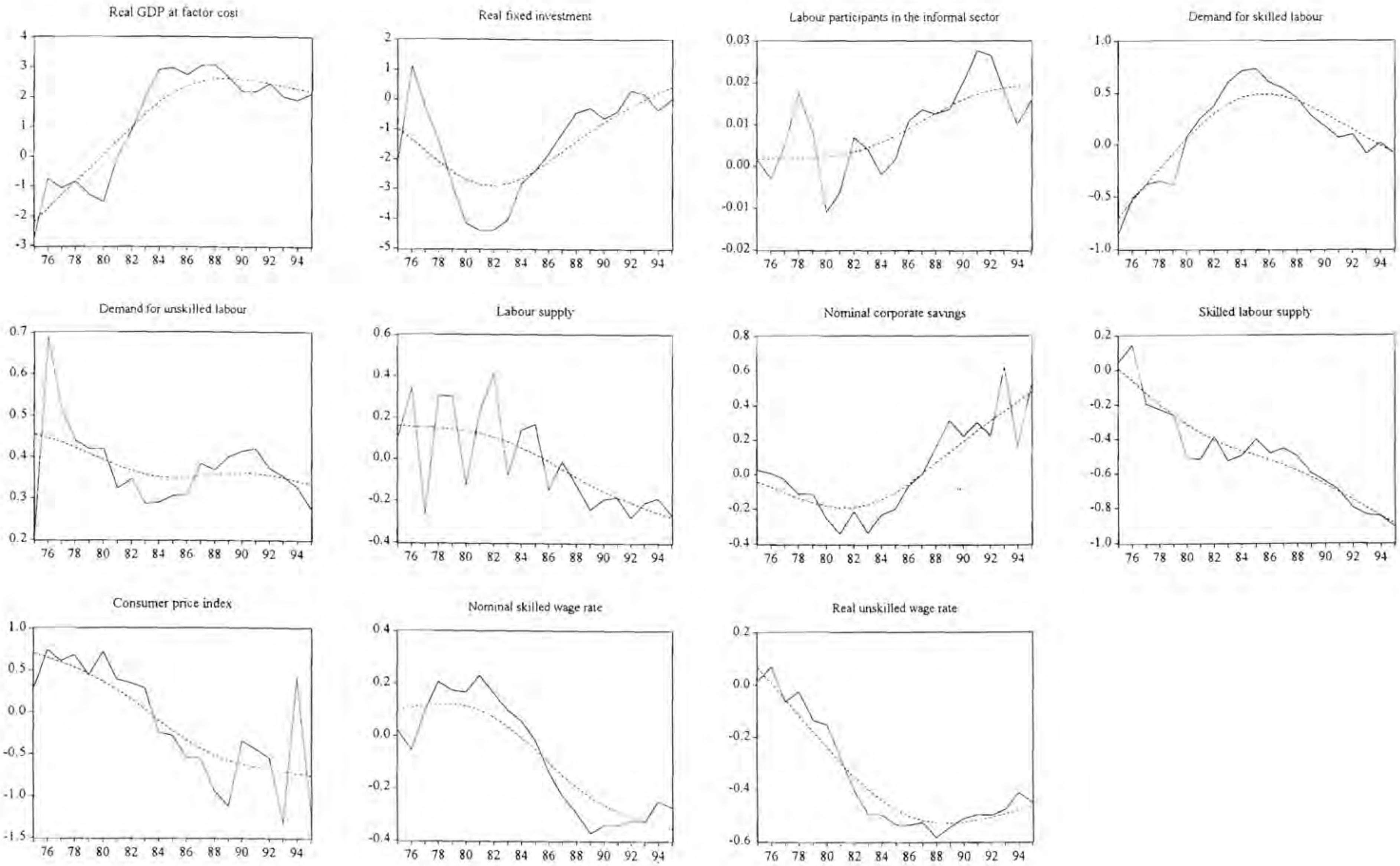


**Figure 15.11(a)** **Long-run elasticities of the full supply-side model : 10% shock to consumer price index (actual and smoothed)**

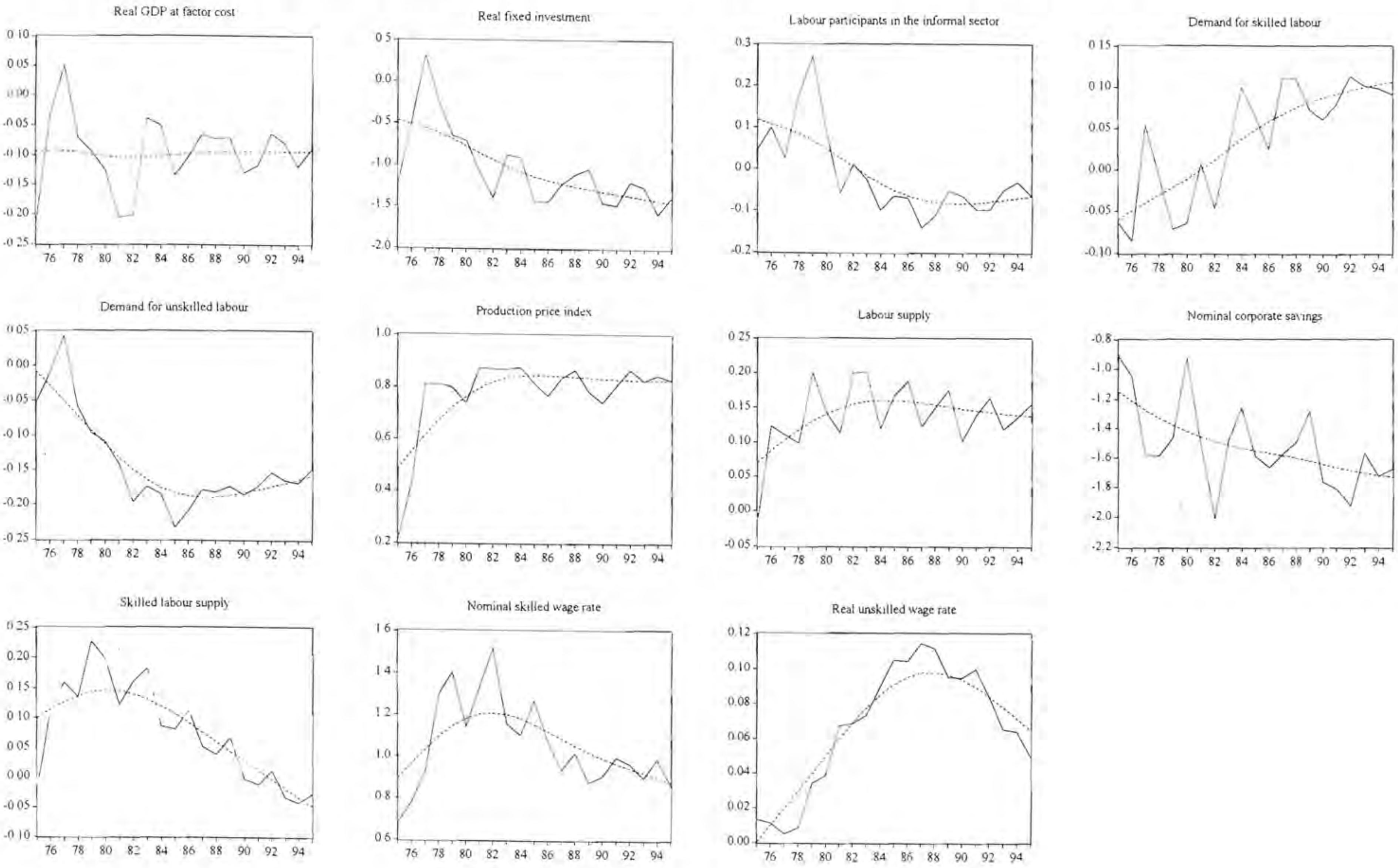
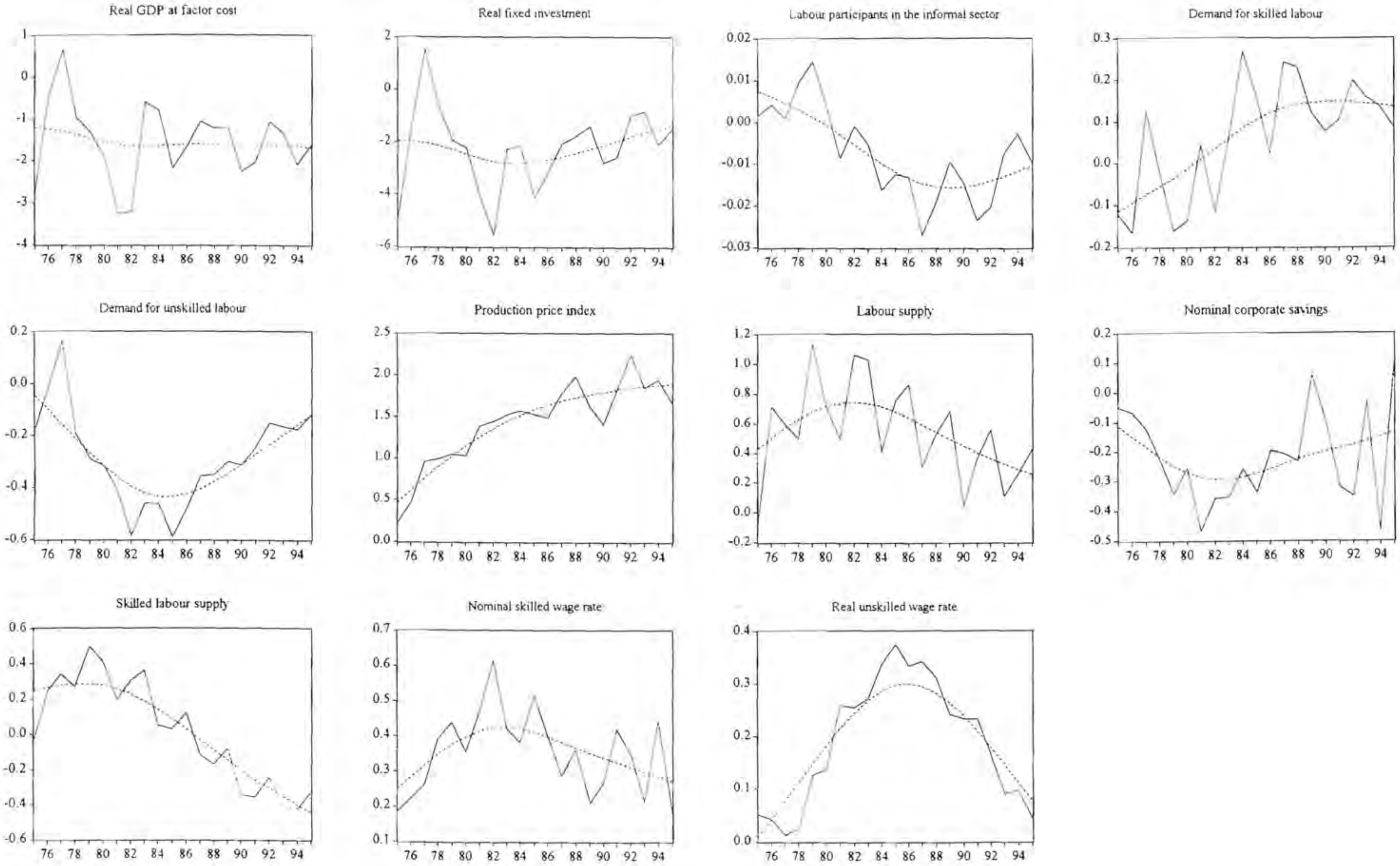


**Figure A15.11(b)** **Long-run multipliers of the full supply-side model : 10% shock to consumer price index in 1975 (actual and smoothed)**



# APPENDIX 16: POLICY SCENARIOS

Figure A16.1(a) Individual scenario 0: Baseline and shocked simulation paths

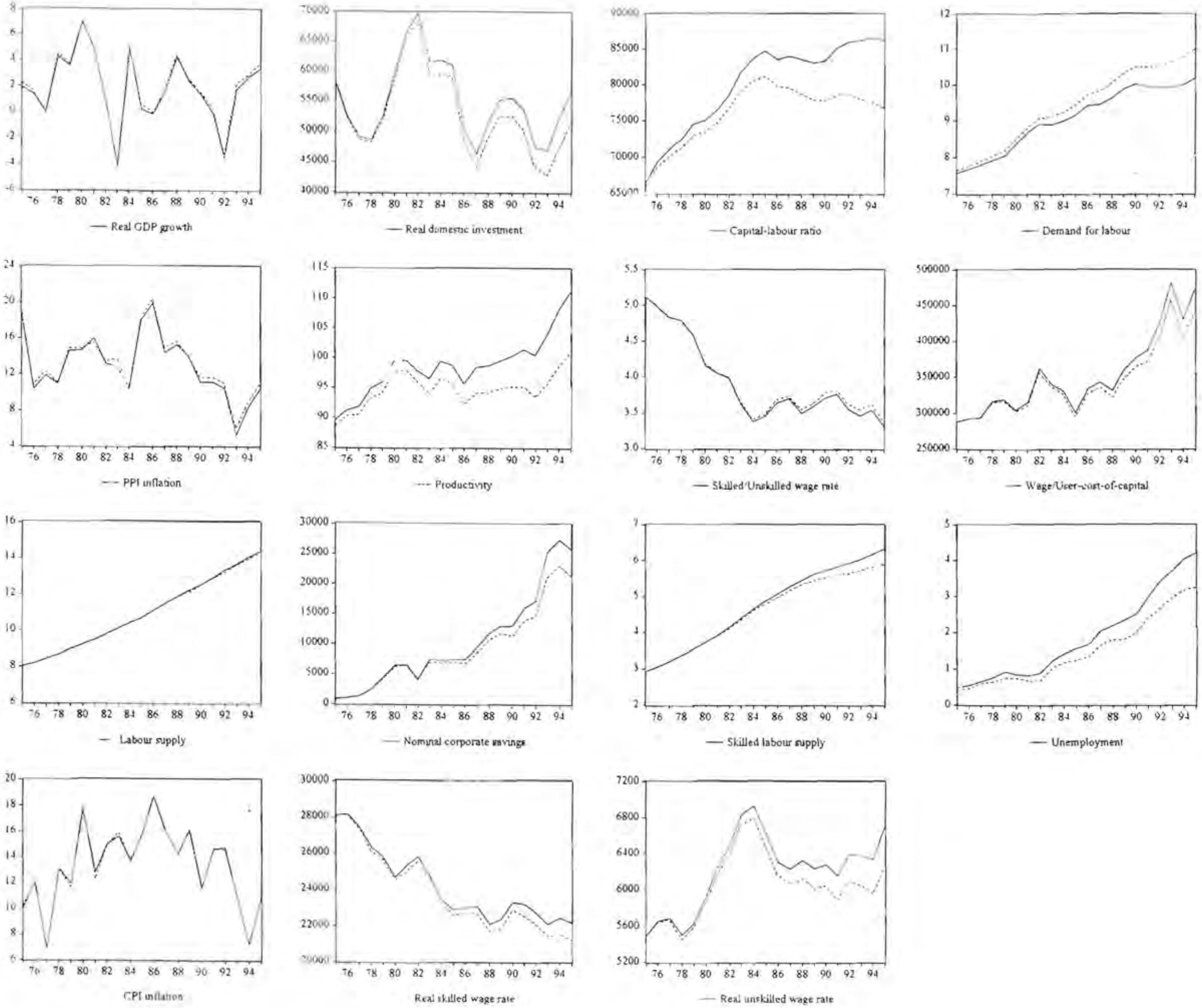


**Figure A16.1(b)** **Individual scenario 0: Percentage differences between shocked and baseline simulation paths**

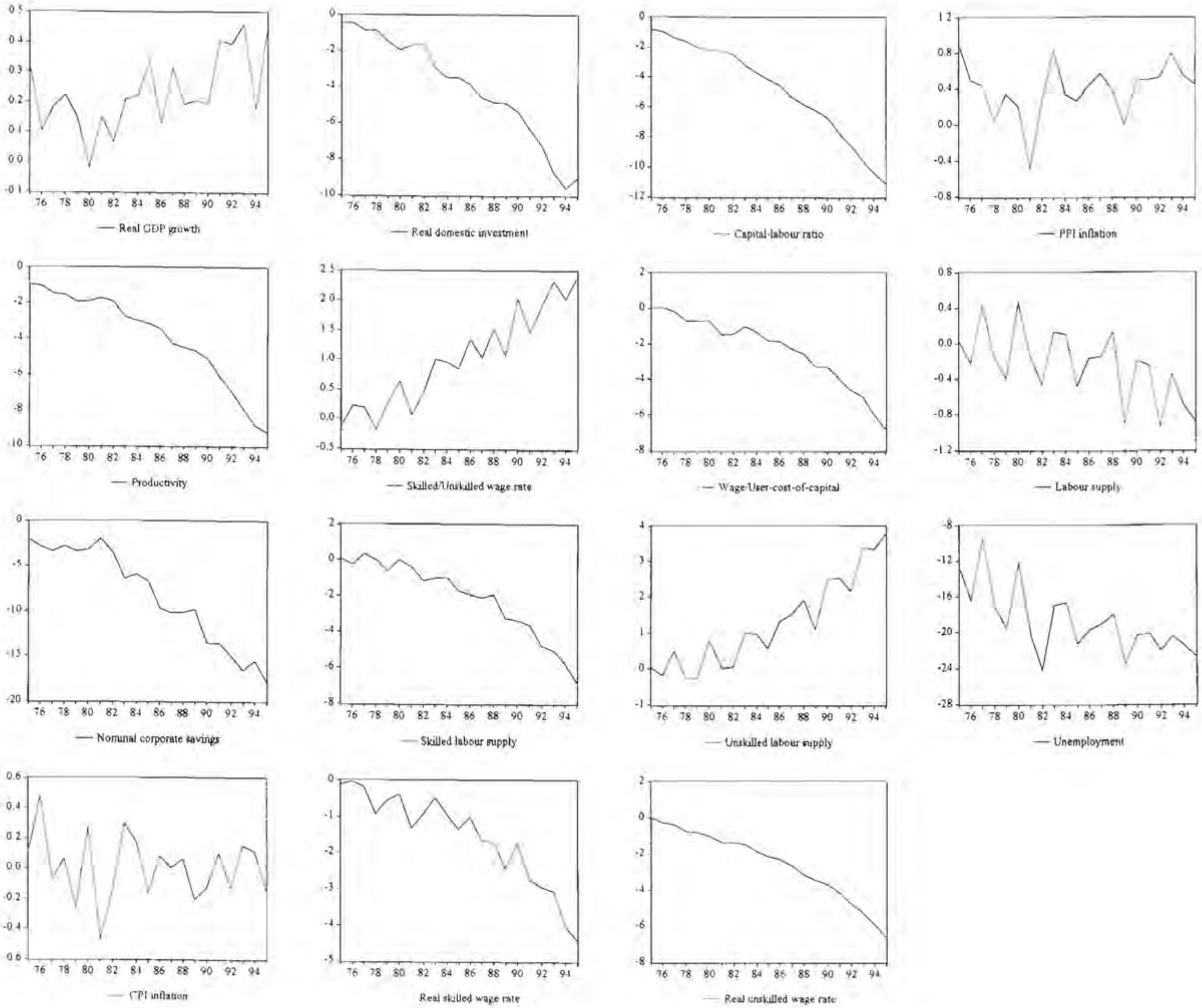


**Figure A16.2(a) Individual scenario 1: Baseline and shocked simulation paths**

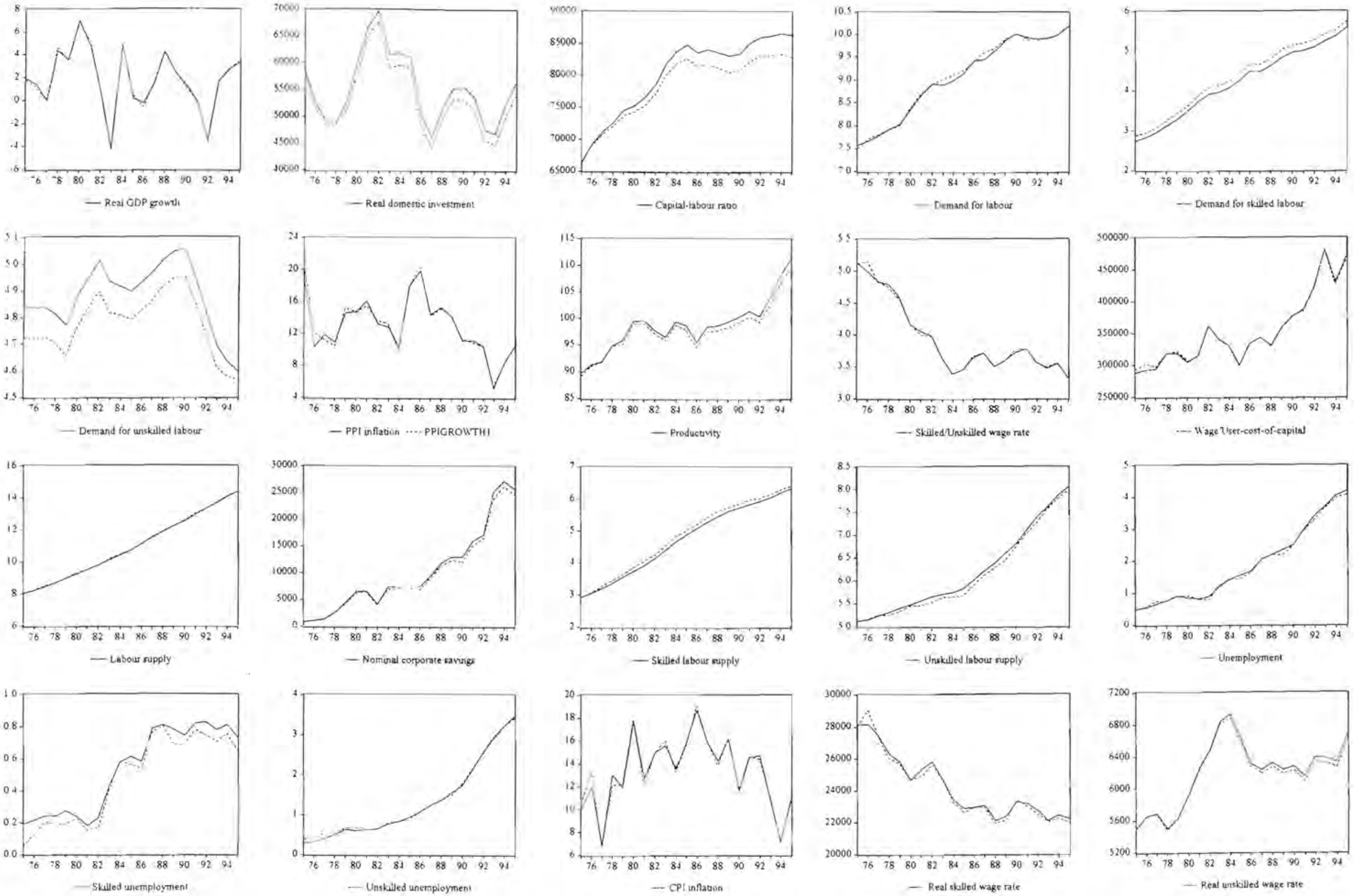


**Figure A16.2(b)** **Individual scenario 1: Percentage differences between shocked and baseline simulation paths**

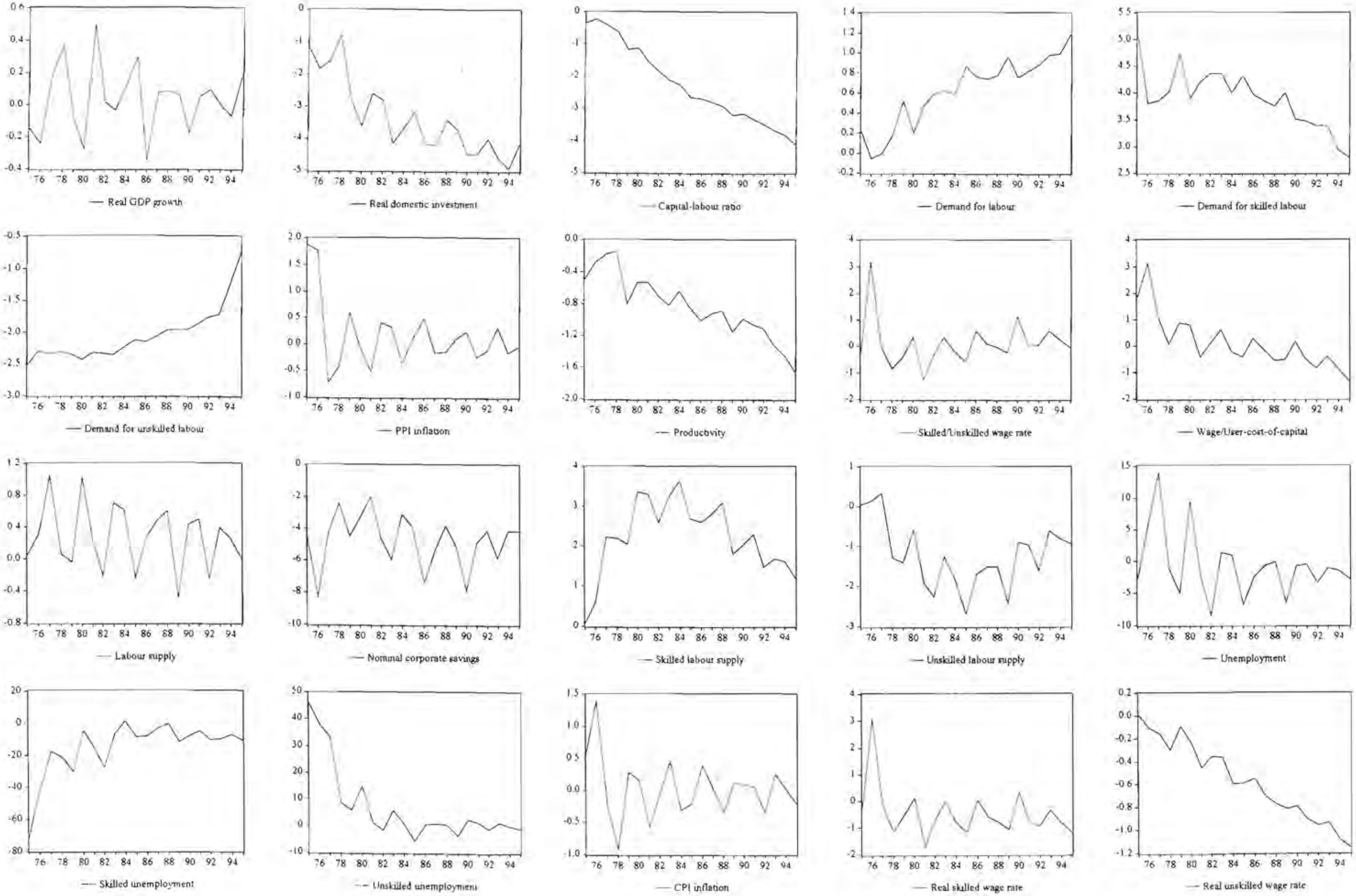


**Figure A16.3(a) Individual scenario 2: Baseline and shocked simulation paths**

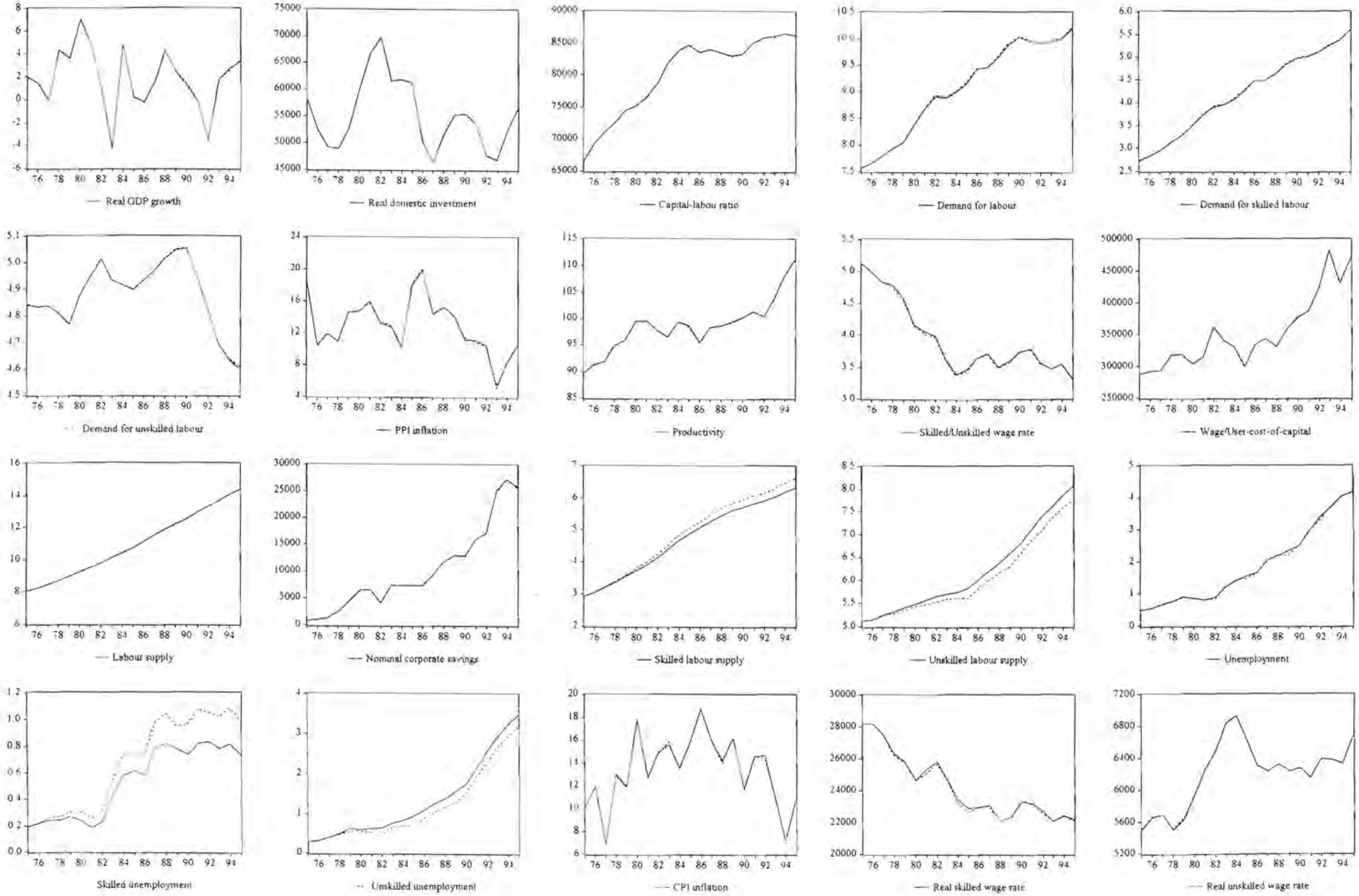
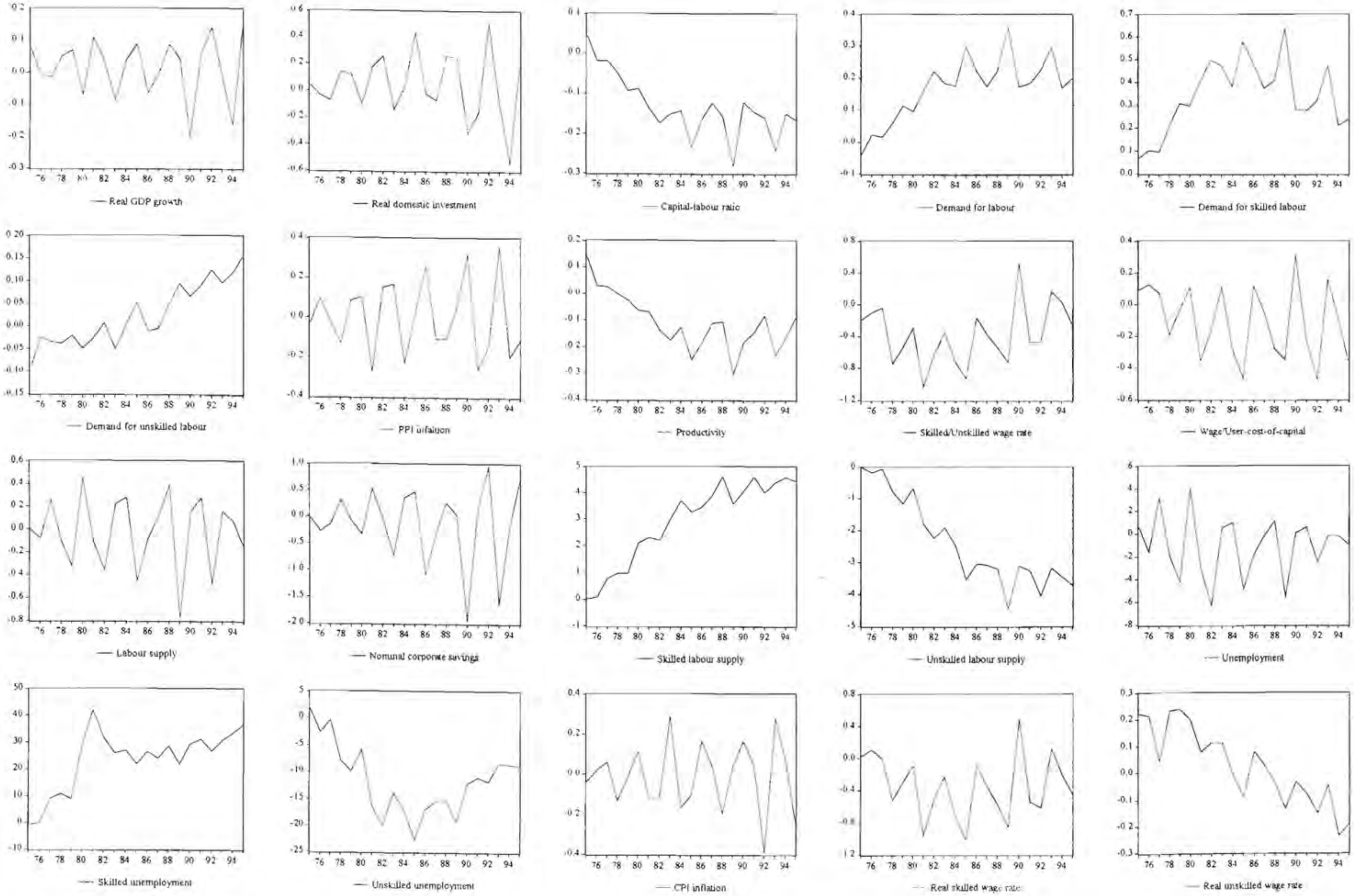


**Figure A16.3(b)** Individual scenario 2: Percentage differences betwen shocked and baseline simulation paths



FigureA16.4(a) Individual scenario 3: Baseline and shocked simulation paths

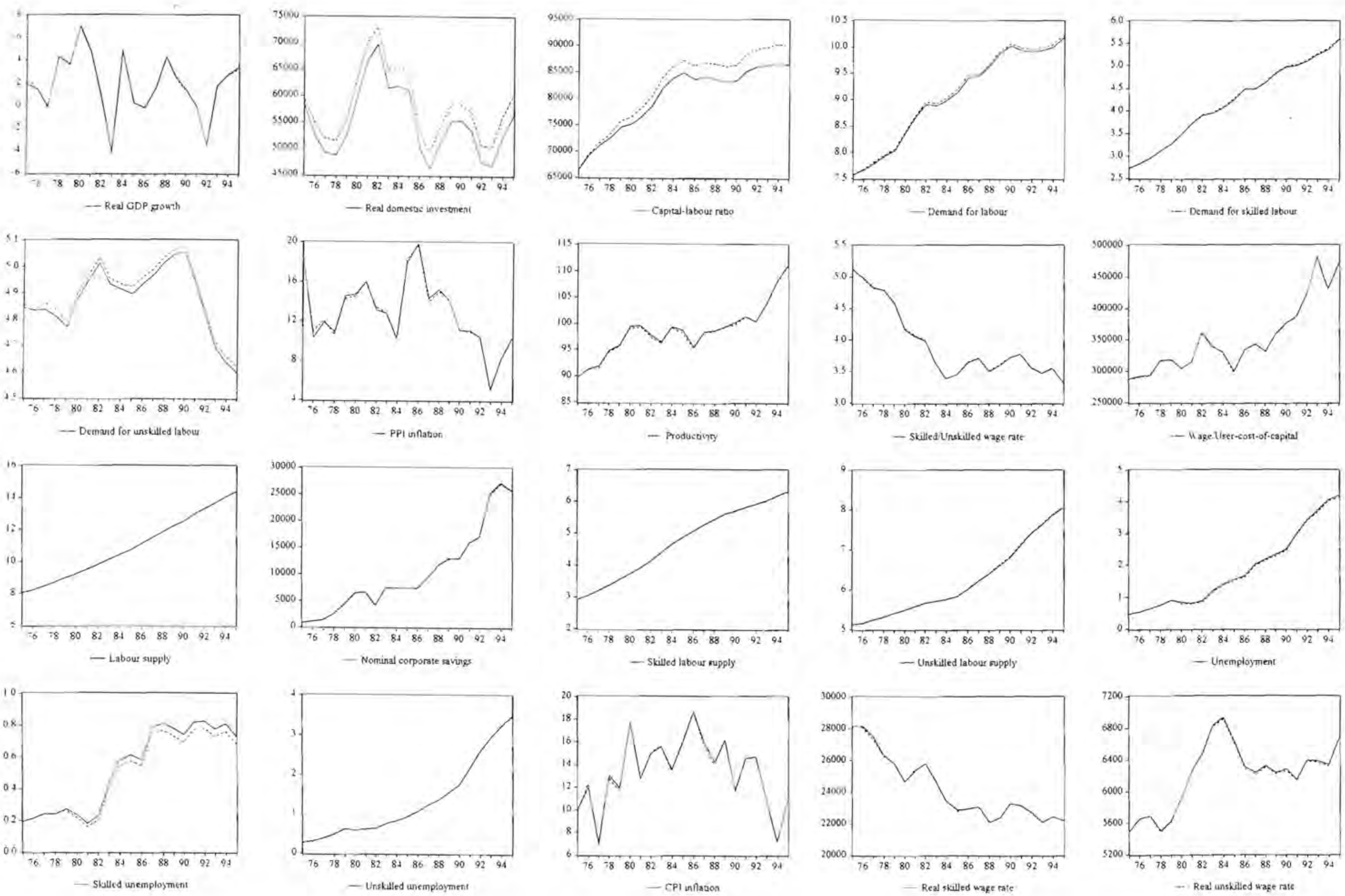


Figure A16.4(b) Individual scenario 3: Percentage differences between shocked and baseline simulation paths

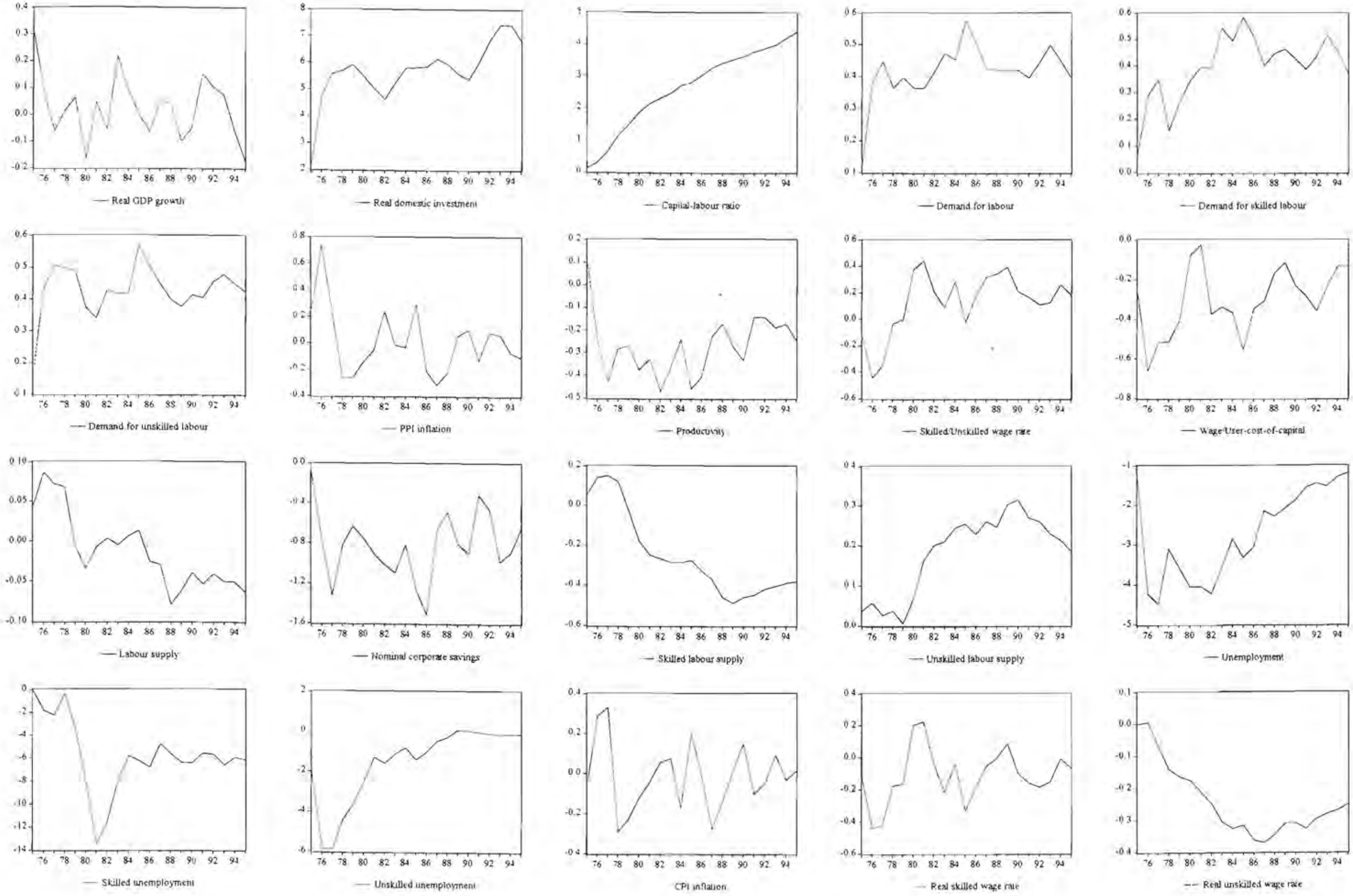


**Figure A16.5(a) Individual scenario 4: Baseline and shocked simulation paths**

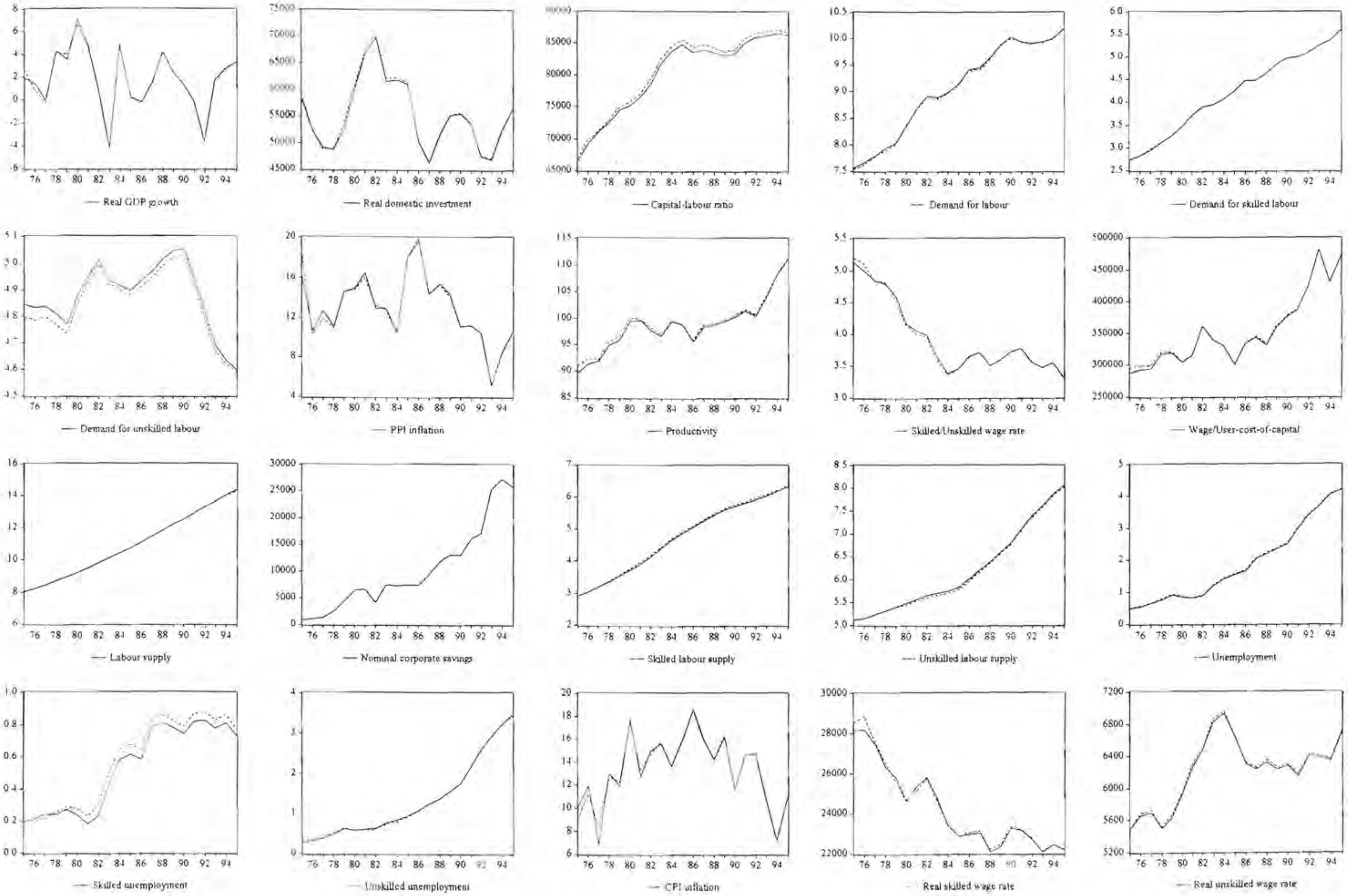


Figure A16.5(b) Individual scenario 4: Percentage differences between baseline and shocked simulation paths

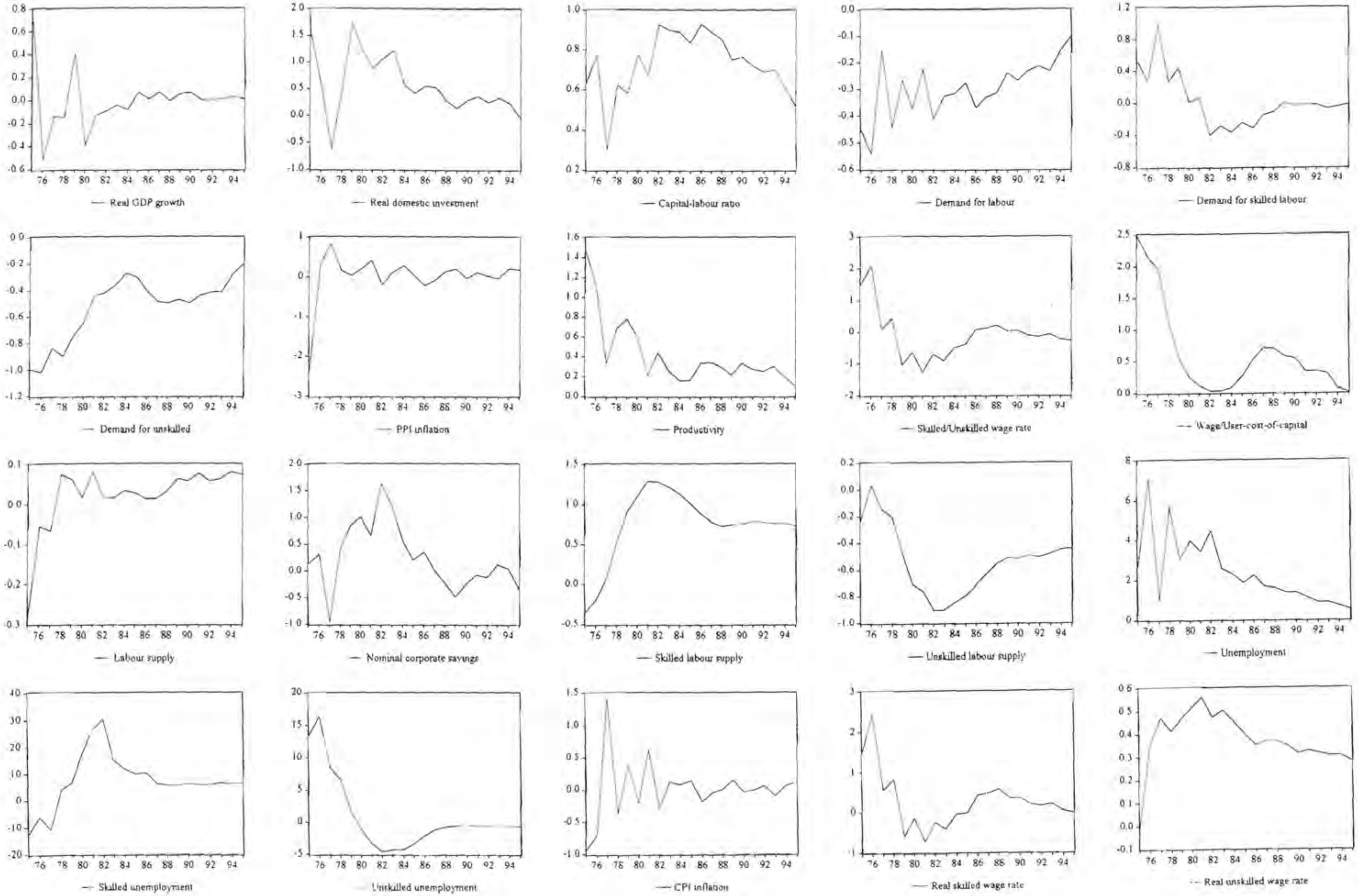
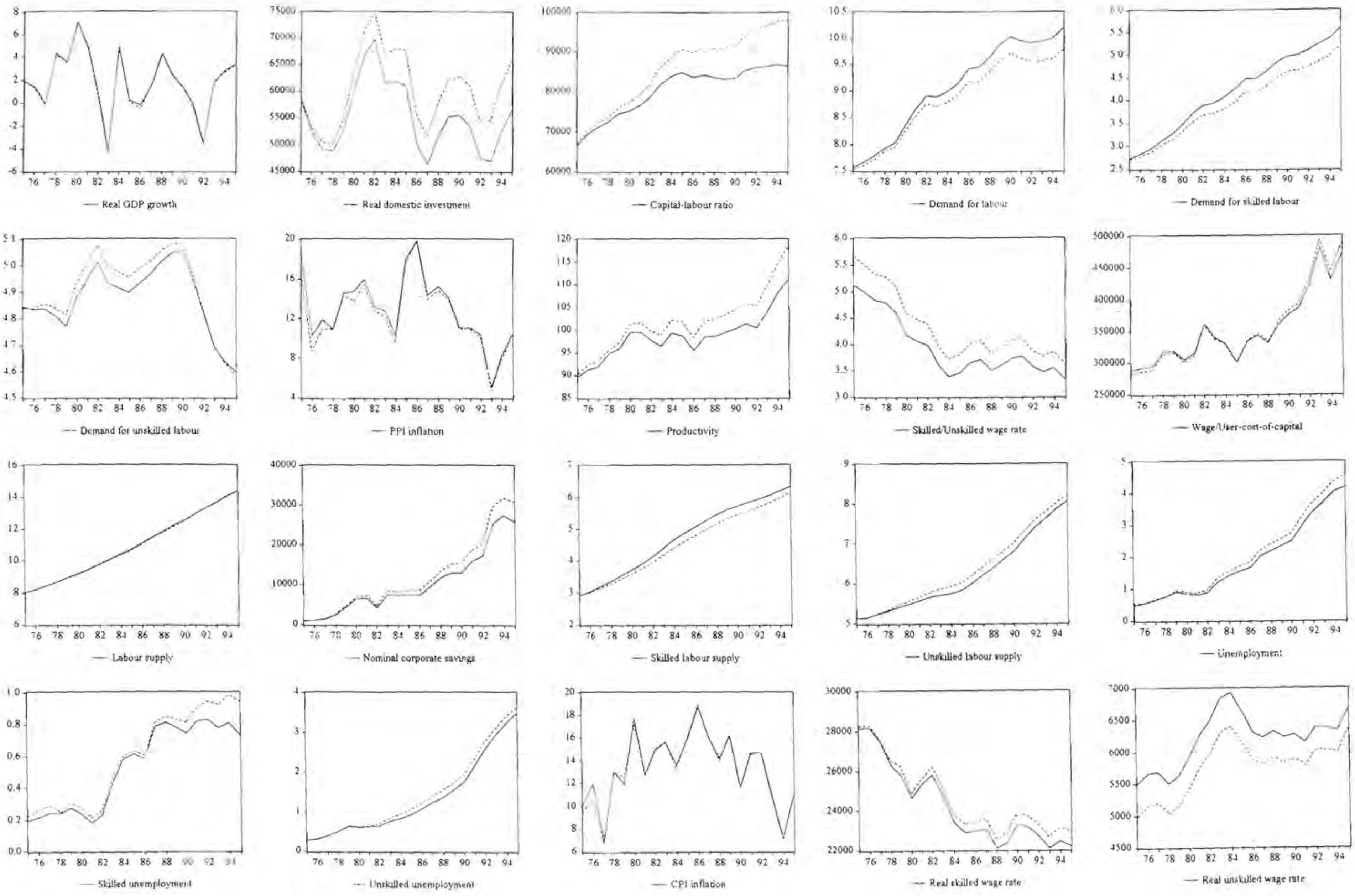


**Figure A16.6(a) Individual scenario 5: Baseline and shocked simulation paths**



— Real GDP growth

— Real domestic investment

— Capital-labour ratio

— Demand for labour

— Demand for skilled labour

— Demand for unskilled labour

— PPI inflation

— Productivity

— Skilled/Unskilled wage rate

— Wage/User-cost-of-capital

— Labour supply

— Nominal corporate savings

— Skilled labour supply

— Unskilled labour supply

— Unemployment

— Skilled unemployment

— Unskilled unemployment

— CPI inflation

— Real skilled wage rate

— Real unskilled wage rate

**Figure A16.6(b)** Individual scenario 5: Percentage differences between baseline and shocked simulation paths

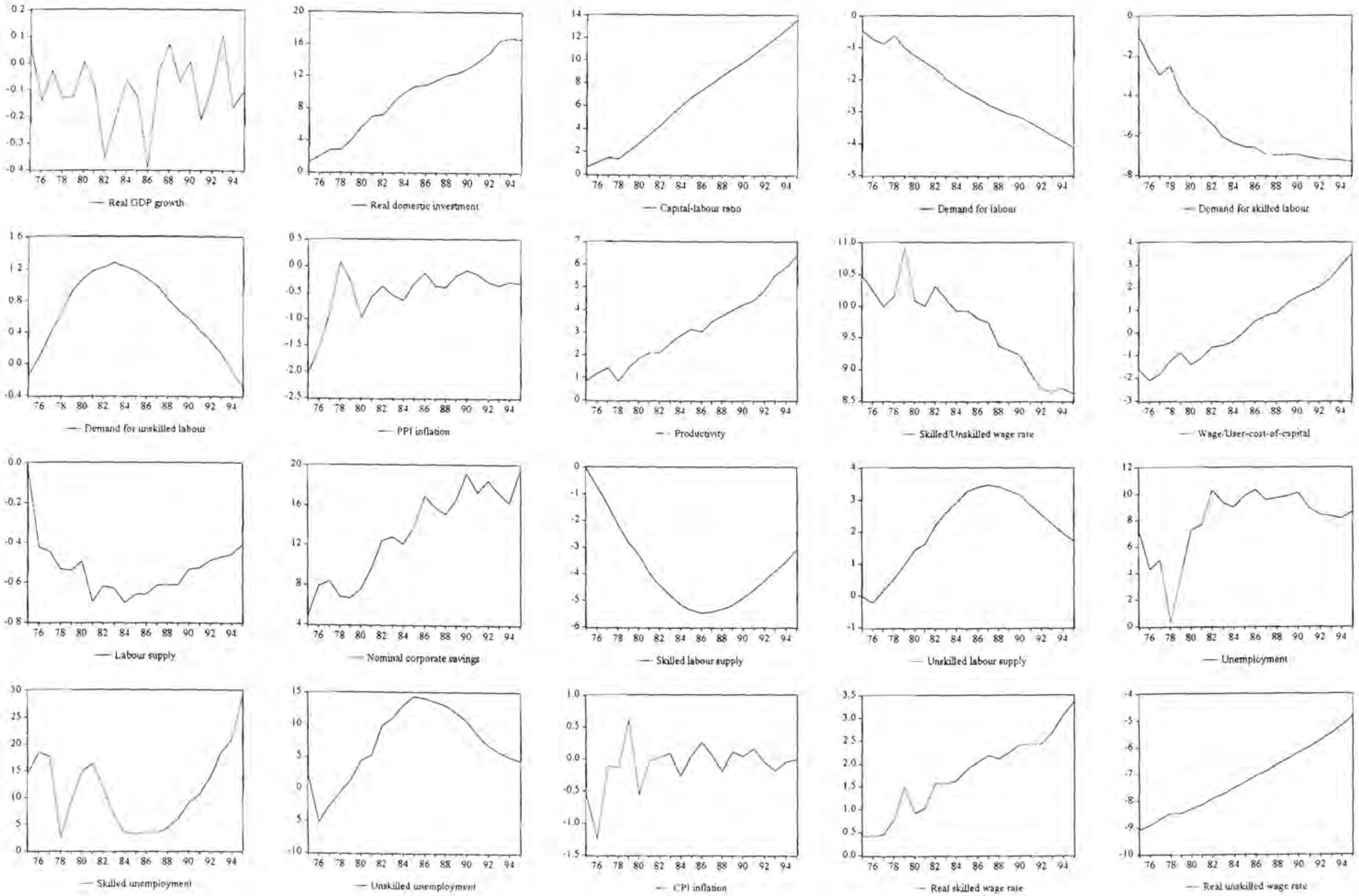


Figure A16.7(a) Individual scenario 6: Baseline and shocked simulation paths

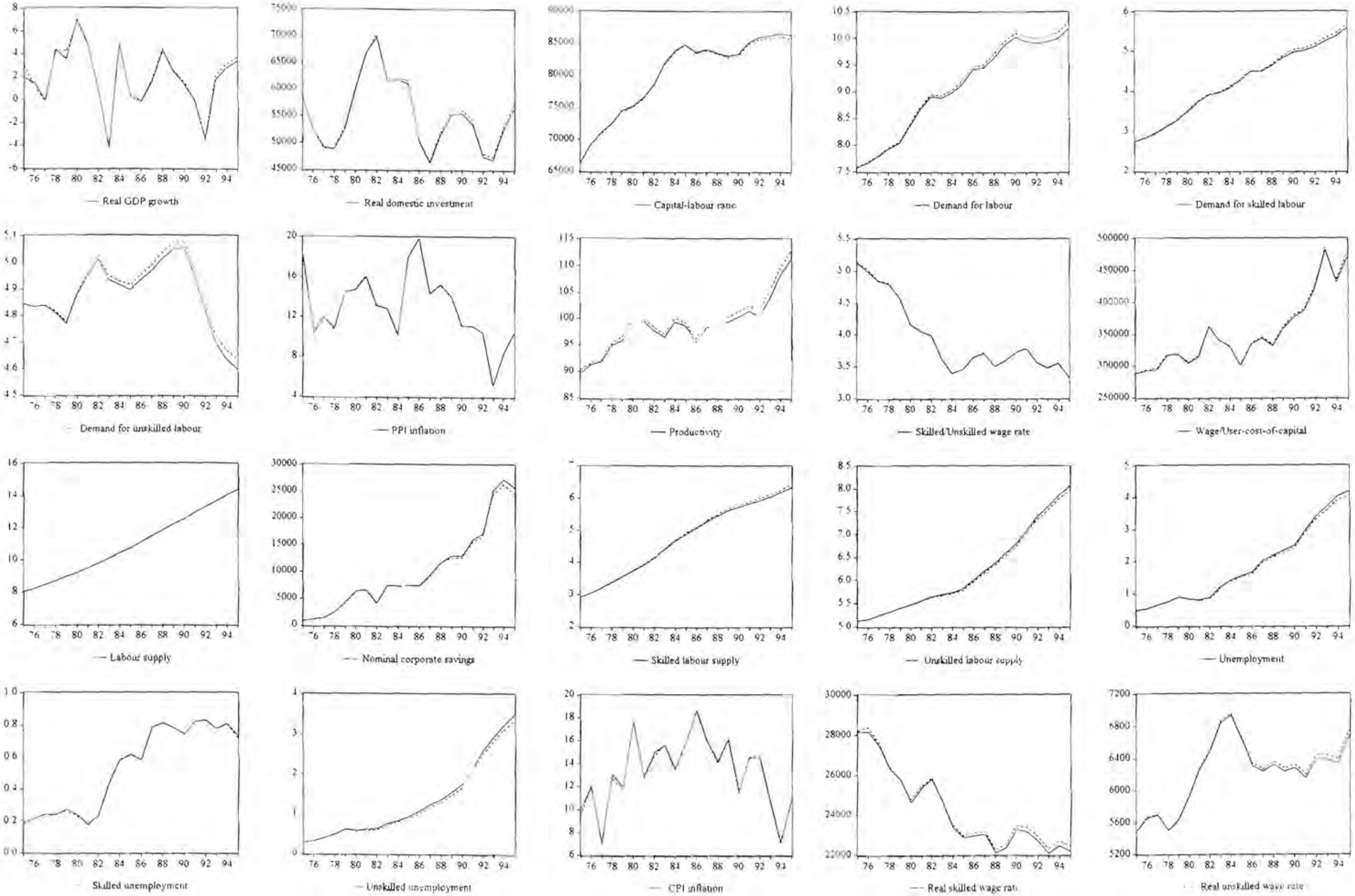


**Figure A16.7(b)** Individual scenario 6: Percentage differences between baseline and shocked simulation paths

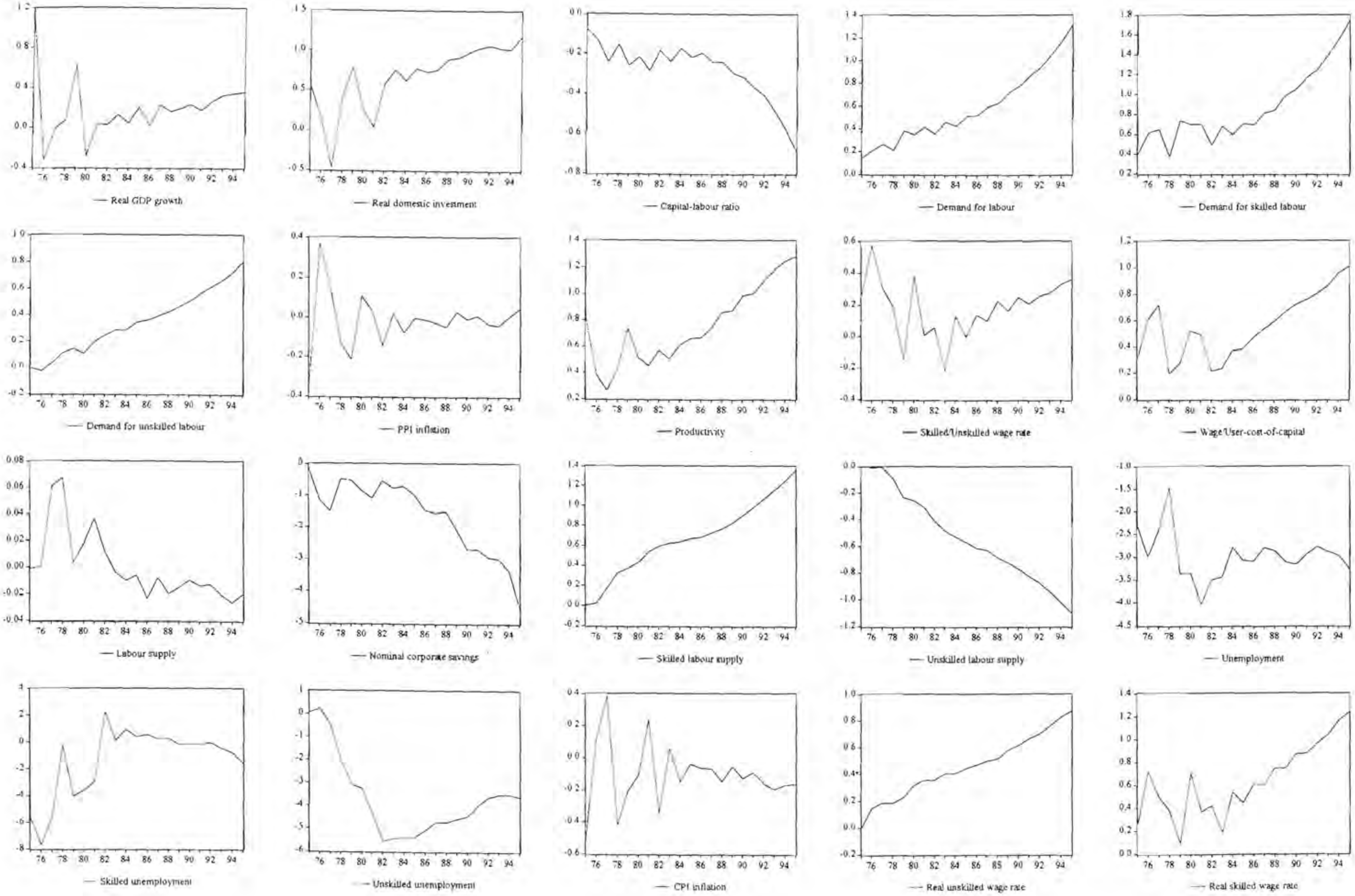


**Figure A16.8(a) Individual scenario 7: Baseline and shocked simulation paths**

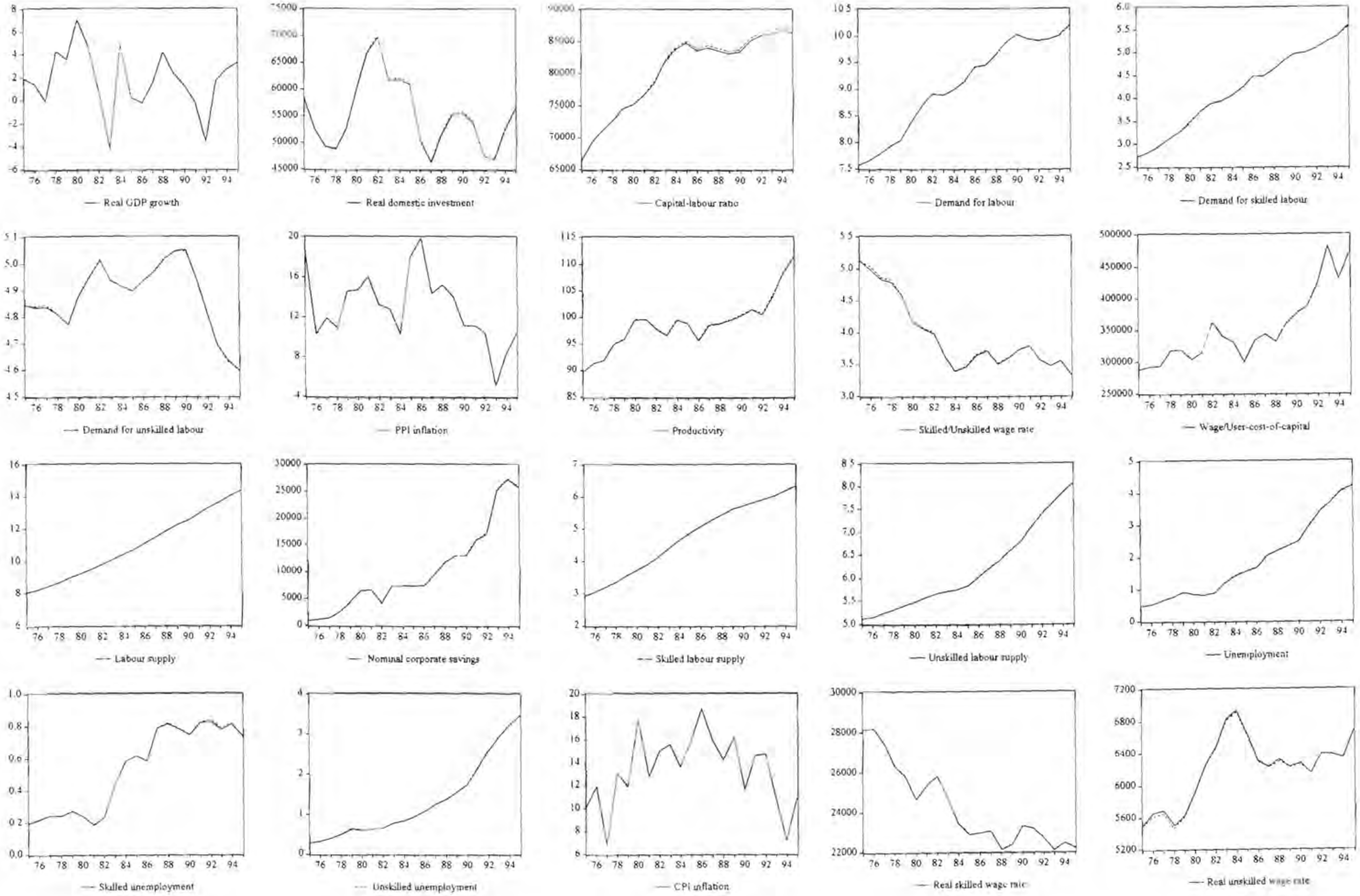


**Figure A16.8(b)** **Individual scenario 7: Percentage differences between baseline and shocked simulation paths**

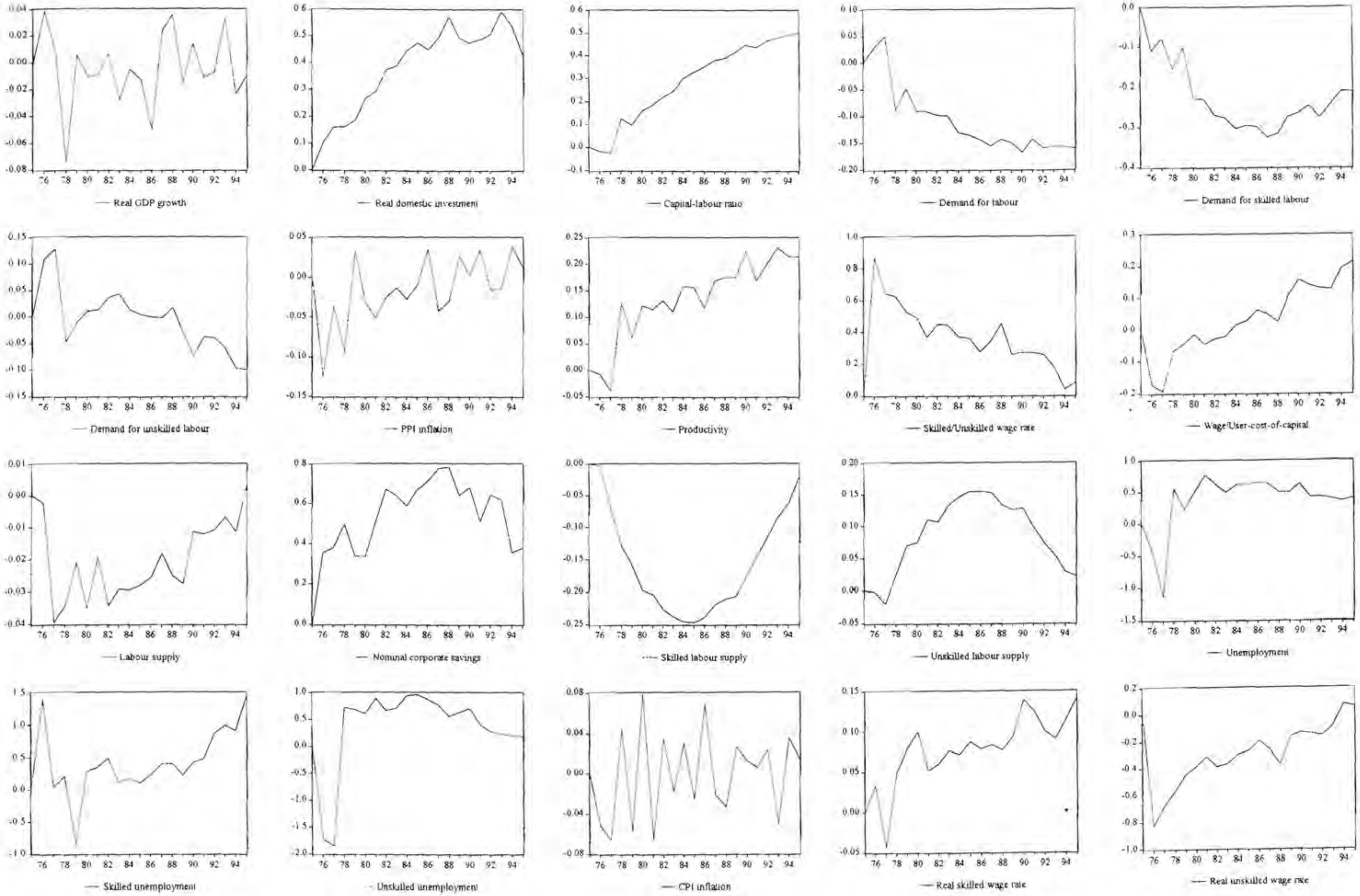


Figure A16.9(a) Individual scenario 8: Baseline and shocked simulation paths

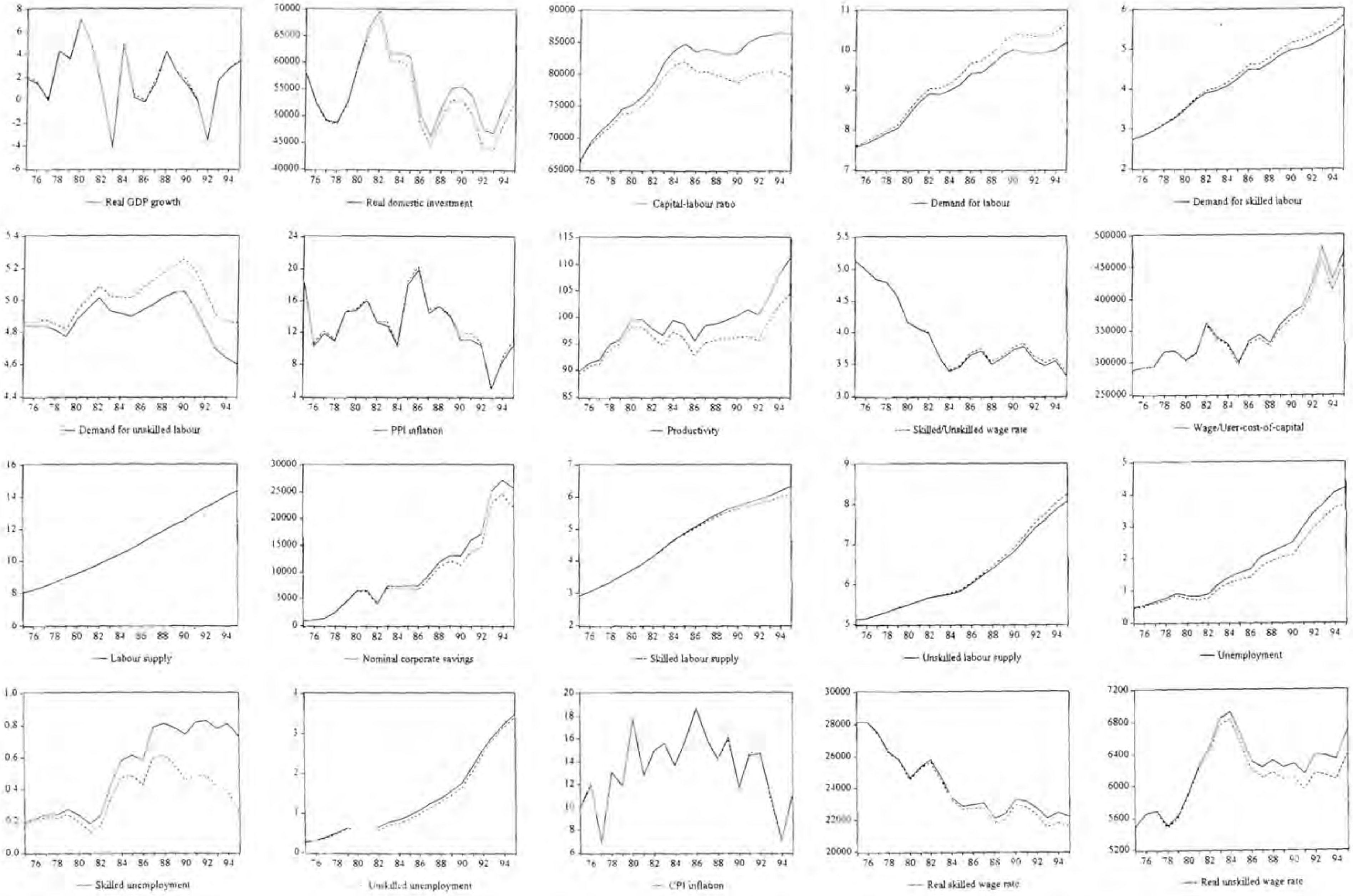
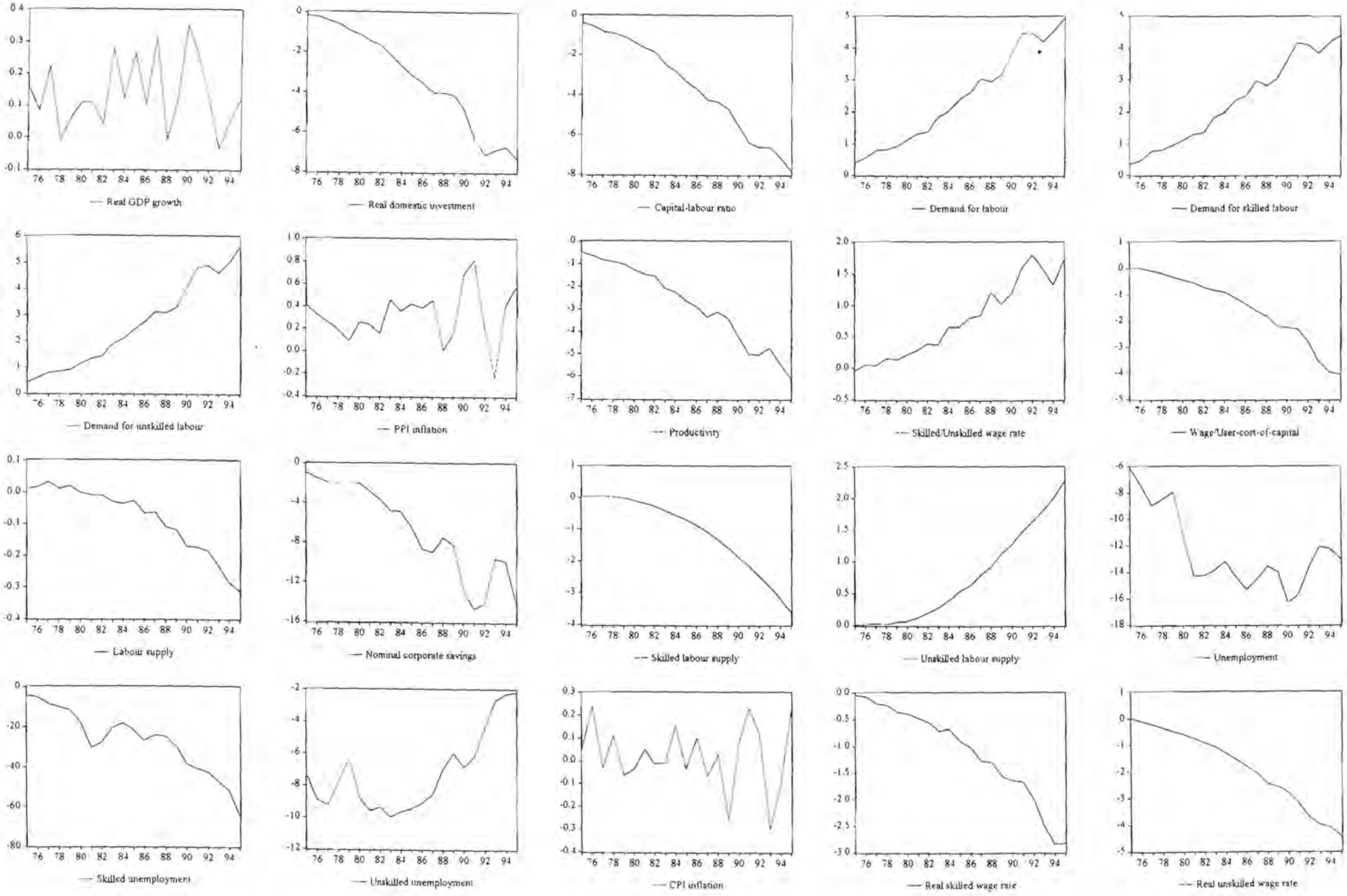


Figure A16.9(b) Individual scenario 8: Percentage differences between baseline and shocked simulation paths



— Real GDP growth

— Real domestic investment

— Capital-labour ratio

— Demand for labour

— Demand for skilled labour

— Demand for unskilled labour

— PPI inflation

— Productivity

— Skilled/Unskilled wage rate

— Wage/User-cost-of-capital

— Labour supply

— Nominal corporate savings

— Skilled labour supply

— Unskilled labour supply

— Unemployment

— Skilled unemployment

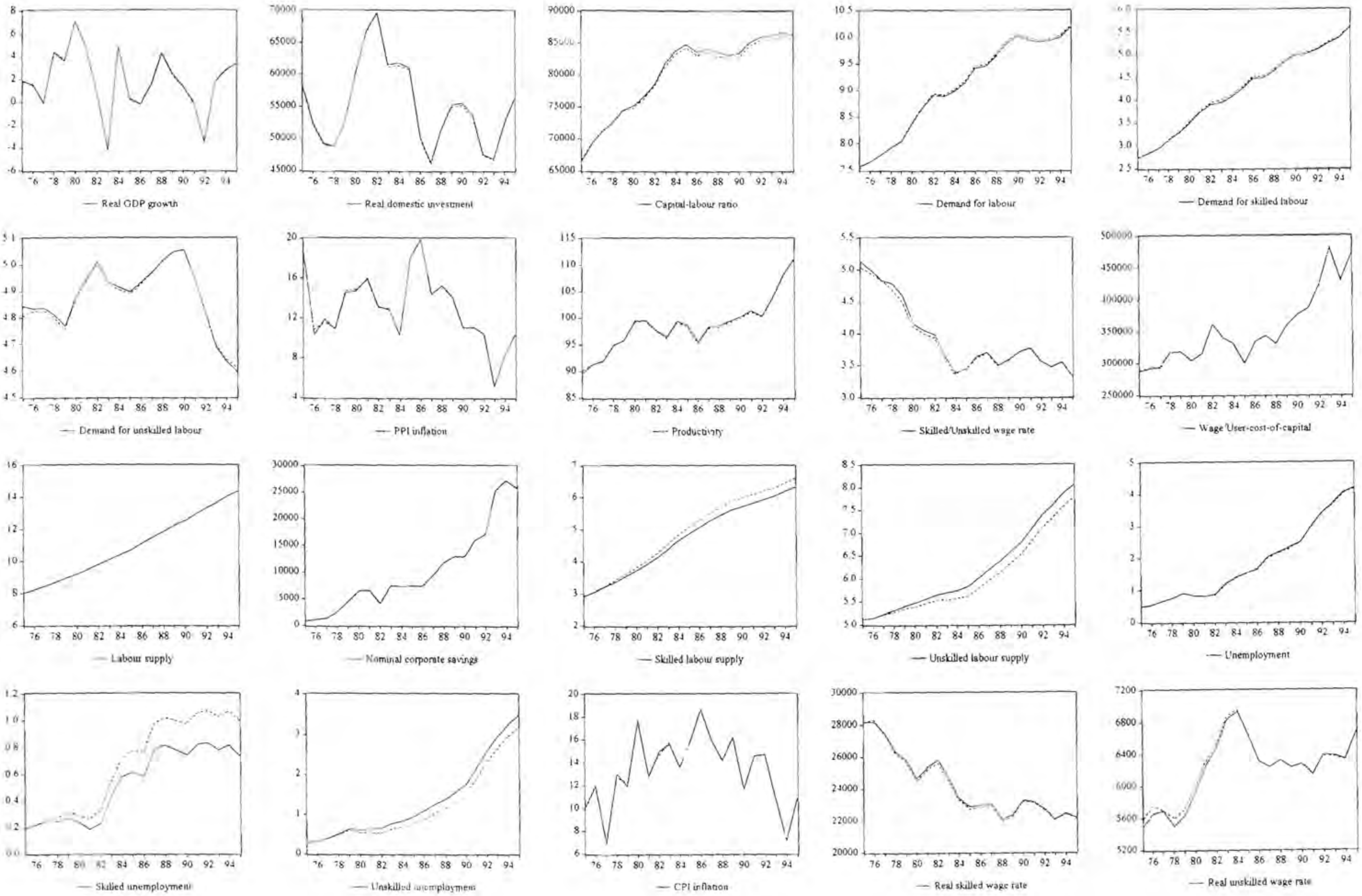
— Unskilled unemployment

— CPI inflation

— Real skilled wage rate

— Real unskilled wage rate

Figure A16.10(a) Individual scenario 9: Baseline and shocked simulation paths



— Real GDP growth

— Real domestic investment

— Capital-labour ratio

— Demand for labour

— Demand for skilled labour

— Demand for unskilled labour

— PPI inflation

— Productivity

— Skilled/Unskilled wage rate

— Wage/User-cost-of-capital

— Labour supply

— Nominal corporate savings

— Skilled labour supply

— Unskilled labour supply

— Unemployment

— Skilled unemployment

— Unskilled unemployment

— CPI inflation

— Real skilled wage rate

— Real unskilled wage rate

**Figure A16.10(b)** **Individual scenario 9: Percentage differences between baseline and shocked simulation paths**

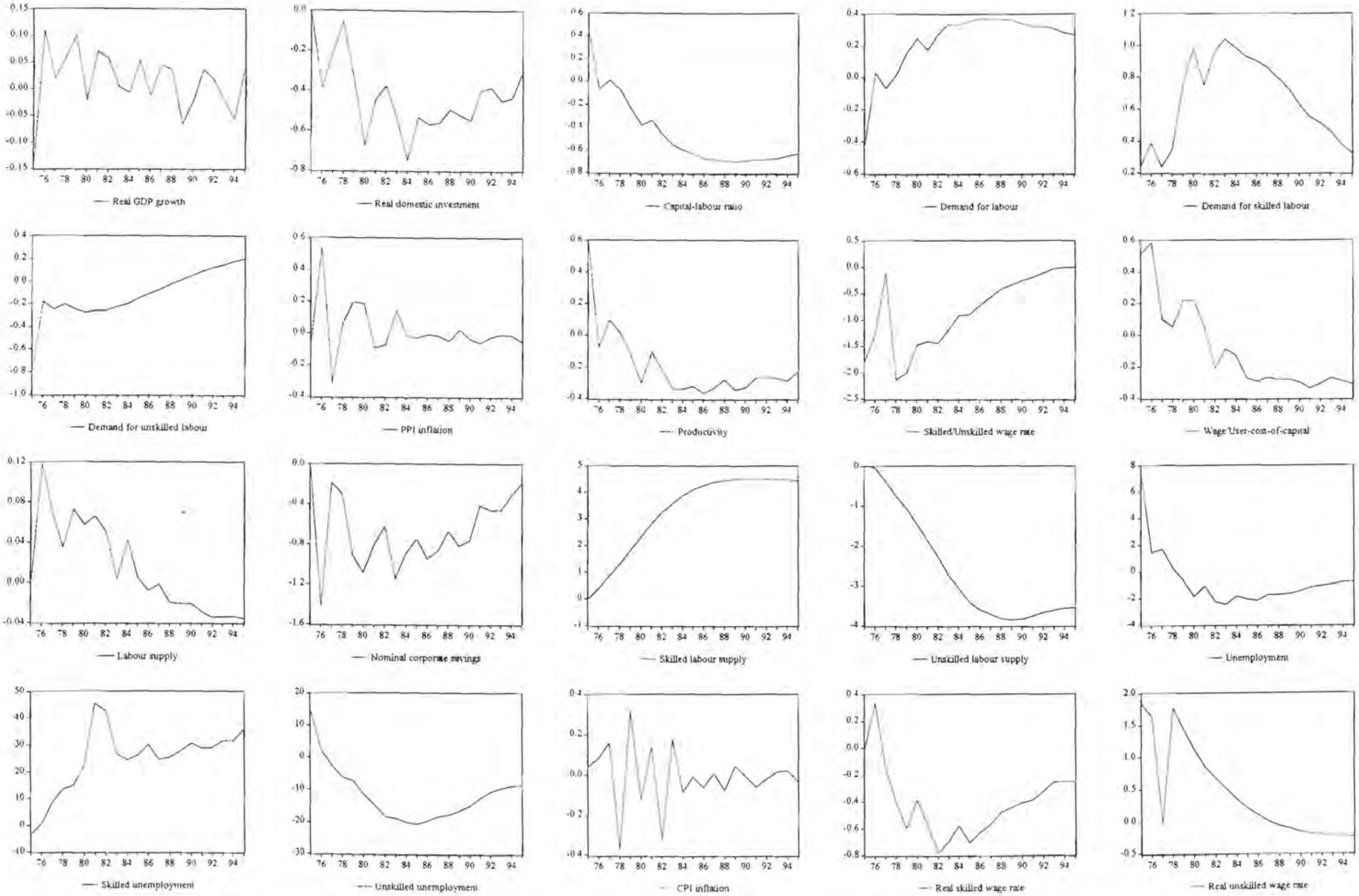
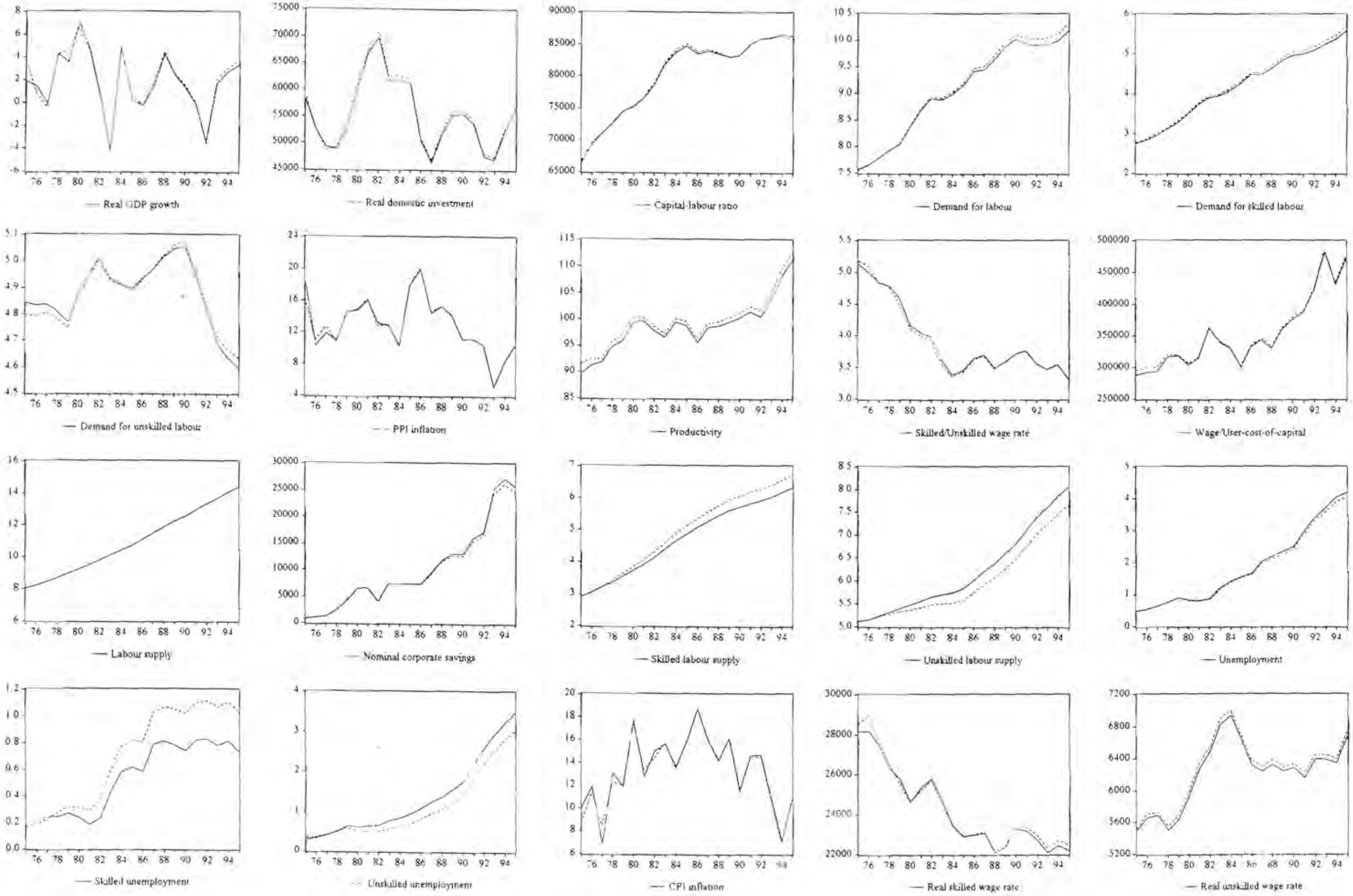


Figure A16.11(a) Combined scenario 1: Baseline and shocked simulation paths



— Real GDP growth

— Real domestic investment

— Capital-labour ratio

— Demand for labour

— Demand for skilled labour

— Demand for unskilled labour

— PPI inflation

— Productivity

— Skilled/Unskilled wage rate

— Wage/User-cost-of-capital

— Labour supply

— Nominal corporate savings

— Skilled labour supply

— Unskilled labour supply

— Unemployment

— Skilled unemployment

— Unskilled unemployment

— CPI inflation

— Real skilled wage rate

— Real unskilled wage rate

Figure A16.11(b) Combined scenario 1: Percentage differences between baseline and shocked simulation paths

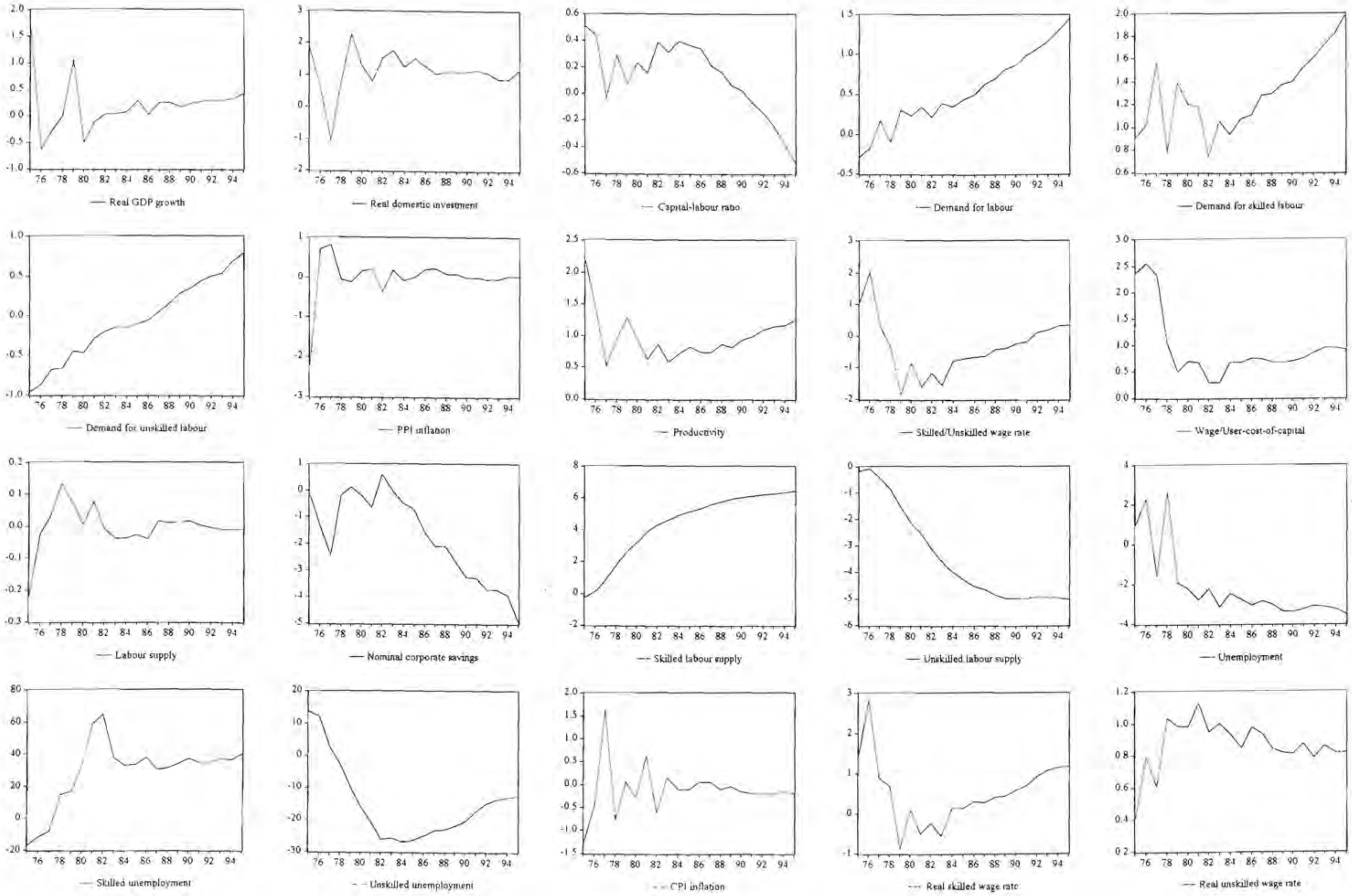


**Figure A16.12(a)** **Combined scenario 2: Baseline and shocked simulation paths**

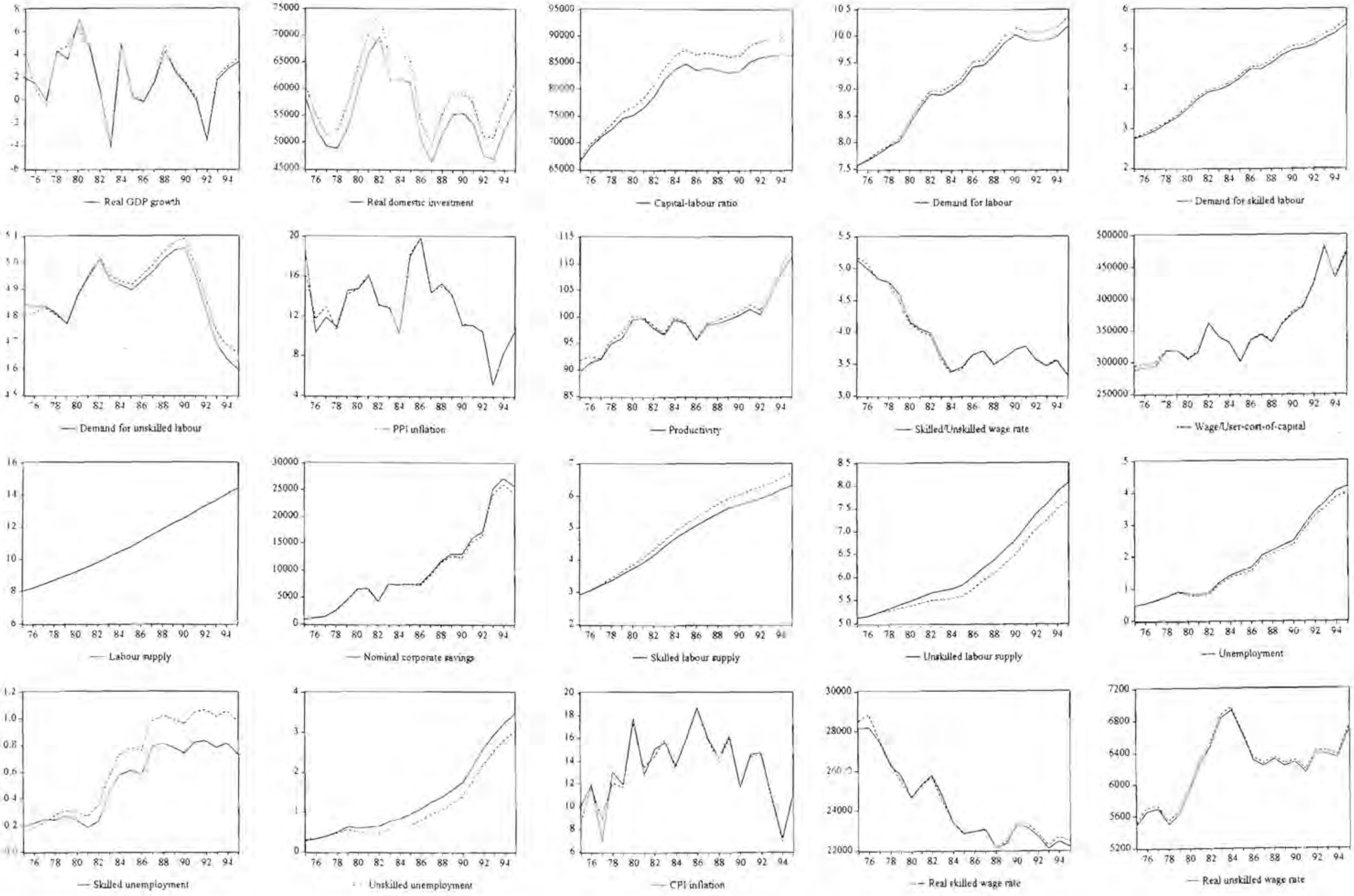


Figure A16.12(b) Combined scenario 2: Percentage differences between baseline and shocked simulation paths

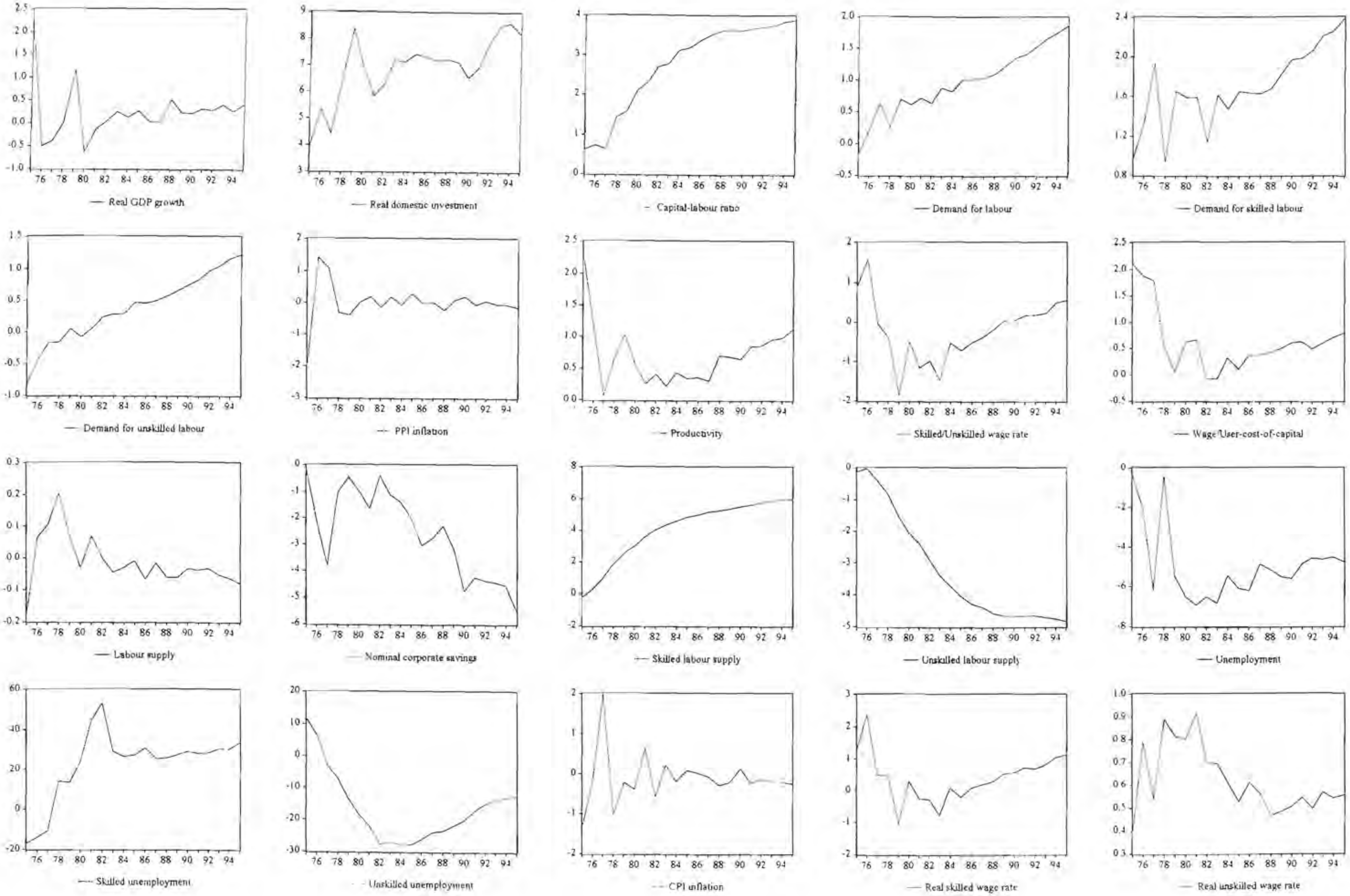


Figure A16.13(a) Combined scenario 3: Baseline and shocked simulation paths

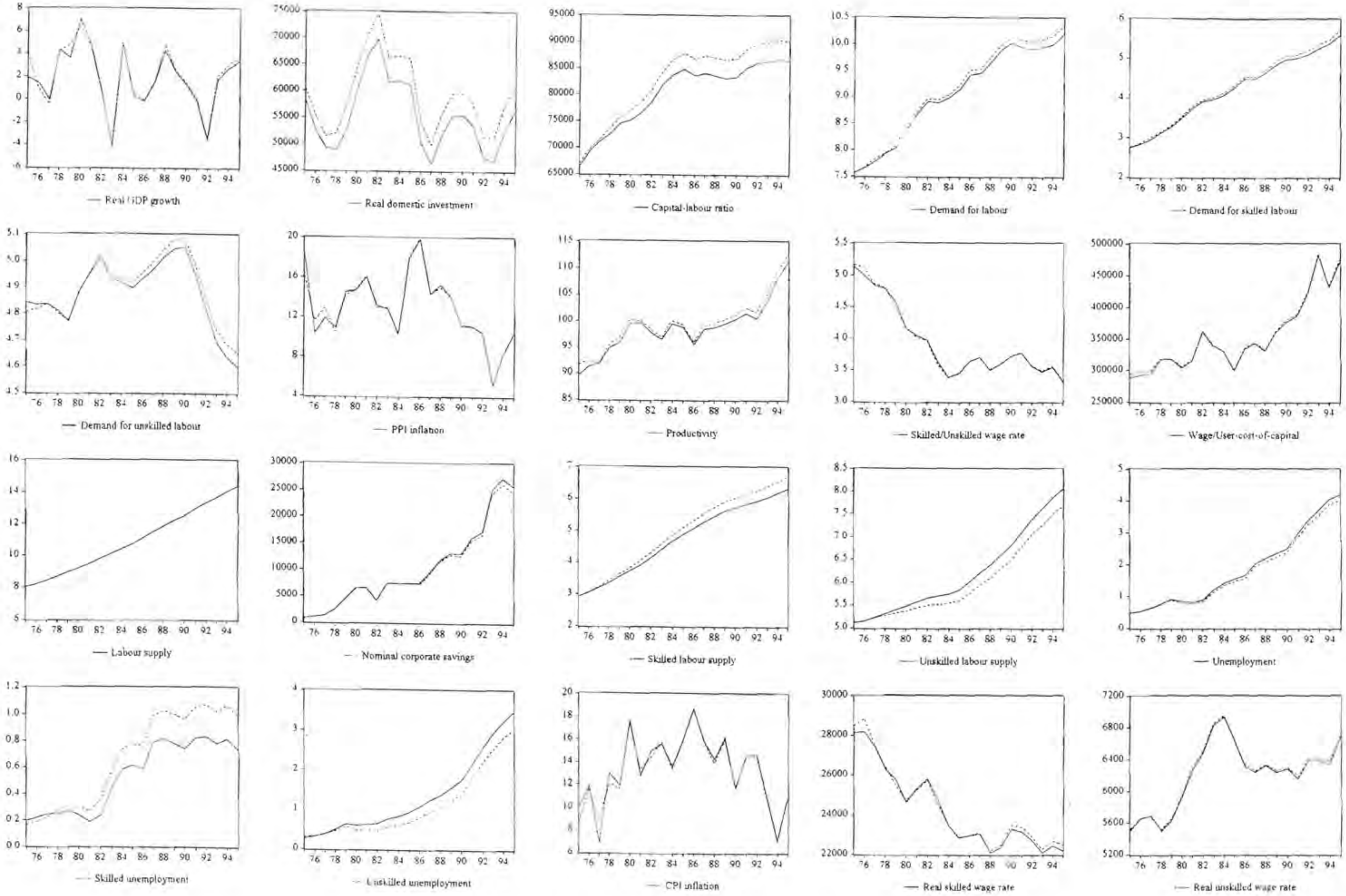


**Figure A16.13(b)** Combined scenario 3: Percentage differences between baseline and shocked simulation paths

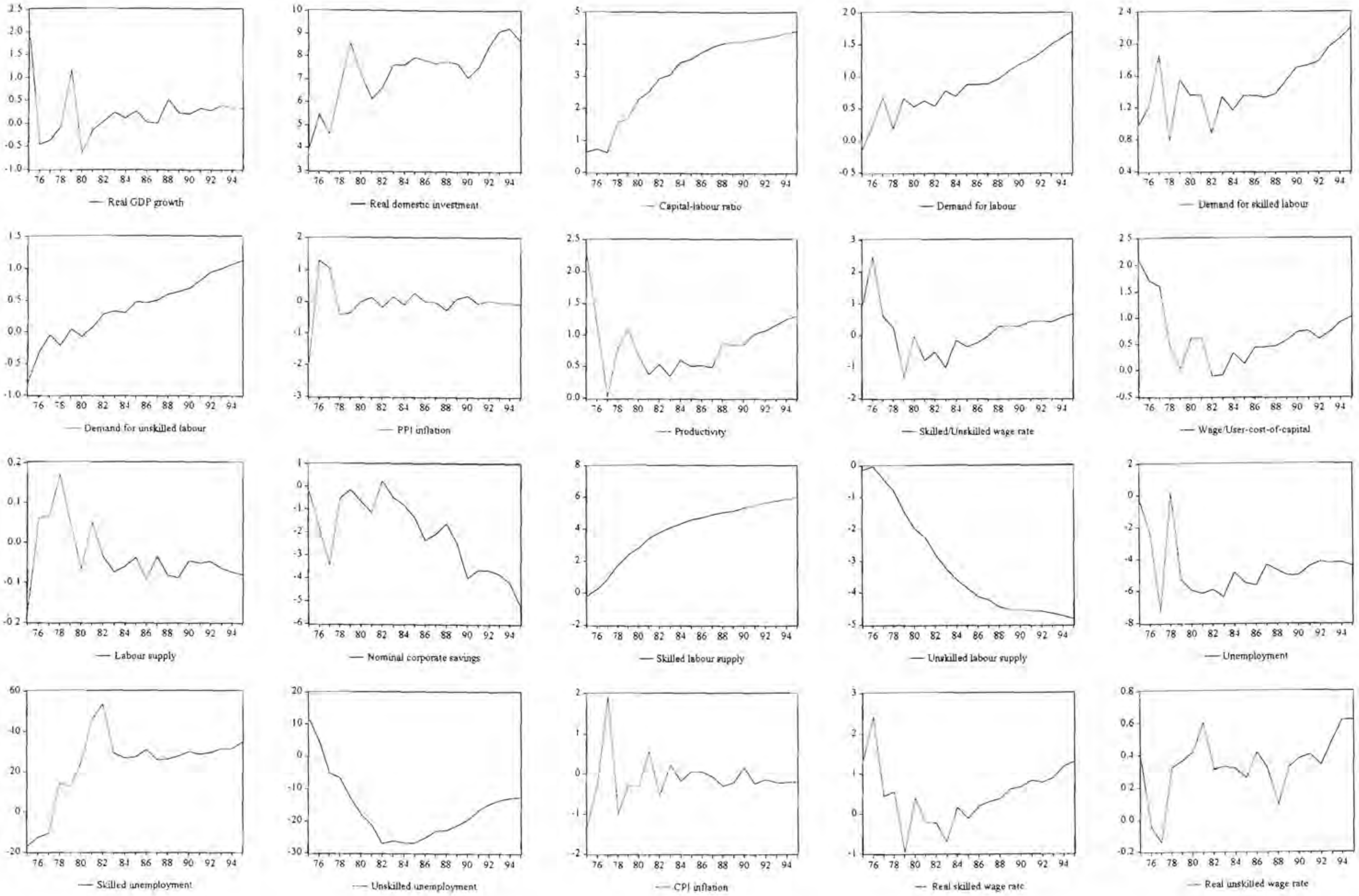


**Figure A16.14(a) Combined scenario 4: Baseline and shocked simulation paths**

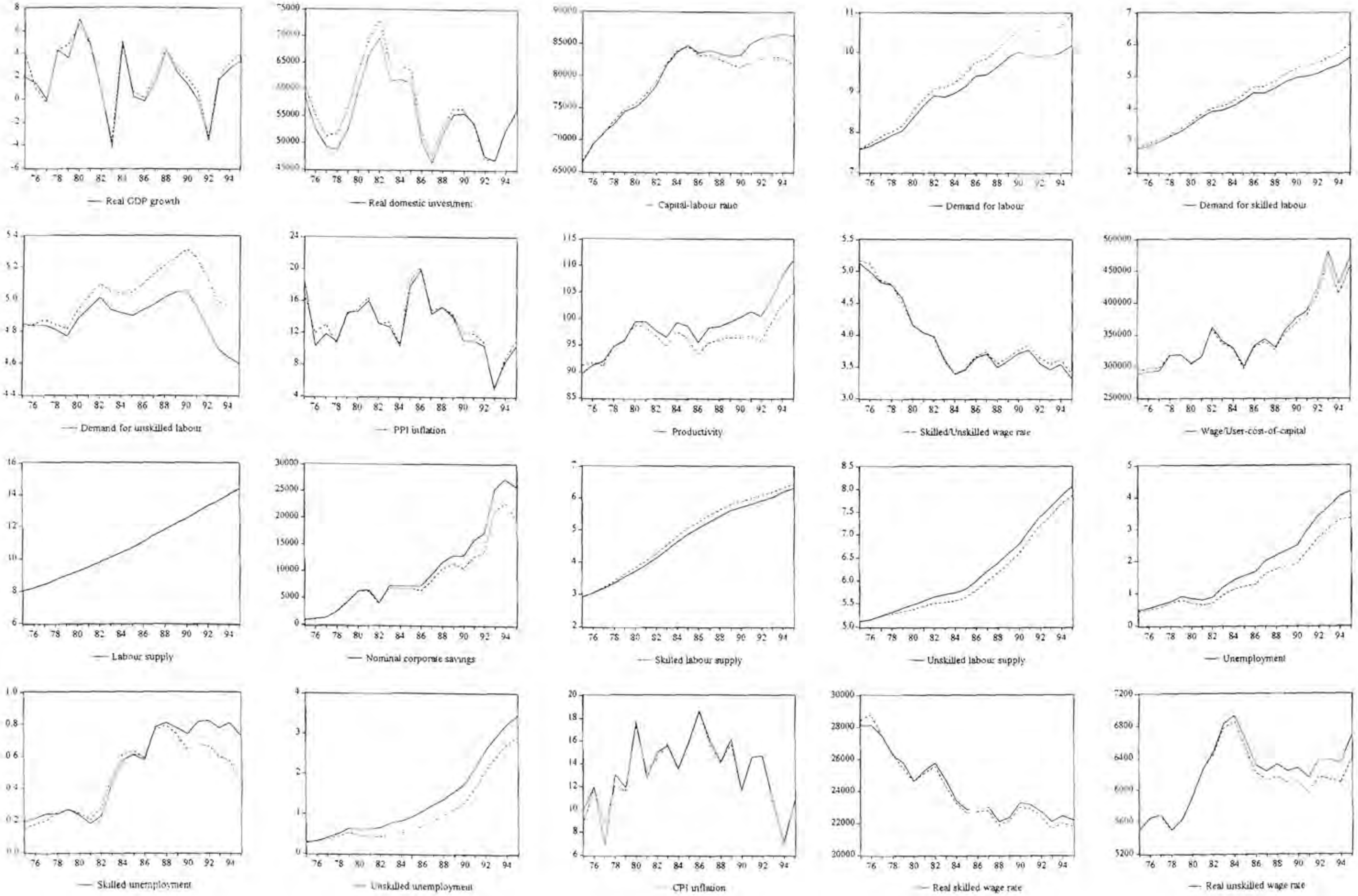


Figure A16.14(b) Combined scenario 4: Percentage differences between baseline and shocked simulation paths

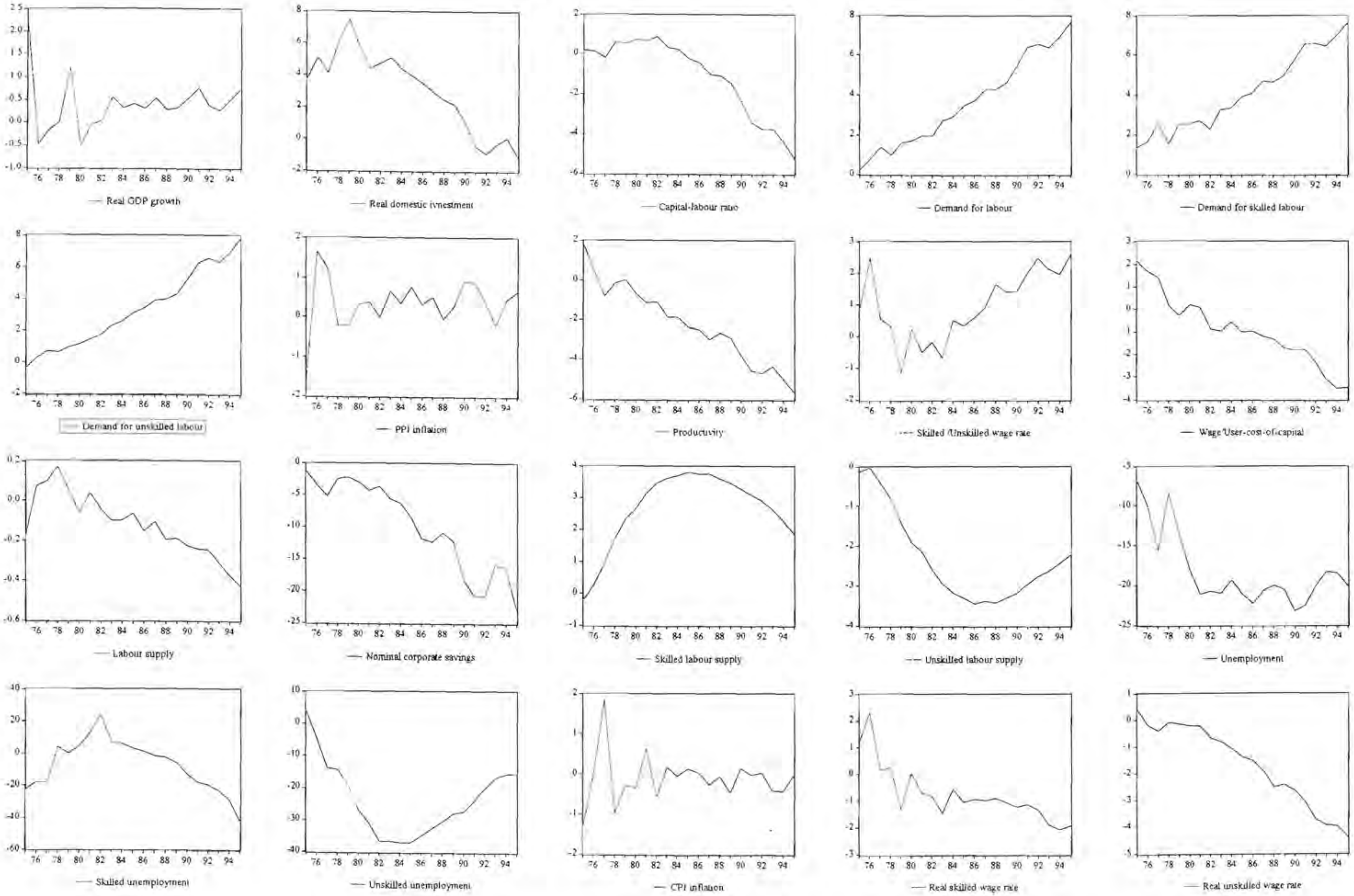


Figure A16.15(a) Combined scenario 5: Baseline and shocked simulation paths

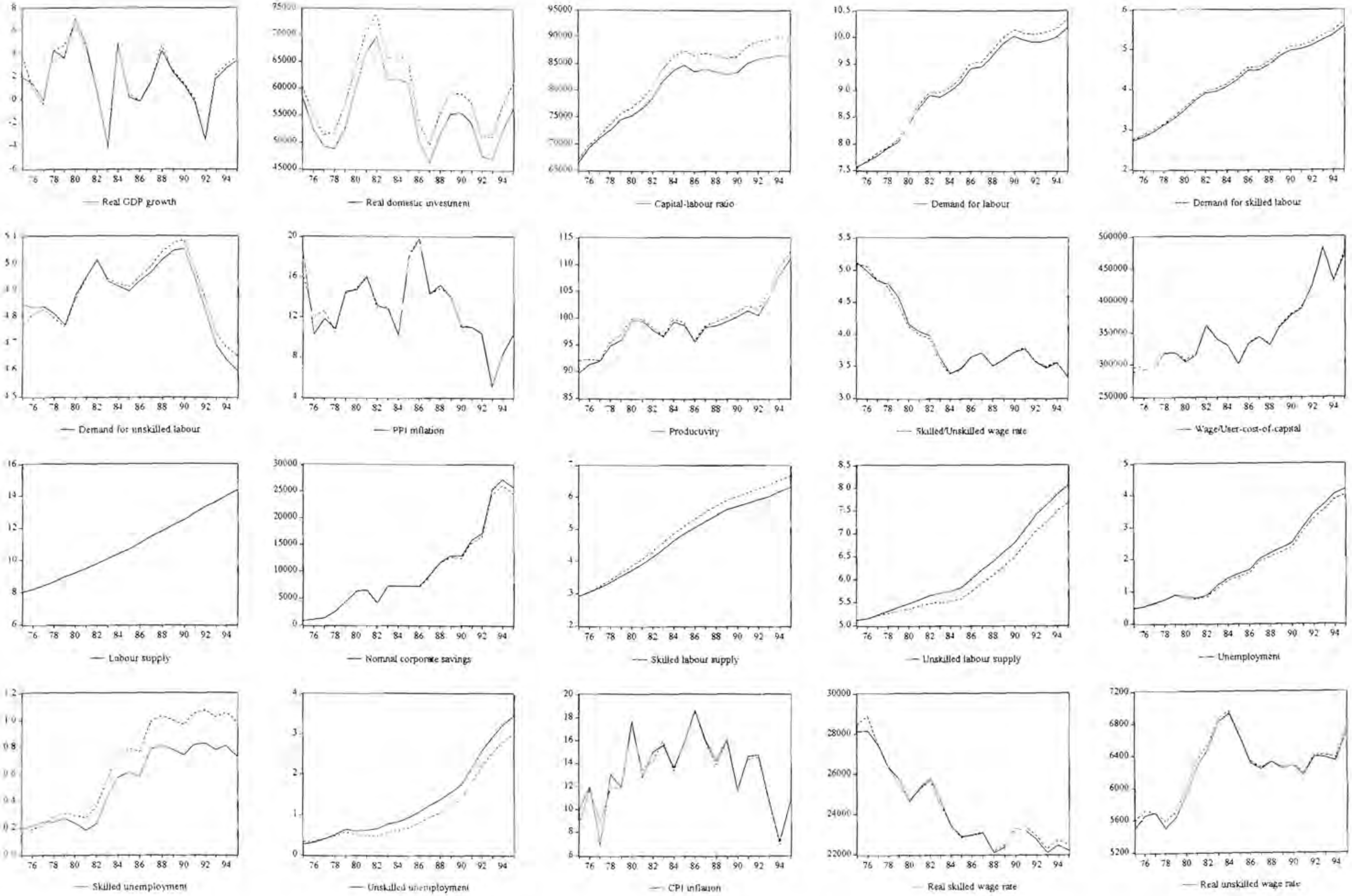


Figure A16.15(b) Combined scenario 5: Percentage differences between baseline and shocked simulation paths

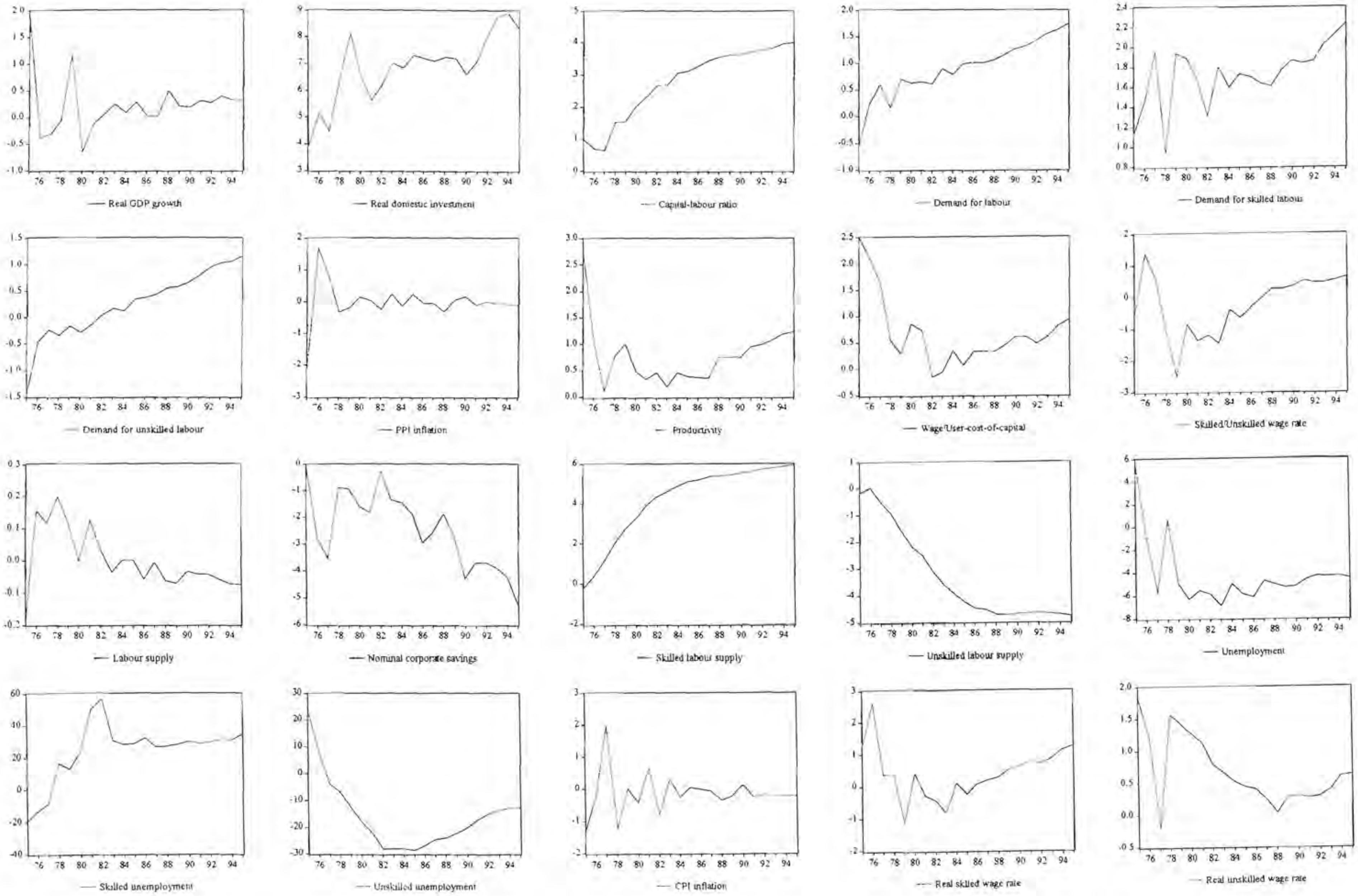


**Figure A16.16(a) Combined scenario 6: Baseline and shocked simulation paths**

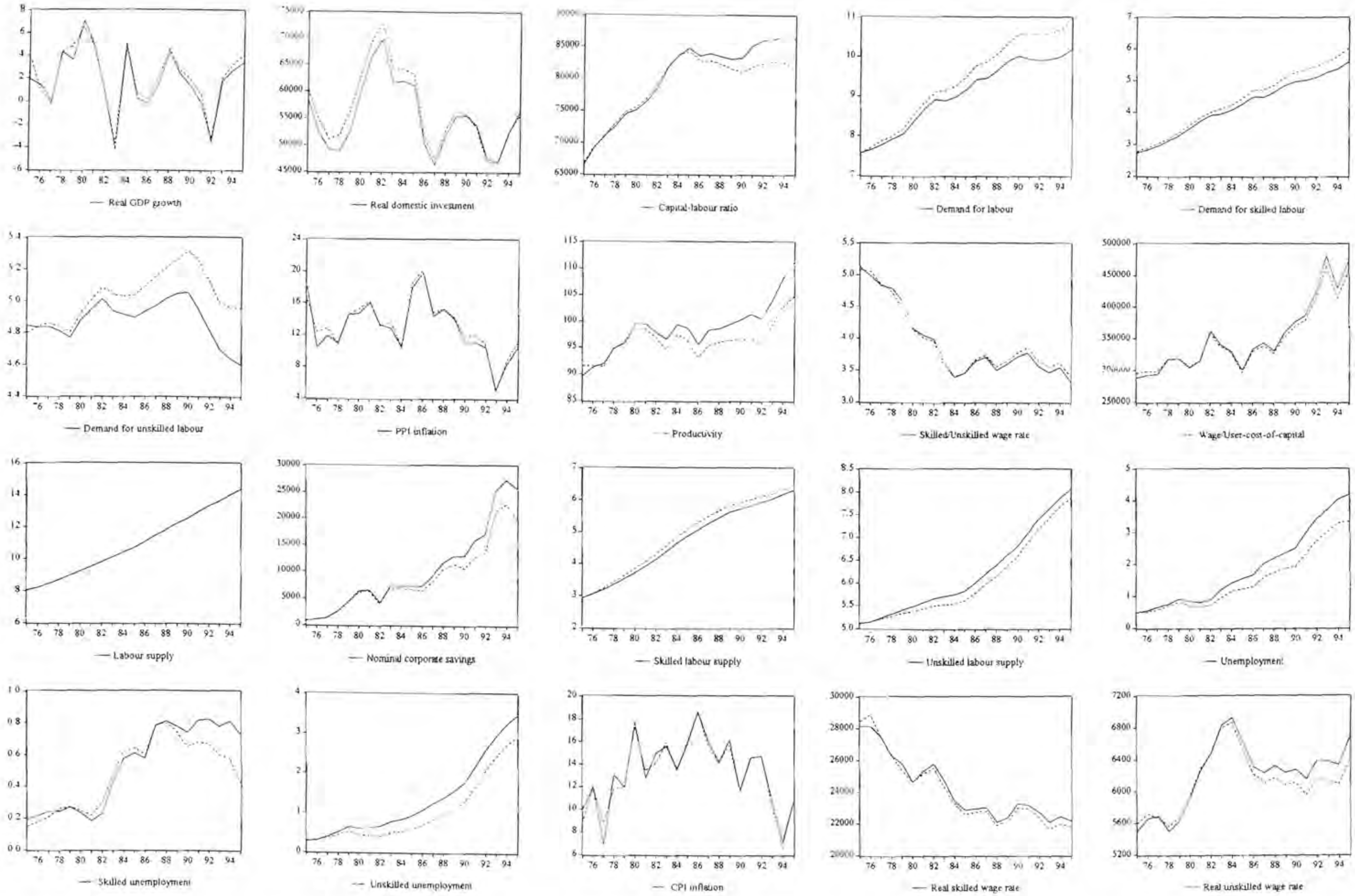
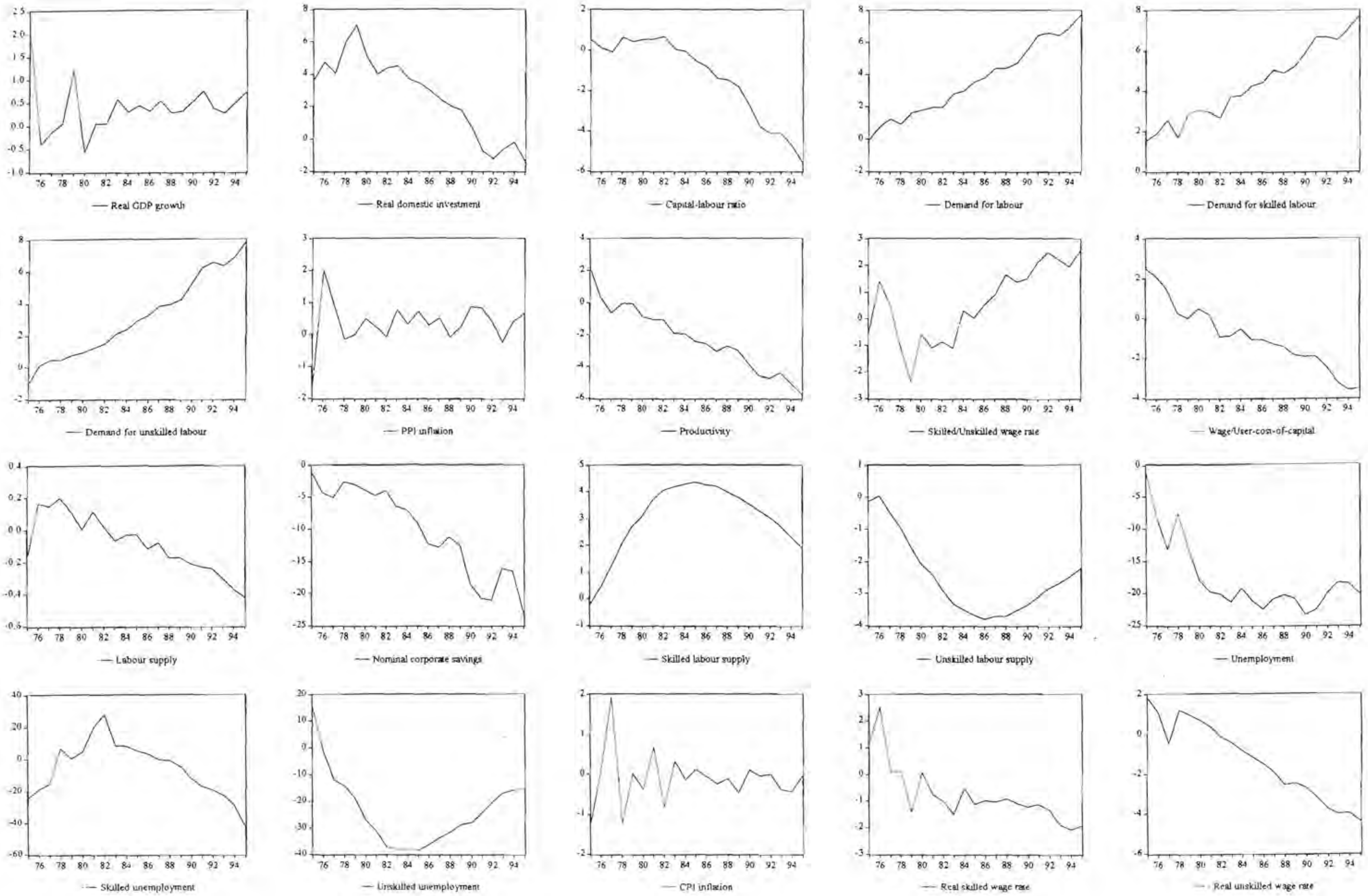


**Figure A16.16(b)** **Combined scenario 6: Percentage differences between baseline and shocked simulation paths**



## APPENDIX 17: ORDER OF INTEGRATION

The augmented Dickey-Fuller unit root test is employed to test whether the data series are stationary or not. The testing strategy suggested by Dolado *et al.* (1990) and applied by Strum and de Haan (1995) is followed.

The augmented Dickey and Fuller (1981) unit root test is specified as the ordinary least squares estimation of:

$$\Delta Y_t = \eta_0 + \eta_1 \text{Trend} + \eta_2 Y_{t-1} + \sum_{i=1}^{m} \eta_{2+i} \; Y_{t-i} + \varepsilon_t \; . \qquad \text{(A17.1)}$$

where $Y_t$ is the series being tested, $m$ is the number of lags in the testing equation and $\epsilon_t$ the residual. The null hypothesis of non-stationarity is rejected in favour of a stationary data series, if the Dickey-Fuller test statistic is significantly less than the relevant critical value.

The test is implemented through the usual *t*-statistic of $\hat{\eta}_2$, denoted as $\tau_\tau$. Under the null hypothesis, $\tau_\tau$ will not follow the standard *t*-distribution and the adjusted critical values computed by MacKinnon (1991) are used for evaluation. If $\tau_\tau$ is significant, the null of non-stationarity is rejected and the data series is stationary.

If $\tau_\tau$ is insignificant, the joint null hypothesis of $\eta_1 = \eta_2 = 0$, using the *F*-statistic denoted as $\Phi_3$, is tested. The relevant critical values from Dickey and Fuller are used to evaluate the test statistic $\Phi_3$. If $\Phi_3$ is significant, the unit root test is repeated, now using the critical values of the standard *t*-distribution.

If the trend is not significant in the maintained model, the next step is to estimate equation 1 without a trend ($\eta_1 \equiv 0$). The unit root test is carried out, now denoting the *t*-statistic of $\hat{\eta}_2$ as $\tau_\mu$ and using the relevant critical values from MacKinnon. If the null hypothesis is rejected, the data series is stationary.

If the null of non-stationarity is not rejected, the joint null hypothesis of $\eta_0 = \eta_2 = 0$, using the *F*-statistic denoted as $\Phi_1$ is tested and the critical values reported by Dickey and Fuller are employed. If $\Phi_1$ is significant, the unit root test is repeated, using the standard normal distribution.

If $\Phi_1$ is insignificant, the Dickey-Fuller $\tau$ test is carried out without a constant in the testing equation, testing the joint hypothesis of $\eta_0 \equiv \eta_2 \equiv 0$. If the test statistic ($\tau$) is significantly less than the relevant MacKinnon critical value, the null hypothesis of non-stationarity is rejected and the data series is stationary.

The number of lags used in the estimation equation is determined in similar way as Perron (1989). Perron suggested starting with eight lags. If the last (eighth) lag is insignificant at a 10 percent level of significance (using the standard normal distribution), it is omitted. The test is repeated with seven lags and the last lag tested for significance. The process is repeated until there are no more lags left, in which case the test has reduced to the standard Dickey-Fuller (DF) test. The large level of significance (10 percent) is taken because, as Perron (1989: 1384) pointed out, "...including too many regressors of lagged first-differences does not affect the size of the test but only decreases its power. Including too few lags may have a substantial effect on the size of the test". Furthermore, Molinas (1986) noticed that "…a rather large number of lags has to be taken in the ADF test in order to capture the essential dynamics of the residuals."

The following reasons necessitate the careful evaluation of the ADF integration test results:

(i) In the *DF*τ test the presumption is that the data generating process (DGP), stationary or not, has a zero mean (no constant or drift term), and no trend: in effect there are no deterministic components to the series. The implication is that the initial $y$ value is zero, since a DGP without deterministic components and a unit root (i.e. either a true stationary or differenced stationary data series) has its mean determined by its initial observation. Where the mean of a non-stationary series is not zero, i.e. where the DGP has a drift component (constant), the *DF*τ test will be inappropriate – it will lead to an over-rejection of the null of non-stationarity (stationarity will too easily be accepted) and therefore generate misleading results[1]. Therefore, if the initial value of $y$ is not certain (i.e. whether the DGP is subject to drift or not), the $DF\tau_\mu$ test need to be employed.

(ii) Under the $DF\tau_\mu$ test: $\Delta y_t = \mu_b + (\rho_b - 1)y_{t-1} + \mu_t$, (only testing for a unit root and drift term), if the series has a unit root $(\rho_b = 1)$, $y_t$ will follow a stochastic trend, drifting upwards or downwards depending on the sign of $\mu_b$.

Alternatively, if the series is stationary $(\rho_b \;\; 1)$, $y_t$ will have no stochastic trend, and will be stationary around a constant mean of $\mu_b/(1-\rho_b)$. If, however, the true DGP is a trend-stationary process (stationary process with a deterministic trend component): i.e. $y_t = \alpha + \beta t + \mu_t$, $y_t$ will also follow a trend (now of a stationary deterministic and not a non-stationary stochastic nature), drifting upwards or downwards depending on the sign of $\beta$. The $DF\tau_\mu$ test will mistaken the stationary deterministic trend for a non-stationary stochastic trend and render the $y_t$ process non-stationary. The $DF\tau_\mu$ test fails to distinguish between a series with a stochastic and a series with a deterministic trend. The $\tau_\tau$ version of the Dickey-Fuller test ($DF\tau_\tau$) allows for the presence of a time trend. However, there are two points to note here:

- If the $DF\tau_\tau$ test is inappropriately **avoided**, there would be a tendency to **over**-accept the null of non-stationarity for series, which are in fact stationary.
- If the $DF\tau_\tau$ test is inappropriately **used**, there would be a tendency to **under**-accept the null of non-stationarity for series, which are in fact non-stationary.

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[1] *DF*τ test: $\Delta y_t = (\rho_a - 1)y_{t-1} + \mu_t$ test whether $\rho = 1$ $(\rho - 1 = 0)$ with $\mu_t \sim IID(0,\sigma^2)$.
If $\rho = 1$ ($y_t$ is a non-stationary data series): $\Delta y_t = 0 + \mu_t$ (indicating that $\rho - 1 = 0$ and, although not explicitly testing for it, indicating that $\Delta y_t$ has a zero mean). Now, if $y_t$ is subject to drift (constant) and the *DF*τ test is applied, still only testing for $\rho - 1 = 0$, $\Delta y_t = \delta + \mu_t$ will indicate that $\rho - 1 = \delta \neq 0$. If, by example, $\delta = -1.2 < 0$, then the *DF*τ test will wrongly indicate that $y_t$ is stationary due to the outcome of $\rho - 1 = \delta = -1.2$.

(iii) Unit root tests have problems with their "power": in small samples they are likely to accept the null-hypothesis of a unit root when the true DGP is in fact stationary, though close to having a unit root. In effect, standard unit root test will under-reject the presence of a unit root (accept stationarity). With small samples, therefore, special care must be exercised in the application of unit root tests. Effectively, in small (finite) samples some unit root processes appear to behave like trend-stationary processes, while some trend-stationary processes appear to behave like random walk (non-stationary) processes. Unit root tests are likely to be fooled in either event: either rejecting non-stationarity where non-stationarity should be accepted, or accepting non-stationarity where non-stationarity should be rejected. This is obviously a very important problem in the current scenario since the sample size used to test for the presence of a unit root only consists of 25 observations.

(iv) Where (unknown) structural breaks are present in the data, application of "standard" unit root tests would again lead to an under-rejection of the null of the presence of a unit root (i.e. accept stationarity). In the South African context the periods of sanctions, disinvestment, outflow of human capital and changes in monetary policy are of importance and need to be taken in consideration.

An important consequence of the above is that inferences concerning the stationarity properties of data should always be based on a range of evidence, of which the formal ADF (and other) tests are merely one component. Economic theory, structural properties of the data, *a priori* information concerning political and other exogenous shocks to the economy over the sample period, data plots, residual plots, plots of the autocorrelation function, and spectral analysis all form part of the evidence required to draw conclusions on the stationarity of data. These inference guidelines should always be taken in consideration when testing for the presence of a unit root.

Tables A17.1, A17.2 and A17.3 report the outcomes of the ADF tests for all relevant data series employed in the estimations. The series tested are given in the first column. The second column reports whether a trend and a constant (Trend), only a constant (Constant), or neither (None) is included. In the third column, the number of lags recorded is reported. The next column shows the ADF $t$-statistic, called $\tau_\tau$ when a trend and constant are included, $\tau_\mu$ when only a constant is included, and $\tau$ when neither occurs. The last column reports the $F$-statistic, $\Phi_3$ ($\Phi_1$), testing whether the trend (constant) is significant under the null hypothesis of no unit root.

According to table A17.1 there are a couple of variables that seem to be stationary in levels. However, apart from the fact that the test results are not conclusive, taking the problems and inference guidelines associated with the testing for a unit root in consideration, it is obvious that these variables cannot be stationary in their levels. The only variable that can indeed be rendered stationary in levels is *ln_cu*. Table A17.2 indicates that all other variables, except *ln_ss* are integrated of order 1. Although *ln_ss* tested as stationary in second differences, consideration of the inference guidelines makes it is plausible that the variable is integrated of order 1 rather than order 2. The ADF test may recognise the structural break as a trend within a trend, rendering *ln_ss* as an I(2) variable. Due to the nature of construction of the dummy variables, they are all integrated of order 0 and are therefore all stationary in levels.

**Table A17.1. Augmented Dickey-Fuller tests for non-stationarity, levels, 1970-1995**

| Series | Model | Lags | $\tau_\tau, \tau_\mu, \tau$ | $\Phi_3, \Phi_1$ |
|---|---|---|---|---|
| ln_bbp_90p | Trend | 0 *(insign)* | -1.68 | 3.21 |
| | Constant | 0 | -2.30 | 5.29* |
| | None | 0 | 4.16 | |
| ln_bbp_min_90p | Trend | 3 | -3.73* | 3.46 |
| | Constant | 3 | -3.72* | 3.46 |
| | None | 0 *(insign)* | -1.28 | |
| ln_bbpfact_90p | Trend | 0 *(insign)* | -1.71 | 4.04 |
| | Constant | 0 | -2.70 | 7.31* |
| | None | 0 | 4.07 | |
| ln_c90p_lrem5 | Trend | 3 | -4.77** | 5.46 |
| | Constant | 4 | 0.15 | 1.37 |
| | None | 4 | 2.66 | |
| ln_cu | Trend | 8 | -3.87* | |
| | Constant | | | |
| | None | | | |
| ln_educind | Trend | 0 | -2.81 | 4.70 |
| | Constant | 0 | 0.45 | 0.20 |
| | None | 0 | -2.60* | |
| ln_empl_rat | Trend | 4 | -0.24 | 3.50 |
| | Constant | 4 | 2.04 | 2.17 |
| | None | 4 | 3.34 | |
| ln_empl_rat_s | Trend | 6 | -1.24 | 1.76 |
| | Constant | 6 | -1.79 | 2.14 |
| | None | 4 | 0.13 | |
| ln_empl_rat_u | Trend | 0 *(insign)* | 0.57 | 23.26 |
| | Constant | 0 | 5.83 | 33.96 |
| | None | 0 | 9.59 | |
| ln_exces_dem_cp | Trend | 0 | -2.35 | 3.37 |
| | Constant | 0 | -2.65 | 7.04* |
| | None | 0 | -1.77 | |
| ln_fincond_ppi | Trend | 1 | -3.05 | 3.26 |
| | Constant | 1 | -3.15* | 5.13 |
| | None | 4 | 0.13 | |
| ln_gostc_cp | Trend | 1 | -5.09** | 8.77* |
| | Constant | 2 | -0.38 | 2.09 |
| | None | 2 | 4.39 | |
| ln_gprys_$ | Trend | 4 | -1.19 | 2.52 |
| | Constant | 4 | -2.58 | 2.72 |
| | None | 2 | 0.89 | |

*(**) Significant at a 5(1) percent level.

a At a 5(1) percent significance level the MacKinnon critical values are –3.60(-4.38) when a trend and a constant are included ($\tau_\tau$), and –3.00(-3.75) when only a constant is included ($\tau_\mu$), and –1.95(-2.66) when neither is included ($\tau$). The standard t-distribution critical value is –1.708(-2.485).

b At a 5(1) percent significance level the Dickey-Fuller critical values (for 25 observations) are 7.24(10.61) when a trend and a constant are included ($\Phi_3$), and 5.18(7.88) when only a constant is included ($\Phi_1$).

*** Significant at a 10 percent level.

*(insign)* Insignificant lag.

**Table A17.1 *(cont.)*. Augmented Dickey-Fuller tests for non-stationarity, levels, 1970-1995**

| Series | Model | Lags | $\tau_\tau, \tau_\mu, \tau$ | $\Phi_3, \Phi_1$ |
|---|---|---|---|---|
| ln_gprys_r | Trend | 4 | 0.27 | 4.31 |
| | Constant | 4 | -3.76** | 4.10 |
| | None | 1 | 1.77 | |
| ln_if | Trend | 2 | -2.32 | 7.90* |
| | Constant | 2 | -2.27 | 9.42** |
| | None | 2 | 0.50 | |
| ln_interposind | Trend | 6 | -3.24 | 3.44 |
| | Constant | 0 *(insign)* | -0.74 | 0.54 |
| | None | 0 | -3.91* | |
| ln_kap_lab_rat | Trend | 4 | -2.36 | 8.56* |
| | Constant | 0 | -6.32** | 39.97** |
| | None | 0 | 4.51 | |
| ln_kap_r | Trend | 2 | -1.76 | 146.30** |
| | Constant | 2 | -3.40 | 187.24** |
| | None | 2 | 0.69 | |
| ln_n | Trend | 4 | 0.80 | 3.95 |
| | Constant | 0 | -3.74* | 14.02** |
| | None | 0 | 6.10 | |
| ln_n_informal | Trend | 1 | -2.80 | 3.28 |
| | Constant | 0 *(insign)* | -1.11 | 1.24 |
| | None | 0 | 3.01 | |
| ln_ns | Trend | 0 *(insign)* | -1.23 | 17.33 |
| | Constant | 0 | -6.01** | 36.22** |
| | None | 0 | 6.68 | |
| ln_nu | Trend | 4 | 1.03 | 3.89 |
| | Constant | 1 | -2.08 | 8.88** |
| | None | 1 | -0.21 | |
| ln_p_manuf | Trend | 1 | -4.01* | 18.01** |
| | Constant | 1 | -0.61 | 11.64 |
| | None | 1 | -1.84 | |
| ln_ppi | Trend | 1 | -1.91 | 6.09 |
| | Constant | 2 | -2.30 | 6.41* |
| | None | 1 | -2.07* | |
| ln_prime_rate | Trend | 3 | -3.46 | 4.23 |
| | Constant | 2 | -1.48 | 2.90 |
| | None | 0 *(insign)* | 0.65 | |
| ln_product | Trend | 1 | -1.82 | 2.82 |
| | Constant | 0 *(insign)* | 1.07 | 1.13 |
| | None | 0 | 2.24 | |

*(**) Significant at a 5(1) percent level.

a At a 5(1) percent significance level the MacKinnon critical values are –3.60(-4.38) when a trend and a constant are included ($\tau_\tau$), and –3.00(-3.75) when only a constant is included ($\tau_\mu$), and –1.95(-2.66) when neither is included ($\tau$). The standard t-distribution critical value is –1.708(-2.485).

b At a 5(1) percent significance level the Dickey-Fuller critical values (for 25 observations) are 7.24(10.61) when a trend and a constant are included ($\Phi_3$), and 5.18(7.88) when only a constant is included ($\Phi_1$).

*** Significant at a 10 percent level.

*(insign)* Insignificant lag.

**Table A17.1** *(cont.)*. **Augmented Dickey-Fuller tests for non-stationarity, levels, 1970-1995**

| Series | Model | Lags | $\tau_\tau$, $\tau_\mu$ , $\tau$ | $\Phi_3$, $\Phi_1$ |
|---|---|---|---|---|
| ln_pz$ | Trend | 2 | -2.07 | 6.36 |
| | Constant | 2 | -3.53* | 8.93** |
| | None | 2 | -2.97** | |
| ln_r$ | Trend | 3 | -2.23 | 2.77 |
| | Constant | 0 *(insign)* | 0.24 | 0.06 |
| | None | 0 | 2.74 | |
| ln_rel_wscost_u | Trend | 6 | 1.82 | 2.05 |
| | Constant | 4 | -1.54 | 2.03 |
| | None | 4 | -3.89** | |
| ln_rel_wsu_rat | Trend | 0 *(insign)* | -1.53 | 2.78 |
| | Constant | 6 | -1.36 | 1.09 |
| | None | 6 | -1.65 | |
| ln_s | Trend | 3 | -1.27 | 2.12 |
| | Constant | 3 | -1.43 | 2.19 |
| | None | 3 | -0.79 | |
| ln_ss | Trend | 1 | 0.33 | 31.27 |
| | Constant | 1 | -2.54 | 46.06** |
| | None | 1 | -0.03 | |
| ln_sc_cp | Trend | 0 | -1.99 | 2.06 |
| | Constant | 0 *(insign)* | -0.90 | 0.81 |
| | None | 0 | 2.47 | |
| ln_socind | Trend | 0 | -1.50 | 1.82 |
| | Constant | 6 | 3.43 | 3.06 |
| | None | 5 | -0.33 | |
| tecno_index | Trend | 0 | -2.01 | 6.14 |
| | Constant | 0 | 1.83 | 3.36 |
| | None | 0 | 4.02 | |
| ln_total_pop | Trend | 4 | 0.36 | 12671.24 |
| | Constant | 4 | -2.94 | 15012.84** |
| | None | 8 | -0.85 | |
| ln_ucc2_90p | Trend | 1 | -5.06** | 8.54* |
| | Constant | 4 | -0.78 | 1.83 |
| | None | 7 | -1.56 | |
| ln_ucc2_nom | Trend | 6 | -1.75 | 1.01 |
| | Constant | 0 *(insign)* | -1.07 | 1.14 |
| | None | 5 | -1.53 | |
| ln_unempl_rat | Trend | 4 | -2.58 | 3.33 |
| | Constant | 4 | 0.76 | 1.70 |
| | None | 6 | -4.02** | |

*(**) Significant at a 5(1) percent level.

a At a 5(1) percent significance level the MacKinnon critical values are –3.60(-4.38) when a trend and a constant are included ($\tau_\tau$), and –3.00(-3.75) when only a constant is included ($\tau_\mu$), and –1.95(-2.66) when neither is included ($\tau$). The standard t-distribution critical value is –1.708(-2.485).

b At a 5(1) percent significance level the Dickey-Fuller critical values (for 25 observations) are 7.24(10.61) when a trend and a constant are included ($\Phi_3$), and 5.18(7.88) when only a constant is included ($\Phi_1$).

*** Significant at a 10 percent level.

*(insign)* Insignificant lag.

Table A17.1 *(cont.)*. **Augmented Dickey-Fuller tests for non-stationarity, levels, 1970-1995**

| Series | Model | Lags | $\tau_\tau, \tau_\mu, \tau$ | $\Phi_3, \Phi_1$ |
|---|---|---|---|---|
| ln_uniopresind | Trend | 7 | -1.99 | 2.36 |
| | Constant | 5 | 2.74 | 2.32 |
| | None | 5 | -1.70 | |
| ln_vpi | Trend | 4 | -0.54 | 4.02 |
| | Constant | 4 | -2.11 | 5.06 |
| | None | 4 | -3.06** | |
| ln_w_prod | Trend | 2 | -0.52 | 10.84 |
| | Constant | 2 | -1.74 | 15.00** |
| | None | 2 | 2.38 | |
| ln_ws_rate | Trend | 1 | -2.73 | 6.88 |
| | Constant | 1 | -0.35 | 5.12 |
| | None | 1 | 1.99 | |
| ln_wtot_ppi_rat | Trend | 3 | -3.24 | 3.74 |
| | Constant | 1 | -0.84 | 1.88 |
| | None | 1 | 0.73 | |
| ln_wtot_rate | Trend | 1 | -3.59 | 9.79* |
| | Constant | 2 | -0.41 | 5.20 |
| | None | 2 | 2.41 | |
| ln_wtot_vpi_rat | Trend | 1 | -3.23 | 5.56 |
| | Constant | 5 | -2.20 | 2.15 |
| | None | 0 | 1.82 | |
| ln_wuppi_rat | Trend | 3 | -3.34 | 2.96 |
| | Constant | 6 | -0.18 | 1.04 |
| | None | 6 | 2.61 | |
| ln_wuvpi_rat | Trend | 0 | -1.92 | 3.87 |
| | Constant | 0 | -2.82 | 7.96** |
| | None | 0 | 2.39 | |
| ln_xgoud_ppi | Trend | 4 | 0.15 | 2.47 |
| | Constant | 5 | -1.28 | 1.86 |
| | None | 5 | -0.35 | |
| ln_xgoud_px | Trend | 0 *(insign)* | -1.29 | 1.72 |
| | Constant | 1 | -2.07 | 2.88 |
| | None | 0 *(insign)* | -0.18 | |

*(**) Significant at a 5(1) percent level.

a At a 5(1) percent significance level the MacKinnon critical values are –3.60(-4.38) when a trend and a constant are included ($\tau_\tau$), and –3.00(-3.75) when only a constant is included ($\tau_\mu$), and –1.95(-2.66) when neither is included ($\tau$). The standard t-distribution critical value is –1.708(-2.485).

b At a 5(1) percent significance level the Dickey-Fuller critical values (for 25 observations) are 7.24(10.61) when a trend and a constant are included ($\Phi_3$), and 5.18(7.88) when only a constant is included ($\Phi_1$).

*** Significant at a 10 percent level.

*(insign)* Insignificant lag

**Table A17.2. Augmented Dickey-Fuller tests for non-stationarity, first differences, 1970-1995**

| Series | Model | Lags | $\tau_\tau, \tau_\mu, \tau$ | $\Phi_3, \Phi_1$ |
|---|---|---|---|---|
| Δln_bbp_90p | Trend | 0 | -3.81* | 7.38* |
| | Constant | 0 | -3.65* | 13.29* |
| | None | 0 | -2.63* | |
| Δln_bbp_min_90p | Trend | 0 | -3.78* | 7.32* |
| | Constant | 0 | -3.90** | 15.25** |
| | None | 0 | -3.84** | |
| Δln_bbpfact_90p | Trend | 0 | -3.85* | 7.55* |
| | Constant | 0 | -3.58* | 12.85** |
| | None | 0 | -2.67** | |
| Δln_c90p_lrem5 | Trend | 3 | -3.26*** | 3.68 |
| | Constant | 3 | -3.32* | 4.78*** |
| | None | 0 | -2.82** | |
| Δln_educind | Trend | 0 | 4.16 | 9.87 |
| | Constant | 0 | -4.45** | 19.83** |
| | None | 0 | -3.28** | |
| Δln_empl_rat | Trend | 3 | -4.75** | 7.27* |
| | Constant | 0 | -2.98* | 8.87** |
| | None | 0 | -2.21* | |
| Δln_empl_rat_s | Trend | 5 | -0.54 | 2.58 |
| | Constant | 3 | -3.44* | 4.76*** |
| | None | 3 | -3.53** | |
| Δln_empl_rat_u | Trend | 0 | -3.29*** | |
| | Constant | | | |
| | None | | | |
| Δln_exces_dem_cp | Trend | 8 | -2.77 | 4.47 |
| | Constant | 3 | -4.26** | 7.05* |
| | None | 3 | -4.35** | |
| Δln_fincond_ppi | Trend | 3 | -3.49 | 5.00 |
| | Constant | 3 | -3.74* | 6.48* |
| | None | 3 | -3.85** | |
| Δln_gostc_cp | Trend | 1 | -5.06** | 9.24* |
| | Constant | 1 | -5.20** | 14.49** |
| | None | 0 | -1.62*** | |
| Δln_gprys_$ | Trend | 3 | -4.53** | 6.58 |
| | Constant | 0 | -3.21* | 10.32** |
| | None | 0 | -3.02** | |

*(**) Significant at a 5(1) percent level.

a At a 5(1) percent significance level the MacKinnon critical values are –3.60(-4.38) when a trend and a constant are included ($\tau_\tau$), and –3.00(-3.75) when only a constant is included ($\tau_\mu$), and –1.95(-2.66) when neither is included ($\tau$). The standard t-distribution critical value is –1.708(-2.485).

b At a 5(1) percent significance level the Dickey-Fuller critical values (for 25 observations) are 7.24(10.61) when a trend and a constant are included ($\Phi_3$), and 5.18(7.88) when only a constant is included ($\Phi_1$).

*** Significant at a 10 percent level.

*(insign)* Insignificant

lag.

Table A17.2 *(cont.)*. **Augmented Dickey-Fuller tests for non-stationarity, first differences, 1970-1995**

| Series | Model | Lags | $\tau_\tau, \tau_\mu, \tau$ | $\Phi_3, \Phi_1$ |
|---|---|---|---|---|
| Δln_gprys_r | Trend | 3 | -6.81** | 12.34** |
| | Constant | 0 | -3.39* | 11.52** |
| | None | 0 | -2.45* | |
| Δln_if | Trend | 1 | -4.49** | 7.33* |
| | Constant | 1 | -4.30** | 9.90** |
| | None | 1 | -4.35** | |
| Δln_interposind | Trend | 0 | -3.45*** | 5.95*** |
| | Constant | 0 | -3.50* | 12.22** |
| | None | 0 | -2.26* | |
| Δln_kap_lab_rat | Trend | 7 | -1.98 | 2.54 |
| | Constant | 5 | -1.33 | 2.09 |
| | None | 5 | -2.54* | |
| Δln_kap_r | Trend | 1 | -3.48*** | 7.13*** |
| | Constant | 2 | -1.12 | 6.43 |
| | None | 2 | -2.34* | |
| Δln_n | Trend | 8 | -1.51 | 7.00 |
| | Constant | 8 | 2.22 | 3.92 |
| | None | 5 | -1.76*** | |
| Δln_n_informal | Trend | 1 | -4.36* | 6.77*** |
| | Constant | 1 | -4.57** | 10.63** |
| | None | 1 | -3.33** | |
| Δln_ns | Trend | 0 | -2.95 | 4.55 |
| | Constant | 0 | -2.07 | 4.29*** |
| | None | | | |
| Δln_nu | Trend | 0 | -3.06 | 4.70 |
| | Constant | 0 | -2.47 | 6.09* |
| | None | 0 | -2.55* | |
| Δln_p_manuf | Trend | 0 | -2.27 | 3.17 |
| | Constant | 0 | -2.53 | 6.38* |
| | None | | | |
| Δln_ppi | Trend | 1 | -4.57** | 7.50* |
| | Constant | 1 | -3.75** | 7.12* |
| | None | | | |
| Δln_prime_rate | Trend | 4 | -5.23** | 8.24* |
| | Constant | 4 | -5.13** | 9.67** |
| | None | 3 | -3.95** | |
| Δln_product | Trend | 0 | -3.24*** | 5.42 |
| | Constant | 0 | -2.98 | 8.89** |
| | None | 0 | -2.56* | |

*(**) Significant at a 5(1) percent level.

a At a 5(1) percent significance level the MacKinnon critical values are –3.60(-4.38) when a trend and a constant are included ($\tau_\tau$), and –3.00(-3.75) when only a constant is included ($\tau_\mu$), and –1.95(-2.66) when neither is included ($\tau$). The standard t-distribution critical value is –1.708(-2.485).

b At a 5(1) percent significance level the Dickey-Fuller critical values (for 25 observations) are 7.24(10.61) when a trend and a constant are included ($\Phi_3$), and 5.18(7.88) when only a constant is included ($\Phi_1$).

*** Significant at a 10 percent level.

*(insign)* Insignificant lag.

**Table A17.2 *(cont.)*. Augmented Dickey-Fuller tests for non-stationarity, first differences, 1970-1995**

| Series | Model | Lags | $\tau_\tau, \tau_\mu, \tau$ | $\Phi_3, \Phi_1$ |
|---|---|---|---|---|
| Δln_pz$ | Trend | 1 | -4.57** | 6.96 |
| | Constant | 2 | -1.76 | 5.28* |
| | None | 2 | -1.68*** | |
| Δln_r$ | Trend | 1 | -4.12* | 6.07*** |
| | Constant | 0 | -3.81** | 14.49** |
| | None | 0 | -3.12** | |
| Δln_rel_wscost_u | Trend | 3 | -4.31* | 8.30* |
| | Constant | 3 | -3.93** | 9.05** |
| | None | 0 | -3.41** | |
| Δln_rel_wsu_rat | Trend | 0 | -4.66** | 10.87** |
| | Constant | 0 | -3.88** | 15.05** |
| | None | 0 | -2.56* | |
| Δln_s | Trend | 2 | -0.90 | 12.08 |
| | Constant | 0 | -6.36** | 40.47** |
| | None | 9 | -7.14** | |
| Δln_ss | Trend | 0 | -2.96 | 4.49 |
| | Constant | 0 *(insign)* | -0.94 | 0.88 |
| | None | 0 *(insign)* | -1.33 | |
| Δln_sc_cp | Trend | 0 | -5.64** | 15.94** |
| | Constant | 0 | -5.72** | 32.75** |
| | None | 0 | -4.53** | |
| Δln_socind | Trend | 5 | -4.12* | 7.89* |
| | Constant | 3 | -3.33* | 5.86* |
| | None | 0 | -3.79** | |
| Δtecno_index | Trend | 0 | -5.22** | 13.66** |
| | Constant | 0 | -4.45** | 19.82** |
| | None | 0 | -2.92** | |
| Δln_total_pop | Trend | 8 | -6.86** | 596.94** |
| | Constant | 7 | 0.04 | 73.39 |
| | None | 7 | -4.04** | |
| Δln_ucc2_90p | Trend | 3 | -3.96* | 7.91* |
| | Constant | 3 | -4.05** | 10.11** |
| | None | 0 | -3.39** | |
| Δln_ucc2_nom | Trend | 0 | -4.18* | 9.12* |
| | Constant | 0 | -3.99** | 15.93** |
| | None | | | |
| Δln_unempl_rat | Trend | 3 | -5.10** | -9.64* |
| | Constant | 3 | -5.39** | 11.46** |
| | None | 0 | -3.42** | |

*(**) Significant at a 5(1) percent level.

a At a 5(1) percent significance level the MacKinnon critical values are –3.60(-4.38) when a trend and a constant are included ($\tau_\tau$), and –3.00(-3.75) when only a constant is included ($\tau_\mu$), and –1.95(-2.66) when neither is included ($\tau$). The standard t-distribution critical value is –1.708(-2.485).

b At a 5(1) percent significance level the Dickey-Fuller critical values (for 25 observations) are 7.24(10.61) when a trend and a constant are included ($\Phi_3$), and 5.18(7.88) when only a constant is included ($\Phi_1$).

*** Significant at a 10 percent level.

*(insign)* Insignificant lag.

**Table A17.2** ***(cont.).*** **Augmented Dickey-Fuller tests for non-stationarity, first differences, 1970-1995**

| **Series** | **Model** | **Lags** | $\tau_\tau, \tau_\mu, \tau$ | $\Phi_3, \Phi_1$ |
|---|---|---|---|---|
| Δln_uniopresind | Trend | 4 | 0.76 | 6.48 |
| | Constant | 0 | -4.96** | 24.61** |
| | None | 0 | -4.72** | |
| Δln_vpi | Trend | 5 | -1.89 | 3.54 |
| | Constant | 0 | -2.15 | 4.61*** |
| | None | | | |
| Δln_w_prod | Trend | 1 | -4.80** | 9.31* |
| | Constant | 1 | -4.31** | 11.37** |
| | None | | | |
| Δln_ws_rate | Trend | 0 | -2.12 | 2.66 |
| | Constant | 0 | -2.36 | 5.55* |
| | None | | | |
| Δln_wtot_ppi_rat | Trend | 6 | -4.28* | 4.38 |
| | Constant | 3 | -2.89*** | 4.20*** |
| | None | 3 | -2.57* | |
| Δln_wtot_rate | Trend | 1 | -3.21 | 3.80 |
| | Constant | 1 | -3.37* | 5.91* |
| | None | | | |
| Δln_wtot_vpi_rat | Trend | 0 | -3.39 | 5.75 |
| | Constant | 0 | -3.23* | 10.47** |
| | None | 0 | -3.07** | |
| Δln_wuppi_rat | Trend | 0 | -3.91 | 7.69* |
| | Constant | 0 | -4.01** | 16.05** |
| | None | 0 | -3.41** | |
| Δln_wuvpi_rat | Trend | 0 | -3.66* | 6.73 |
| | Constant | 0 | -3.19* | 10.20** |
| | None | 0 | -2.67** | |
| Δln_xgoud_ppi | Trend | 3 | -4.81** | 6.82 |
| | Constant | 0 | -3.27* | 10.70** |
| | None | 0 | -3.34** | |
| Δln_xgoud_px | Trend | 0 | -3.73 | 7.01 |
| | Constant | 0 | -3.58* | 12.82** |
| | None | 0 | -3.66** | |

*(**) Significant at a 5(1) percent level.

a At a 5(1) percent significance level the MacKinnon critical values are –3.60(-4.38) when a trend and a constant are included ($\tau_\tau$), and –3.00(-3.75) when only a constant is included ($\tau_\mu$), and –1.95(-2.66) when neither is included ($\tau$). The standard t-distribution critical value is –1.708(-2.485).

b At a 5(1) percent significance level the Dickey-Fuller critical values (for 25 observations) are 7.24(10.61) when a trend and a constant are included ($\Phi_3$), and 5.18(7.88) when only a constant is included ($\Phi_1$).

*** Significant at a 10 percent level.

*(insign)* Insignificant lag.

**Table A17.3. Augmented Dickey-Fuller tests for non-stationarity, second differences, 1970-1995**

| Series | Model | Lags | $\tau_\tau, \tau_\mu, \tau$ | $\Phi_3, \Phi_1$ |
|---|---|---|---|---|
| ΔΔln_ss | Trend | 1 | -5.36** | 16.00** |
| | Constant | 1 | -5.37** | 24.29** |
| | None | 1 | -4.78** | |

*(**) Significant at a 5(1) percent level.

a At a 5(1) percent significance level the MacKinnon critical values are –3.60(-4.38) when a trend and a constant are included ($\tau_\tau$), and –3.00(-3.75) when only a constant is included ($\tau_\mu$), and –1.95(-2.66) when neither is included ($\tau$). The standard t-distribution critical value is –1.708(-2.485).

b At a 5(1) percent significance level the Dickey-Fuller critical values (for 25 observations) are 7.24(10.61) when a trend and a constant are included ($\Phi_3$), and 5.18(7.88) when only a constant is included ($\Phi_1$).

*** Significant at a 10 percent level.

*(insign)* Insignificant lag.