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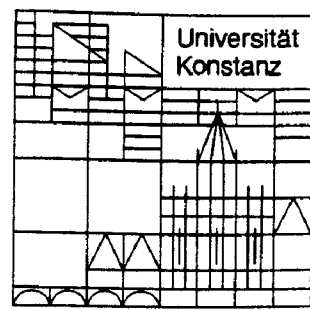
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Diskussionsbeiträge



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**Dynamic Adjustment
in Open Economies**

DYNAMIC ADJUSTMENT IN OPEN ECONOMIES

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Abstract

This paper analyzes adjustment to exogenous shocks in a dynamic version of the specific-factors model in which capital is assumed to be a quasi-fixed factor. Capital allocation is treated as an issue in investment theory, thus endogenizing long-run capital stocks of industries. Convex costs of adjustment generate finite Keynesian investment demand functions which are incorporated in a two-sector trade model. Depending on the source of the exogenous shock comparative static effects are ambiguous and the adjustment path to the long-run equilibrium may be characterized by an overadjustment of capital stocks and/or of the national product. The long-run equilibrium is almost always characterized by non-equalization of capital rentals.

1 Introduction

In the literature it is quite common to interpret the specific-factors (SF) model as a short-run version of the Heckscher-Ohlin-Samuelson (HOS) model [see e.g. Jones and Neary (1984) p. 26]. The dynamic interpretation of these two static models assumes that the capital-reallocation process is slow and driven by intersectoral differentials in capital rentals. Slow adjustment is the dynamic equivalent to incomplete mobility and presupposes increasing marginal costs of adjustment (convex adjustment costs). The above adjustment mechanism, however, does not explicitly refer to adjustment costs. Furthermore, capital accumulation seems to be allowed only after reallocation has finished. This is stated explicitly in the Oniki-Uzawa (OU) model where each point on the adjustment path to the long-run equilibrium can be described by the HOS model. Thus the OU model seems to apply for the very long run. This hierarchy of the SF, HOS and OU model reflects the dichotomy of reallocation and accumulation characteristic for these models.

Mussa (1978) analyzed adjustment in a dynamic model with explicit reference to the adjustment process. He considers capital allocation as a problem of investment theory, thereby overcoming the dichotomy of capital reallocation and accumulation reflected in the above models: from the view of investment theory capital reallocation is only a side effect of investment or — equivalently — of accumulation. Capital can only be allocated between sectors by a special capital-allocating sector and convex adjustment costs are the consequence of diminishing returns due to sector-specific capital there. This creates an incentive to spread adjustment over time in order to reduce costs. The long-run equilibrium is of the HOS type with equal capital rentals unless adjustment costs are sector specific. This model, however, suffers from the following deficiencies: slow capital reallocation between two sectors is explained with the help of total immobility of capital in a third sector that does not employ any labour after capital reallocation has ceased in the long-run equilibrium; its stock of sector-specific capital is unemployed then with the respective return to capital being zero. Thus the long-run equilibrium is a HOS equilibrium only if one abstracts from this type of capital in the steady state. Furthermore, there is an asymmetry of investment possibilities since it is not possible to invest in the capital-allocating industry.

This paper analyzes the process of adjustment in a dynamic version of the SF model. Like Albert (1989) and Albert and Meckl (1990), the dynamic theory of the firm is used to model sectoral investment decisions. Thereby two types of capital mobility are distinguished: physical mobility describes the mobility of physical units of capital and financial mobility stands for the mobility of savings. In the following physical mobility is assumed to be completely absent, whereas

financial mobility of capital is assumed to be perfect¹. Thus investment is the process of building up sector-specific stocks of physical capital and physical capital can only be 'reallocated' via investment and depreciation. There is good reason to assume total immobility of physical capital units resulting from the prerequisites for physical mobility: first, markets for second-hand capital goods must exist and, second, the respective capital goods must be applicable to more than one industry. Thus the investment-depreciation view of capital mobility seems very reasonable, especially as far as international capital mobility is concerned.

It will be shown that with convex costs of adjustment sectoral investment demand is finite and investment is positive for both industries even if capital rentals don't equalize. Marginal costs of investment almost always differ between sectors (except if both sectors have the same capital stock). Thus perfect financial mobility of capital is an imperfect substitute for physical mobility since capital returns will almost never be equalized even in the long-run equilibrium. The steady state of this model is a kind of SF equilibrium; capital stocks, however, are endogenous.

Whereas Albert and Meckl (1990) discuss the long-run equilibrium of different varieties of the two sector model, the present paper focusses on the comparative static behaviour and the dynamics of the adjustment process of the simple model of a small open economy with free access to international financial markets. Before putting forth the basic model in section 3, the necessary elements of the dynamic theory of the firm [see Söderström (1976) for a survey] are summarized in section 2. Section 4 turns to stability and comparative static behaviour of the model. The adjustment process is then analyzed in section 5 and section 6 eventually summarizes the main results and discusses problems of generalizing the model.

2 The Dynamic Theory of the Firm

The dynamic theory of the firm describes the optimal adjustment of a firm or a sector² in a situation where capital stocks are neither completely variable nor definitely fixed, but adjustable at a cost³. The sector's investment decision therefore becomes part of the cost minimizing problem and the theory becomes dynamic in the sense that the speed of adjustment is determined endogenously. Let sector

¹Note that with complete immobility of physical capital units adjustment is always slow (e.g. disinvestment is restricted to depreciation), without any further assumptions. Nevertheless adjustment costs generate imperfect substitutability of both types of capital mobility.

²One can argue with a representative firm since all firms are price takers in the commodity and factor markets and there are no distortions in the production sector; firms of different size have the same long-run capital stock.

³Nickell (1986) considers adjustment in a model in which labour is treated as a quasi-fixed factor due to convex adjustment costs.

j 's production of commodity x_j be described by the linearly-homogeneous production function f_j with inputs of capital K_j and labour L_j . With a given wage rate w and given commodity prices p_j the problem of the industry is to maximize the present value of net revenue

$$\max_{L_j, I_j} \left\{ \int_0^{\infty} e^{-it} \cdot [p_j \cdot x_j - w \cdot L_j - p_I \cdot C(I_j)] dt \right\} \quad (1)$$

$$\text{s.t.} \quad \begin{aligned} \dot{K}_j &= I_j - \delta_j \cdot K_j \\ x_j &= f_j(K_j, L_j) \\ I_j &\geq 0, \end{aligned}$$

where p_I is the price of the investment good (set equal to unity hereafter), i is the interest rate and δ_j is sector j 's rate of depreciation. $C(I_j)$ is an increasing and strictly convex function⁴ with $C(0) = 0$ and derivative $C'(0) = 0$; it gives the quantity of investment goods necessary to produce gross investment I_j in the respective sector. Investment is financed by selling shares on perfect capital markets. For the sake of simplicity an infinite time horizon and static expectations are assumed.

The solution of this problem is given by

$$p_j \cdot (\partial f_j / \partial L_j) = w \quad (2)$$

$$r_j \equiv p_j \cdot (\partial f_j / \partial K_j) = (i + \delta_j) \cdot C'(I_j). \quad (3)$$

(2) is the traditional condition for labour demand. The left-hand side of (3) gives the marginal return to investment, the right-hand side the marginal cost (or user cost) of investment; r_j denotes sector j 's rental rate of (physical) capital. Since C is convex, (3) can be solved for the optimal (constant) investment I_j^* :

$$I_j^* = (C')^{-1} \left[\frac{r_j}{i + \delta_j} \right]. \quad (4)$$

(4) is a Keynesian investment demand function. Defining $K_j^* := I_j^* / \delta_j$ as the desired long-run capital stock, the dynamic constraint can be written in the flexible-accelerator form

$$\dot{K}_j = \delta_j \cdot (K_j^* - K_j). \quad (5)$$

Equations (1) to (5) characterize the behaviour of a sector. If only the long-run equilibrium is of interest, the following static maximization problem can be used

⁴Note that costs of adjustment are assumed to depend on gross investment. Sargent (1987, p. 132), however, assumed adjustment cost depending on net investment; consequently adjustment costs are not relevant in the long-run equilibrium. For further discussion of Sargent's approach in a two-sector trade model see Albert and Meckl (1990).

which directly yields the steady-state conditions; the problem is to maximize the steady-state net revenue of sector j :

$$\max_{L_j, K_j} \left\{ p_j \cdot x_j - w \cdot L_j - \frac{(i + \delta_j)}{\delta_j} \cdot C(\delta_j \cdot K_j) : x_j = f_j(K_j, L_j) \right\}. \quad (6)$$

where $[(i + \delta_j)/\delta_j] \cdot C(\delta_j \cdot K_j)$ are the industry's steady-state costs of maintaining its capital stock made up by the sum of replacement costs $C(\delta_j \cdot K_j)$ and of opportunity costs $i \cdot C(\delta_j \cdot K_j)/\delta_j$ of holding the whole capital stock. Obviously new and old capital are assumed to be perfect substitutes and only differ in their state of depreciation if opportunity costs are made up in the above manner.

The maximization problem (6) yields first-order conditions which are identical to the solution of (5) in the steady state. An equivalent maximization problem will be used in section 3 to describe the long-run equilibrium of a two-sector model.

Up to now we simply assumed convex costs of adjustment without any justification. The above formulation of the firm's maximization problem in equation (1) implicitly assumes purely external adjustment costs, i.e. the extent of adjustment does not affect the firm's production activities. In such circumstances an economy with perfect competition on the investment goods market will in general be characterized by linear costs of adjustment without further assumptions. Convex costs of adjustment can result from indivisibilities of investment projects at the firm level together with the assumption that it is more expensive to do things quickly than to do them slowly. The investment decision then is a decision about the use of two factors of production, capital goods and time, in realizing an investment project where both factors are substitutes. Now it seems realistic that total costs of building, for example, a factory increase overproportionally with the speed of building. In the extreme, costs of building instantaneously a factory are infinitely high. So it is economically reasonable to spread investment over time⁵. As usual indivisibilities will be smoothed out more or less at the industry level. Thus sectoral investment decisions can be approximated by convex costs of adjustment.

On the other hand, we can derive some justification for the assumption of convex costs of adjustment from their implications concerning the distribution of savings in an economy. Convex costs generate finite investment demand and therefore a spreading of savings over all sectors of an economy. This is more conform with the real world than the concentration of savings in only one sector (which has the highest return on physical capital) as would follow from linear adjustment costs.

⁵Rothschild (1971) points out that convex costs of adjustment are especially reasonable for high levels of investment, whereas concave costs are important for relatively low investment levels.

3 The Two-Sector Model

In a two-sector small open economy facing exogenous commodity prices from the world market and producing an investment good x_I and a consumption good x_C , convex adjustment costs generate a concave capital-input-transformation curve in the K_I - K_C -plane. This input-transformation curve is a parallel to the static models of partial factor mobility of Mussa (1982) and Grossman (1983): these models, however, assume a fixed level of the input-transformation curve. In the dynamic model the level of this curve is given by $V := [(i + \delta_I)/\delta_I] \cdot C(\delta_I \cdot K_I) + [(i + \delta_C)/\delta_C] \cdot C(\delta_C \cdot K_C)$ and is determined endogenously since capital stocks are endogenous. V can be interpreted as a magnitude representing the economy's demand for financial capital. With perfect international mobility of financial capital the supply of financial capital is perfectly elastic at a given world interest rate; moreover, trade need not be balanced. Therefore it is possible to concentrate solely on the production side.

We first look at the economy's long-run equilibrium. Since allocation of labour poses no interesting problems, we define with $p_I \equiv 1$, $p := p_C$

$$y(p, L, K_I, K_C) = \max_{L_I, L_C} \{x_I + p \cdot x_C : L_I + L_C = L; x_j = f_j(K_j, L_j); j = I, C\}, \quad (7)$$

where L stands for the economy's fixed endowment of labour.

(7) is the national product function of the SF model; it is concave and linearly homogeneous in factor quantities and therefore strictly concave in capital stocks. (7) summarizes the result of the short-run labour allocation process⁶. The long-run result of the adjustment process is described by the following two-step maximization problem:

$$\max_{K_I, K_C} \left\{ y(p, L, K_I, K_C) - \frac{i + \delta_I}{\delta_I} \cdot C(\delta_I \cdot K_I) - \frac{i + \delta_C}{\delta_C} \cdot C(\delta_C \cdot K_C) \right\}. \quad (8)$$

This is an unconstrained maximization problem since the national product function y already contains the constraints of the production sector and the supply of financial capital is perfectly elastic at the given world interest rate. Obviously (8) is the two-sector equivalent of (6). The first-order conditions necessary for a maximum of (8) are:

$$\frac{\partial y}{\partial K_j} = (i + \delta_j) \cdot C'(\delta_j \cdot K_j); \quad j = I, C \quad (9)$$

with $\partial y / \partial K_j = r_j$. These first-order conditions are identical to the steady-state conditions of the dynamic model analyzed in the next section.

⁶See Dixit and Norman (1980), p. 43, for the properties of this function.

4 Stability and Comparative–Static Results

The relevant dynamic system is given by

$$\begin{aligned}\dot{K}_I &= \delta_I \cdot (K_I^* - K_I) \\ \dot{K}_C &= \delta_C \cdot (K_C^* - K_C)\end{aligned}\tag{10}$$

and the condition of equal wages in both sectors. It is easy to see that any steady state of (10) (given by (3), substituting I_j by $\delta_j \cdot K_j$) satisfies the first-order conditions of (8). Since the maximand of (8) is strictly concave in capital stocks, there can be only one solution to the first-order conditions and therefore to the steady-state conditions. Global stability can be proved by using the maximand of (8) as a Liapunov function: since the maximand of (8) has a unique maximum at the steady state, one only has to prove that it increases monotonically under the dynamic system. This can be seen by differentiating (8) with respect to time:

$$[r_I - (i + \delta_I) \cdot C'(\delta_I \cdot K_I)] \cdot \dot{K}_I + [r_C - (i + \delta_C) \cdot C'(\delta_C \cdot K_C)] \cdot \dot{K}_C > 0 \tag{11}$$

The short-run reaction to exogenous shocks is described by the SF model and short-run comparative static effects can be calculated from (7). A rise in p raises the value of the marginal product of labour and capital in sector C and generates labour reallocation from industry I to industry C ; for factor prices the following well-known relation holds in the short run:

$$\hat{r}_C > \hat{p} > \hat{w} > 0 > \hat{r}_I.\tag{12}$$

Additionally output rises in sector C and falls in sector I .

The change in capital rentals drives up investment in sector C and lowers sector I 's investment demand. The long-run effects of a change in the relative price p can be derived from the unit cost curves in fig. 1: c_I and c_C are the sectors' unit cost curves and show combinations of the wage rate and sectoral capital returns which are compatible with zero profits in each sector. With the wage determined on the labour market the equilibrium capital rentals are determined. Let w^0 be the initial long-run equilibrium wage rate; the corresponding capital rentals are given by r_I^0 and r_C^0 . An increase in p shifts sector C 's unit cost curve (proportionally) to the north-east to c'_C . The short-run labour reallocation raises w to w' and r_C to r'_C whereas r_I falls to r'_I . For the new long-run equilibrium wage rate a lower and an upper bound can now be determined: w cannot fall below w^0 since then long-run capital returns would rise in both sectors thereby increasing the long-run capital stocks according to (4). Thus capital intensity would have to rise in both sectors; that is, however, incompatible with a fall in w . The upper bound of the wage rate is \bar{w} which is the wage rate corresponding to

the initial capital return in sector C — r_C^0 — at new prices: w cannot rise beyond \bar{w} since then both capital returns would have to fall in both sectors implying smaller long-run capital stocks. Hence labour intensity would have to rise in both industries which is incompatible with a rise in w . The new steady-state wage rate w^1 must therefore lie between \bar{w} and w^0 implying that r_C rises and r_I falls and consequently K_C also rises and K_I declines. Whether w rises or falls during the capital accumulation process is ambiguous and depends on the industries' substitution possibilities between factors. Sectoral labour employment, however, changes with capital stocks; thus industry C 's output must increase and industry I 's output must fall. This completes the comparative static effects of price changes.

The short-run effects of changes in the economy's labour endowment can also be described by the SF model: an increase of L raises employment and output in both industries and causes the rental rates of capital to rise. This short-run reaction will drive up investment in both sectors, thereby raising capital stocks and driving down capital rentals. Since wages equalize instantaneously both returns on capital always change in the same direction and so must capital stocks. Steady-state capital stocks cannot fall since this would presuppose a decrease in steady-state capital returns or — equivalently — an increase of the steady-state wage rate; the latter, however, is only possible with rising capital stocks. This ensures that steady-state capital returns and steady-state capital stocks must rise in both sectors. As steady-state capital returns rise, labour intensities must increase implying that long-run labour employment also rises; consequently output increases in both industries.

Comparative static effects of changes in the world interest rate are ambiguous. A rise in i has no short-run labour reallocation effects. Over time investment in both sectors begins to decline, driving up capital rentals. Since steady-state capital stocks depend on $r_j/(i + \delta_j)$, and since it is not clear whether this term rises or falls as r_j and i increase, the change of steady-state capital stocks is also indeterminate. But increase and decrease of capital stocks are only compatible with increasing capital returns; consequently the wage rate must definitely fall and labour intensity must rise in both sectors, independent of capital stock reaction. A rise in labour intensities, however, implies that with exogenous labour endowments the capital stock of the economy as a whole must decrease. Thus capital stocks can never increase in both sectors. Sectoral output increases as the sector's capital stock rises.

Assuming identical rates of depreciation for both sectors ($\delta := \delta_C = \delta_I$) and ruling out factor-intensity reversals ambiguous capital stock reactions due to interest-rate changes are only possible in the sector that is relatively labour intensive in the sense that its share of wages in the value of its output is greater

than the other sector's⁷. Defining R as the ratio of capital rentals $R := r_C/r_I$, R must fall as the interest rate rises if sector C is relatively capital intensive⁸. Since the ratio of sectoral capital stocks K_C/K_I is a monotonically increasing function of R and the economy's overall capital stock must increase, the reaction of sector C 's capital stock is unambiguously determined whereas sector I 's capital stock may even fall.

5 Dynamic Adjustment of Capital Stocks and National Product

In the preceding section only the comparative static effects concerning the long-run equilibrium and the short-run effects of exogenous shocks were discussed. This section analyzes the adjustment path of capital stocks and national product from the short-run to the long-run equilibrium. Capital accumulation and reallocation effects are analyzed qualitatively in a phase diagram in the K_I - K_C -plane.

The slope of the isokines $\dot{K}_i = 0$ can be derived from the dynamic system (10), recognizing that K_i^* is an increasing function of r_i and a decreasing function of i . Implicit differentiation of (10) yields

$$\begin{aligned} \left. \frac{dK_I}{dK_C} \right|_{\dot{K}_I=0} &= -\frac{(\partial K_I^*/\partial r_I) \cdot (\partial r_I/\partial K_C)}{(\partial K_I^*/\partial r_I) \cdot (\partial r_I/\partial K_I) - 1} < 0 \\ \left. \frac{dK_I}{dK_C} \right|_{\dot{K}_C=0} &= -\frac{(\partial K_C^*/\partial r_C) \cdot (\partial r_C/\partial K_C) - 1}{(\partial K_C^*/\partial r_C) \cdot (\partial r_C/\partial K_I)} < 0. \end{aligned} \tag{13}$$

(13) states that both isokines are negatively sloped. The $\dot{K}_i = 0$ -curves illustrated in fig. 2 divide the K_I - K_C -plane into four regions wherein the intertemporal changes of the capital stocks are indicated by the set of directional arrows. They result from the dynamic behaviour of the system: given \bar{K}_C , for points right to the $\dot{K}_I = 0$ -curve K_I is greater than K_I^* and \dot{K}_I must be negative. On the other hand, given \bar{K}_I , for points above the $\dot{K}_C = 0$ -curve K_C is greater than K_C^* and \dot{K}_C must be negative. The long-run equilibrium must be the intersection point of both isokines. Since it is unique as proved above, there can be only one point of intersection denoted by A in fig. 2. Furthermore the dynamic behaviour implies that the $\dot{K}_C = 0$ -curve must be flatter than the $\dot{K}_I = 0$ -curve (at least in a neighbourhood of the long-run equilibrium) since otherwise the long-run equilibrium would be a saddle point; the latter, however, is incompatible with global stability of the model. Thus the long-run equilibrium A is a stable node.

⁷Cf. Jones and Neary (1984, p. 22) for this definition of factor intensity.

⁸See appendix II.

The trajectories in fig. 2 indicate that all K_I - K_C -combinations in the regions I and III converge to the steady state without leaving their respective region; i.e. the adjustment of both capital stocks is monotonic in those regions. On the other hand non-monotonic adjustment is possible for initial combinations in region II or IV.

The adjustment path of capital stocks resulting from exogenous changes can now be analyzed. An increase of p raises r_C and consequently K_C^* rises; for a given \bar{K}_I , K_C must rise for $\dot{K}_C = 0$ to hold. Consequently the rise in p shifts the $\dot{K}_C = 0$ -curve upwards. Additionally r_I falls as p increases and so does K_I^* . Thus the price increase shifts the $\dot{K}_I = 0$ -curve to the left. As fig. 3 shows the old steady state A^0 lies in region III relative to the new steady state A^1 ; the adjustment of capital stocks therefore is monotonic, i.e. K_C always rises and K_I always falls during the adjustment process. All possible adjustment paths are qualitatively similar to the one shown in fig. 3.

Adjustment of capital stocks due to changes in the economy's labour endowments or in the world interest rate may be non-monotonic. A rise in i results in a decrease of K_I^* and K_C^* at initial values of r_I and r_C . This shifts the $\dot{K}_I = 0$ -curve to the left and the $\dot{K}_C = 0$ -curve downwards; the initial long-run equilibrium A^0 necessarily lies in region IV relative to the new steady state A^1 , independent from the possibility that one sector may expand. Thus overadjustment due to non-monotonic adjustment can occur in one sector and it is the necessary outcome if both sectors adjust in opposite directions. However, overadjustment can never occur in both sectors since the long-run equilibrium is a stable node. In fig. 4. adjustment path a describes monotonic adjustment of both capital stocks. Path b describes overadjustment in sector I ; during the adjustment process sector I 's capital stock falls below its steady-state value and then begins to rise whereas sector C 's capital stock continually decreases. Path c eventually describes overadjustment in sector C .

A change in the interest rate generates adjustment in a sector even if its long-run capital stock does not change: if e.g. i rises investment demand initially falls in both sectors. During the adjustment process disinvestment eventually drives up the sector's return to capital and its capital stock begins to rise. A decrease of the economy's labour endowment generates qualitatively the same adjustment paths as an increase in i ; in this case, however, both sectors must necessarily shrink.

The change of the national product during the capital-stock adjustment process can be analyzed by differentiating the national product function (7) with respect to time:

$$\dot{y} = \frac{\partial y}{\partial K_I} \cdot \dot{K}_I + \frac{\partial y}{\partial K_C} \cdot \dot{K}_C \quad (14)$$

Obviously \dot{y} will never change sign if long-run capital stocks change in the same

direction and both capital stocks adjust monotonically. But \dot{y} may change sign if (a) capital stocks adjust non-monotonically due to changes in the interest rate or in the economy's labour endowment or if (b) long-run capital-stock changes differ in sign as prices vary or if (c) the exogenous shock is a combination of changes in prices, labour endowments and the interest rate. A numerical example of overadjustment of the endogenous variables is given in appendix III. Fig. 5 illustrates non-monotonic adjustment of national product: since $y(p, L, K_I, K_C)$ is strictly concave in capital stocks the iso- y -curves are strictly convex in the K_I - K_C -plane. If adjustment follows the illustrated path, the national product falls below its new steady-state value y^1 ; the latter must be less than the initial steady-state national product y^0 since both capital stocks have fallen.

Nevertheless it should be emphasized that overadjustment of the national product is solely a positive result without any normative content. Especially the national product is not an appropriate measure of the economy's welfare in a model with imbalanced trade.

6 Summary and Conclusions

This paper has analyzed adjustment in a dynamic version of the SF model by allowing capital stocks to adjust over time. Capital allocation is treated as an issue in investment theory thereby overcoming (a) the traditional dichotomy of reallocation and accumulation and (b) the rather ad-hoc adjustment mechanism such as that the rate of capital movement is proportional to differentials in capital returns which is used in dynamic interpretations of the SF model as a short-run version of the HOS model. Convex costs of adjustment generate Keynesian investment demand functions with finite optimal non-negative investment for both industries. Thus the size of the firms within industries is determined. External shocks to the economy yield investment in both sectors even if rental rates of capital are not equalized intersectorally. This feature is an important difference to models with linear (or without) adjustment costs [see Hori and Stein (1977) or Koch (1989)] where (a) investment is always concentrated in the industry with the highest capital return, (b) sectoral investment demand is either infinite or zero and (c) the size of firms is indetermined. This spreading of savings is even conform with indifference of shareholders; special assumptions about shareholders' preferences need not be introduced to avoid the indeterminacy of the capital market in the long-run equilibrium.

Concerning international factor mobility this model shows an asymmetry between labour and capital movements: if labour moves into the economy both sectors necessarily will expand since capital rentals rise in both industries. On the other hand, capital inflows presuppose a decline in the world interest rate and lower capital rentals in both industries. Hence it is not clear how capital

stocks react since sectoral investment depends on the relation of sectoral rental rate of capital and interest rate. With identical rates of depreciation, however, the labour intensive sector's investment demand may fall and the capital intensive sector's investment demand necessarily rises. This is a kind of Rybczynski result; thus the above model generates results in the spirit of the HOS model in some cases. The long-run equilibrium, however, is almost always a SF equilibrium with endogenous capital stocks.

The analysis of the adjustment path to the long-run equilibrium shows qualitative differences depending on the source of exogenous shocks. So price changes generate monotonic adjustment of both industries whereas factor endowment shocks may generate overadjustment in one industry. Moreover, the national product may adjust non-monotonically if capital stocks change in opposite directions. This can occur if prices change exogenously or/and if non-monotonic adjustment of capital stocks due to exogenous changes in the economy's labour endowment or in the interest rate takes place. A numerical example illustrated the overadjustment of endogenous variables.

The above model of course is very special since it assumes a small open two-sector economy with perfectly mobile labour. The introduction of more than two sectors does no harm to uniqueness, stability and comparative static results of the above model; adjustment paths, however, cannot be easily analyzed. Endogenizing prices and interest rate in a two-country model generates difficulties in proving the uniqueness of the equilibrium; since the interest rate changes along with prices no determinate results can be derived for the reaction of both sectors. Consequently the countries' excess demand functions may be non-monotonic thereby giving rise to multiple equilibria.

Further interesting problems may arise from the introduction of unemployment into this model. Neary (1982) discussed sluggish labour adjustment due to sticky wages combined with sluggish capital reallocation. He refers quite critically to the adhocness of his assumed adjustment mechanism. Introducing investment demand as above could solve this problem.

One should, however, bear in mind that the adjustment process in the above model is rather ad hoc from another perspective: by assuming static expectations of investors investment responds myopically to current capital rentals rather than to the present value of investing one additional unit of capital. Mussa (1978) has shown that the introduction of rational expectations plays a critical role in determining the efficiency of the adjustment process but does not alter the long-run equilibrium itself; this is obvious since in the steady state static expectations correspond to rational expectations. Only for the case of rational expectations the competitive path is socially optimal; rational expectations imply a slower convergence to the steady state since future diminution of capital rentals is correctly anticipated and reduces the investment incentives. Thus introducing rational ex-

pectations in the above model may prevent the economy from overadjustment during the adjustment process.

Appendix I

This appendix contains the comparative-static analysis of section 3's model. The equilibrium can be described by the following conditions:

$$c_C(w, r_C) = p \quad (15)$$

$$c_I(w, r_I) = 1 \quad (16)$$

$$\frac{\partial c_C}{\partial w} \cdot x_C + \frac{\partial c_I}{\partial w} \cdot x_I = L \quad (17)$$

$$\frac{\partial c_C}{\partial r_C} \cdot x_C = K_C \quad (18)$$

$$\frac{\partial c_I}{\partial r_I} \cdot x_I = K_I \quad (19)$$

$$K_C = \frac{1}{\delta_C} \cdot C'^{-1} \left[\frac{r_C}{i + \delta_C} \right] \equiv \frac{1}{\delta_C} \cdot g_C \quad (20)$$

$$K_I = \frac{1}{\delta_I} \cdot C'^{-1} \left[\frac{r_I}{i + \delta_I} \right] \equiv \frac{1}{\delta_I} \cdot g_I. \quad (21)$$

(15) and (16) state that unit costs are equal to prices in both sectors. (17) is the labour market equilibrium condition and (18)–(21) determine the industries' capital input. Substituting (18)–(21) into (17) yields:

$$\frac{l_C(w, r_C)}{\delta_C} \cdot g_C + \frac{l_I(w, r_I)}{\delta_I} \cdot g_I = L, \quad (22)$$

where $l_j(w, r_j)$ is sector j 's labour intensity. Differentiating the system (15), (16) and (22) totally yields:

$$\begin{pmatrix} a_{CL} & a_{CK} & 0 \\ a_{IL} & 0 & a_{IK} \\ s_0 & s_1 & s_2 \end{pmatrix} \cdot \begin{pmatrix} dw \\ dr_C \\ dr_I \end{pmatrix} = \begin{pmatrix} dp \\ 0 \\ dL + \beta \cdot di \end{pmatrix}, \quad (23)$$

where a_{jL} is sector j 's labour input coefficient ($= \partial c_j / \partial w$) and a_{jK} sector j 's capital input coefficient ($= \partial c_j / \partial r_j$); the remaining terms of the coefficient matrix A are given by:

$$\begin{aligned} s_0 &= \frac{\partial l_C}{\partial w} \cdot \frac{g_C}{\delta_C} + \frac{\partial l_I}{\partial w} \cdot \frac{g_I}{\delta_I} < 0 \\ s_1 &= \frac{\partial l_C}{\partial r_C} \cdot \frac{g_C}{\delta_C} + \frac{l_C}{\delta_C} \cdot \frac{g'_C}{i + \delta_C} > 0 \\ s_2 &= \frac{\partial l_I}{\partial r_I} \cdot \frac{g_I}{\delta_I} + \frac{l_I}{\delta_I} \cdot \frac{g'_I}{i + \delta_I} > 0 \end{aligned}$$

and β is given by

$$\beta \equiv \sum_{j=I,C} \frac{l_j}{\delta_j} \cdot \frac{r_j}{i + \delta_j} \cdot \frac{g'_j}{i + \delta_j} > 0.$$

The sign pattern of A can be determined as:

$$\text{sign}(A) = \begin{pmatrix} + & + & 0 \\ + & 0 & + \\ - & + & + \end{pmatrix}. \quad (24)$$

Thus $\det(A)$ is negative. Using Cramer's Rule comparative static effects of a change in p with $dL = di = 0$ can be derived from (23):

$$\text{sign} \left(\frac{dw}{dp} \right) = -\text{sign} \begin{vmatrix} 1 & + & 0 \\ 0 & 0 & + \\ 0 & + & + \end{vmatrix} \Rightarrow \frac{dw}{dp} > 0 \quad (25)$$

$$\text{sign} \left(\frac{dr_c}{dp} \right) = -\text{sign} \begin{vmatrix} + & 1 & 0 \\ + & 0 & + \\ - & 0 & + \end{vmatrix} \Rightarrow \frac{dr_c}{dp} > 0 \quad (26)$$

$$\text{sign} \left(\frac{dr_I}{dp} \right) = -\text{sign} \begin{vmatrix} + & + & 1 \\ + & 0 & 0 \\ - & + & 0 \end{vmatrix} \Rightarrow \frac{dr_I}{dp} < 0. \quad (27)$$

From (20) and (21) it follows that

$$\frac{dK_j}{dp} = \frac{g'_j}{\delta_j \cdot (i + \delta_j)} \cdot \frac{dr_j}{dp}; \quad j = I, C. \quad (28)$$

Thus

$$\frac{dK_c}{dp} > 0; \quad \frac{dK_I}{dp} < 0. \quad (29)$$

(25) indicates that labour intensity must fall in sector I and consequently output declines there. Sector C 's output, however, increases as labour employment and capital stocks rise.

Comparative static effects of changes in labour endowments can be derived by setting $dp = di = 0$ in (23). Hence

$$\text{sign} \left(\frac{dw}{dL} \right) = -\text{sign} \begin{vmatrix} 0 & + & 0 \\ 0 & 0 & + \\ 1 & + & + \end{vmatrix} \Rightarrow \frac{dw}{dL} < 0 \quad (30)$$

$$\text{sign} \left(\frac{dr_c}{dL} \right) = -\text{sign} \begin{vmatrix} + & 0 & 0 \\ + & 0 & + \\ - & 1 & + \end{vmatrix} \Rightarrow \frac{dr_c}{dL} > 0 \quad (31)$$

$$\text{sign} \left(\frac{dr_I}{dL} \right) = -\text{sign} \begin{vmatrix} + & + & 0 \\ + & 0 & 0 \\ - & + & 1 \end{vmatrix} \Rightarrow \frac{dr_I}{dL} > 0. \quad (32)$$

From (20) and (21) we have

$$\frac{dK_j}{dL} = \frac{g'_j}{\delta_j \cdot (i + \delta_j)} \cdot \frac{dr_j}{dL}; \quad j = I, C. \quad (33)$$

Hence

$$\frac{dK_C}{dL} > 0; \quad \frac{dK_I}{dL} > 0. \quad (34)$$

As (30) indicates labour intensities rise in both sectors and therefore outputs must also increase.

To derive comparative static effects of changes in the interest rate we set $dp = dL = 0$ in (23). Thus

$$\text{sign} \left(\frac{dw}{di} \right) = -\text{sign} \begin{vmatrix} 0 & + & 0 \\ 0 & 0 & + \\ \beta & + & + \end{vmatrix} \Rightarrow \frac{dw}{di} < 0 \quad (35)$$

$$\text{sign} \left(\frac{dr_C}{di} \right) = -\text{sign} \begin{vmatrix} + & 0 & 0 \\ + & 0 & + \\ - & \beta & + \end{vmatrix} \Rightarrow \frac{dr_C}{di} > 0 \quad (36)$$

$$\text{sign} \left(\frac{dr_I}{di} \right) = -\text{sign} \begin{vmatrix} + & + & 0 \\ + & 0 & 0 \\ - & + & \beta \end{vmatrix} \Rightarrow \frac{dr_I}{di} > 0. \quad (37)$$

Differentiating (20) and (21) it follows that:

$$\frac{dK_j}{di} = \frac{g'_j}{\delta_j \cdot (i + \delta_j)} \cdot \left[\frac{dr_j}{di} - \frac{r_j}{i + \delta_j} \right]; \quad j = I, C. \quad (38)$$

(38) indicates that both $dK_j/di > 0$ and $dK_j/di < 0$ is possible.

Appendix II

With (35) we have to show that dR/dw is positive if sector C is relatively capital intensive to prove that $dR/di = dR/dw \cdot dw/di$ is negative. To do that we differentiate R with respect to w :

$$\frac{dR}{dw} = \frac{1}{r_I} \cdot \left(\frac{dr_C}{dw} - R \cdot \frac{dr_I}{dw} \right). \quad (39)$$

We know that on the unit-cost curve

$$\frac{dr_j}{dw} = -\frac{1}{k_j} \quad j = I, C \quad (40)$$

holds where $k_j := K_j/L_j$ stands for the capital intensity of sector j . Inserting (40) into (39) yields

$$\frac{dR}{dw} = \frac{1}{r_I} \cdot \left(\frac{R}{k_I} - \frac{1}{k_C} \right). \quad (41)$$

It follows that dR/dw is positive if R is greater than k_I/k_C . Define $\epsilon_{jK}(w, r_j)$ as the cost share of capital in sector j (or, equivalently, as the elasticity of sector j 's production with respect to its capital input)

$$\epsilon_{jK} := \frac{\partial f_j}{\partial K_j} \cdot \frac{K_j}{f_j} \quad (42)$$

and ϵ_{jL} as the cost share of labor in sector j

$$\epsilon_{jL} := \frac{\partial f_j}{\partial L_j} \cdot \frac{L_j}{f_j}. \quad (43)$$

With constant returns to scale factor cost shares sum up to unity and we can write the ratio of capital intensities as

$$\frac{k_I}{k_C} = \frac{r_C}{r_I} \cdot \frac{\frac{\epsilon_{IK}}{1 - \epsilon_{IK}}}{\frac{\epsilon_{CK}}{1 - \epsilon_{CK}}}. \quad (44)$$

Hence

$$\begin{aligned} \frac{dR}{dw} > 0 &\iff \frac{\epsilon_{IK}}{1 - \epsilon_{IK}} < \frac{\epsilon_{CK}}{1 - \epsilon_{CK}} \\ &\iff \epsilon_{CK} > \epsilon_{IK}. \end{aligned} \quad (45)$$

(45) shows that R rises with w if sector C is capital intensive where relative factor intensity is defined as above.

Appendix III

The following numerical simulation of the adjustment path illustrates the possibility of overadjustment of capital stocks and national product in the two-sector small open economy. Production functions are assumed to be Cobb–Douglas; elasticities of production with respect to capital are set to 0.7 in sector I and 0.3 in sector C . The rates of depreciation are set to $\delta_I = 0.1, \delta_C = 0.3$ and

the adjustment cost function is given by $C(I) = I^{1+z}$; the mobility parameter z is set to unity thus yielding a quadratic adjustment cost function as it is often assumed in the literature [c.f. Sargent (1987, p. 134)]. For exogenous values of the relative price and the interest rate the long-run equilibrium can be determined. Setting p to 8 and i to 0.003175, the steady-state allocation is given by: $K_I^0 = 7.923321$, $K_C^0 = 4.818682$. Setting p to 2 and i to 0.1 yields another long-run equilibrium with $K_I^1 = 7.923321$, $K_C^1 = 1.217181$. These values of the exogenous variables have been chosen to ensure equal values of sector I 's capital stock in both steady states. The adjustment path to the new steady state (due to the combined change in p and i) can be solved numerically using the Runge-Kutta method of fourth order. The time path of the endogenous variables K_I and y are illustrated in fig. 6 and 7; sector I 's capital stock and the national product both fall below their new steady-state values during the adjustment process in this example. This proves that the possibility of overadjustment of endogenous variables exists.

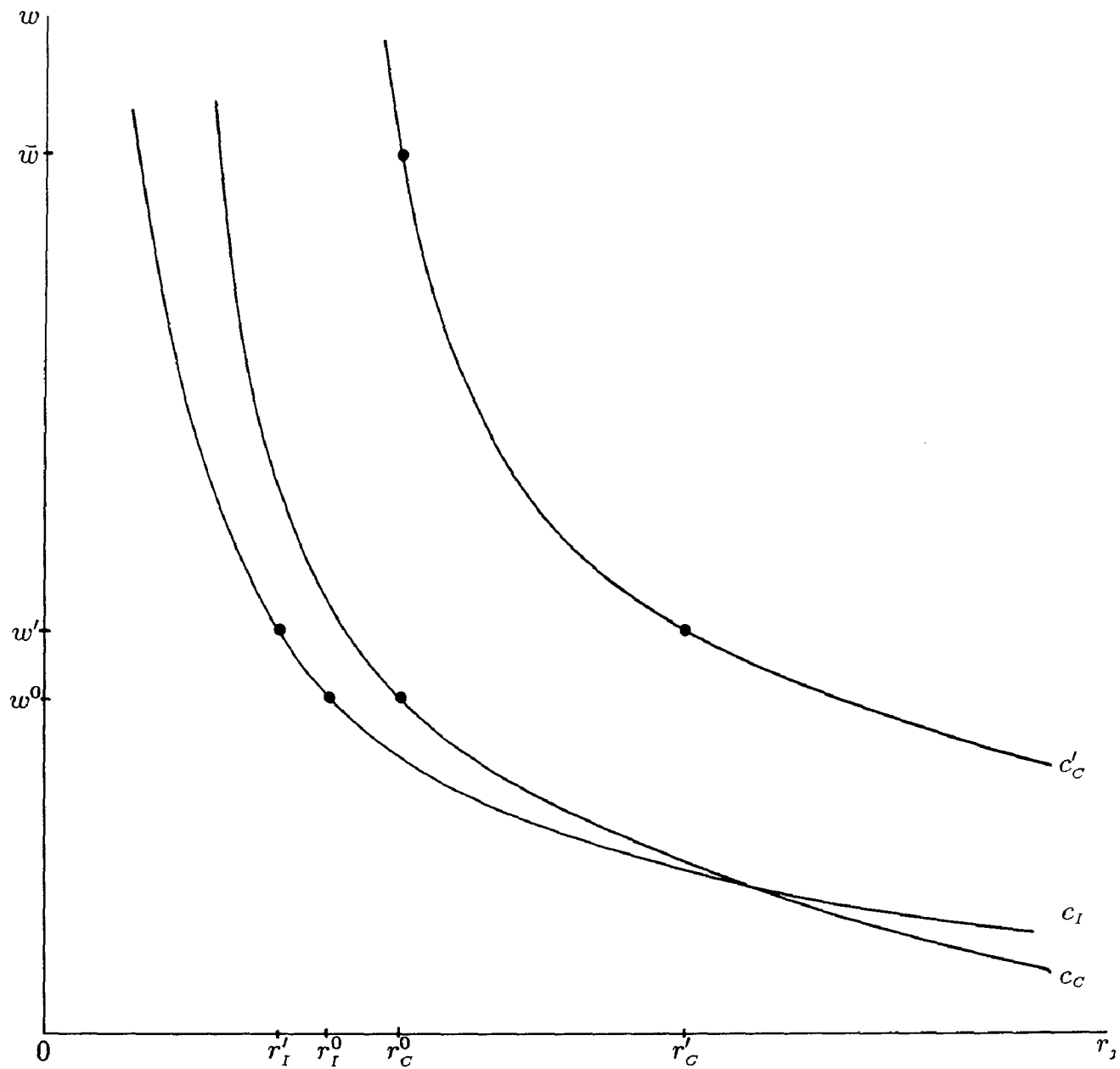


Figure 1: Comparative Static Effects of Price Changes.

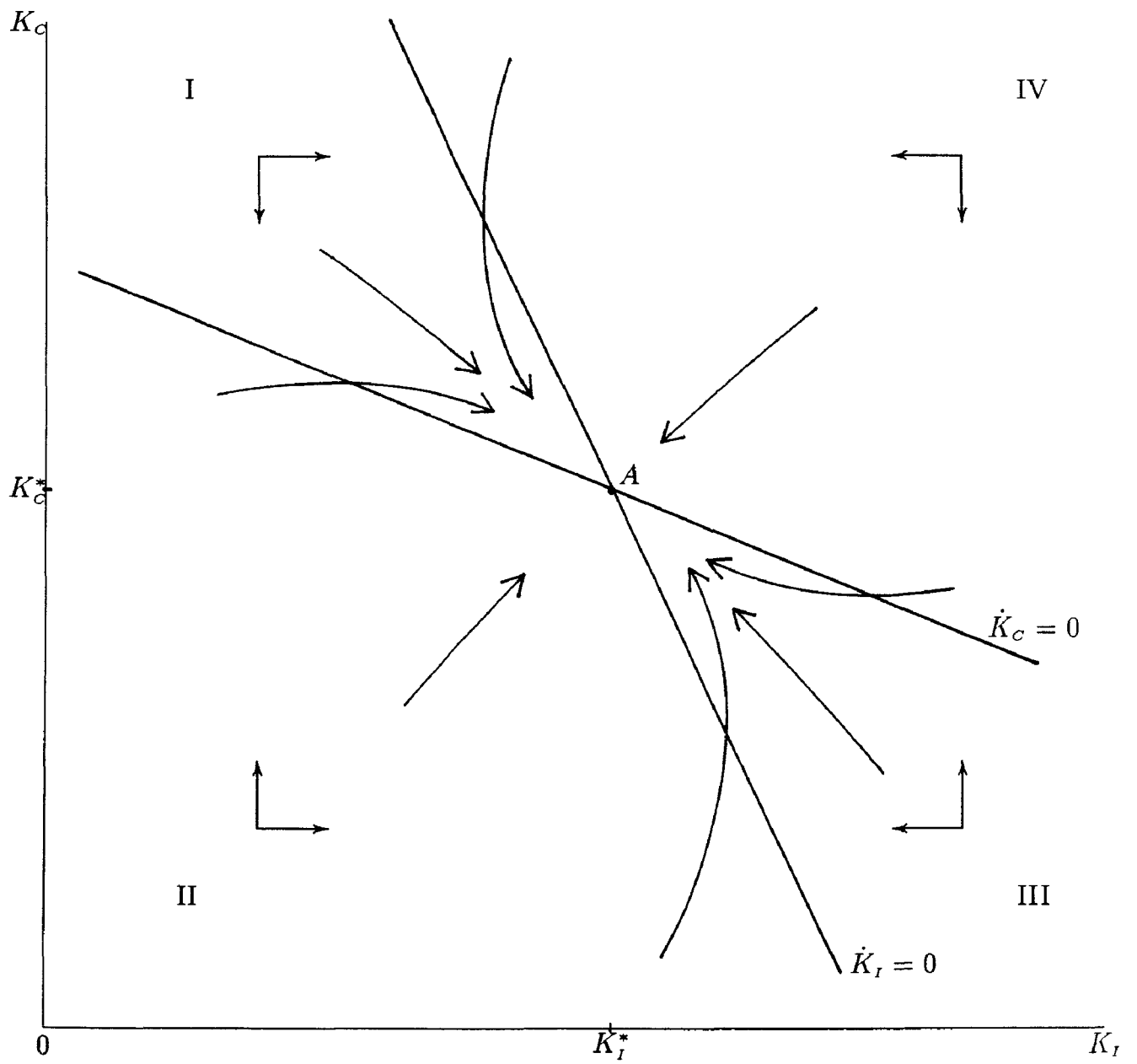


Figure 2: Dynamics of the Two-Sector Model.

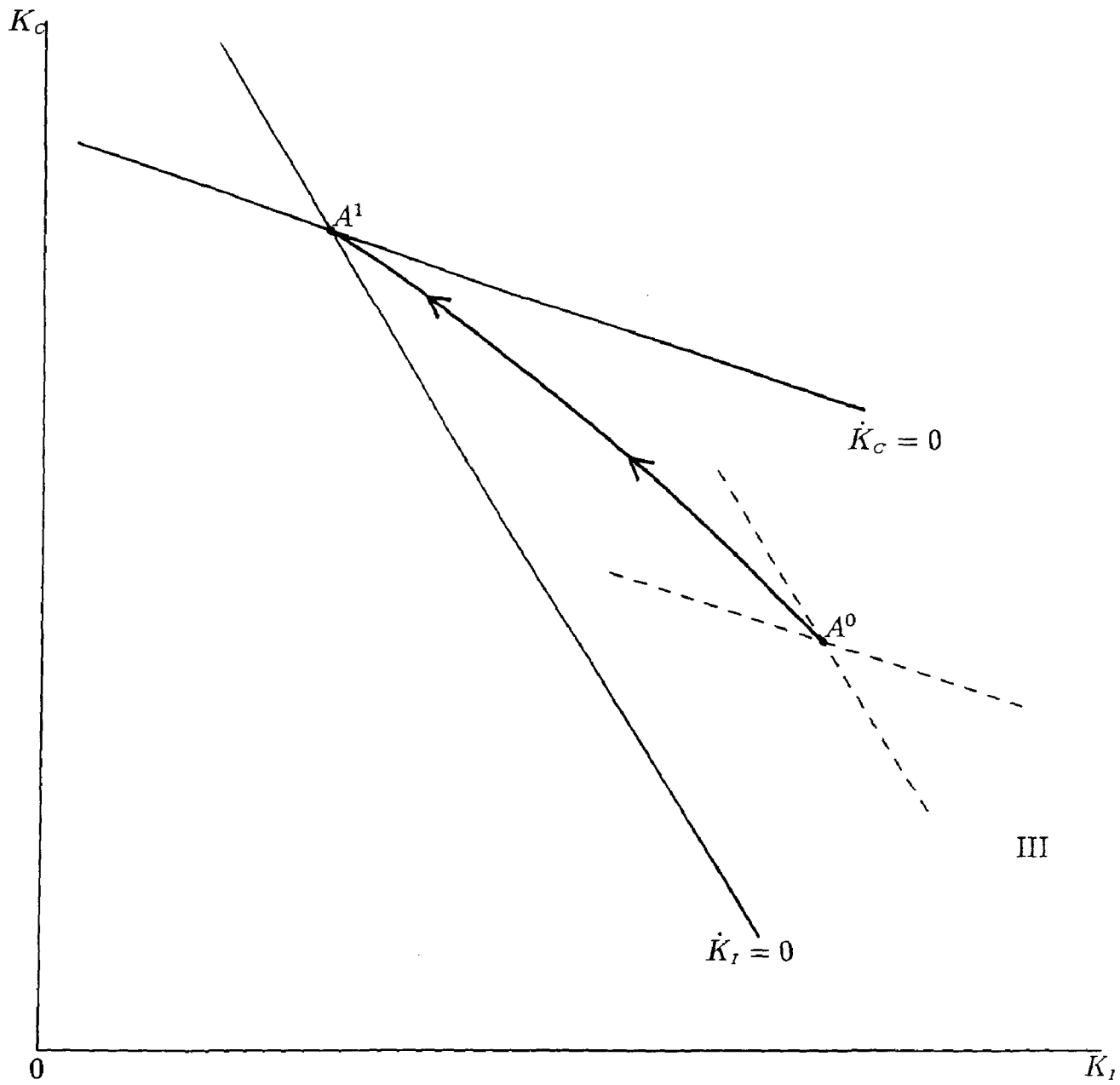


Figure 3: Adjustment to an Increase in the Relative Price.

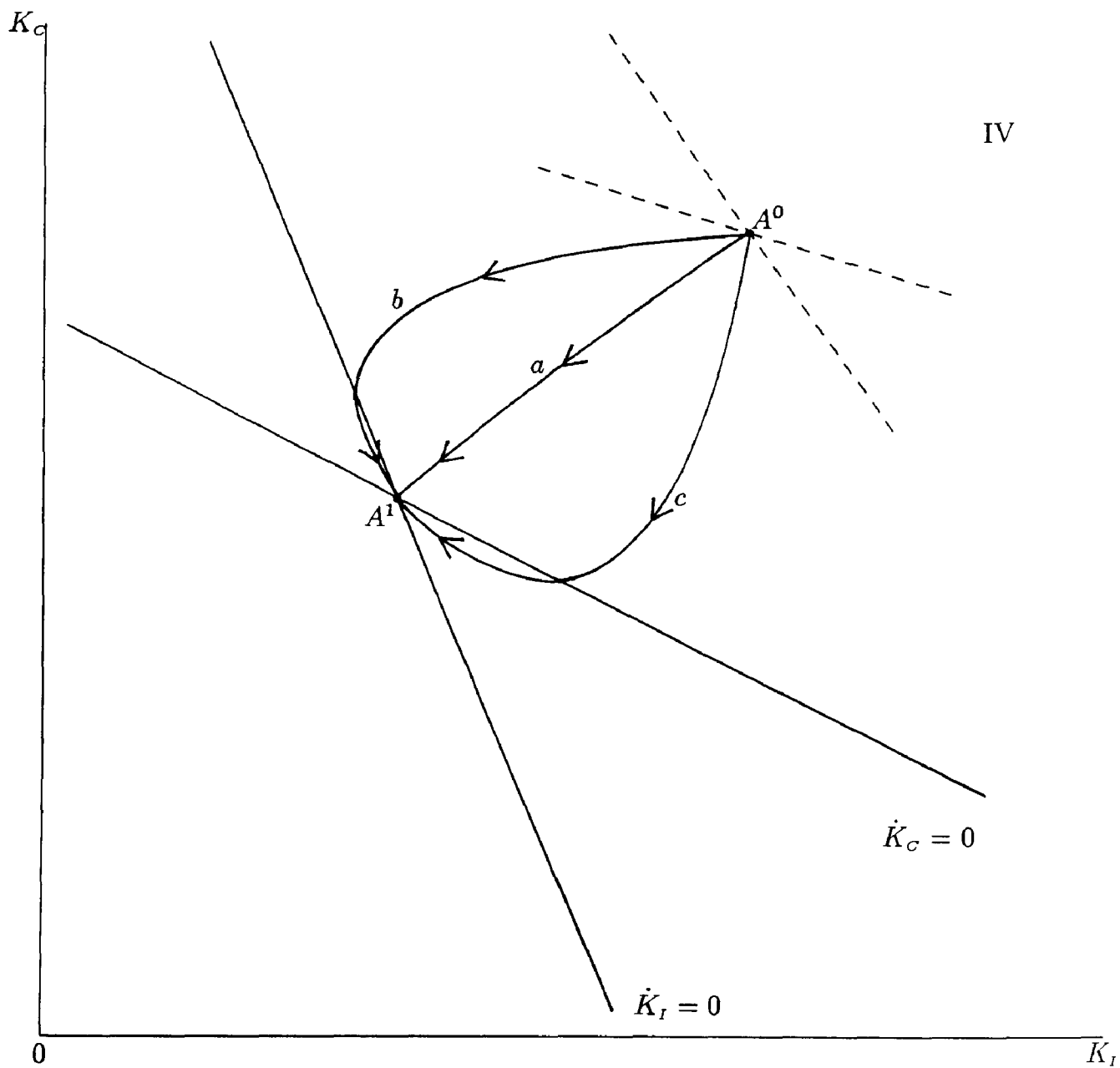


Figure 4: Adjustment to Changes in Labour Endowment or in the Interest Rate.

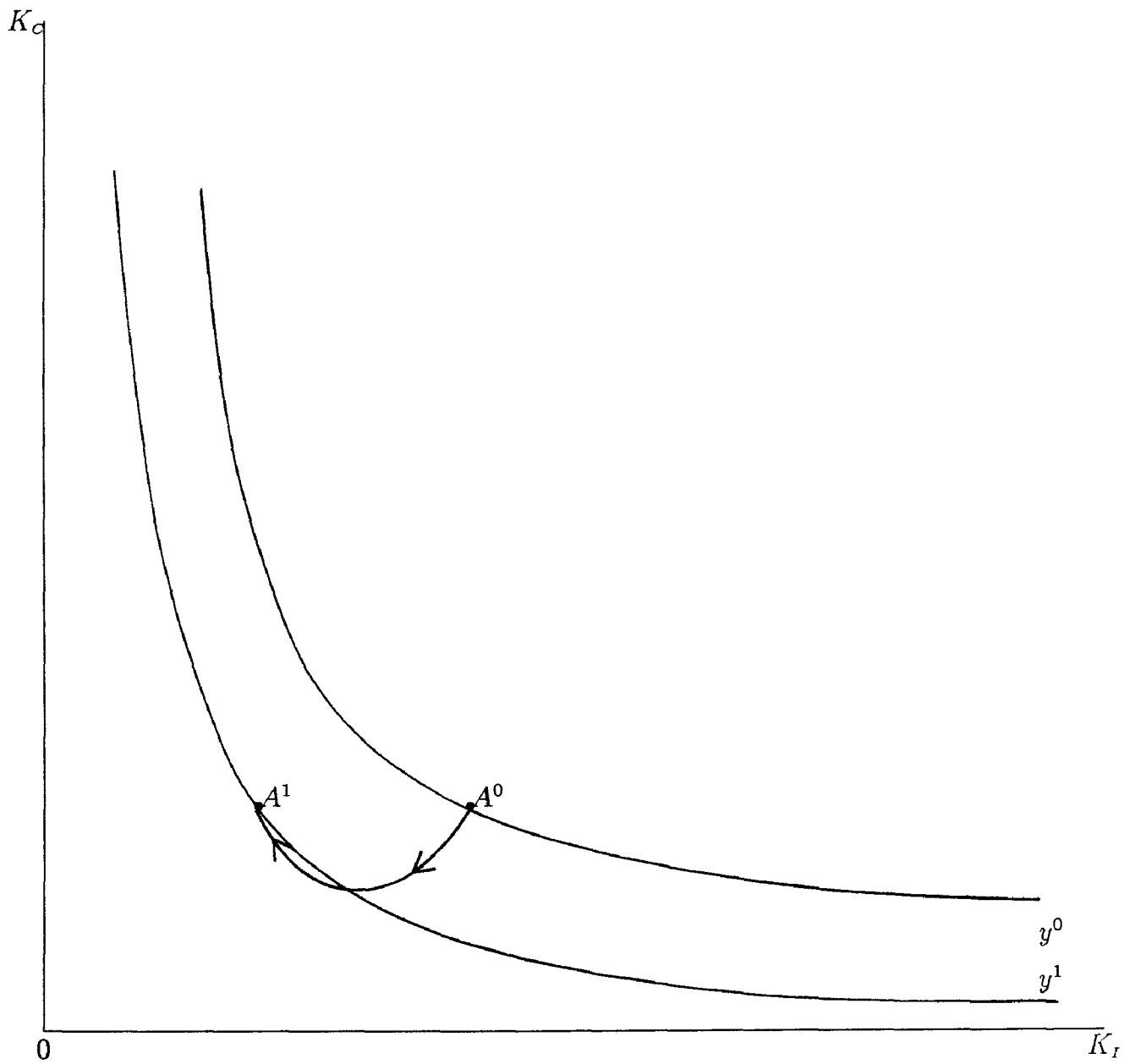
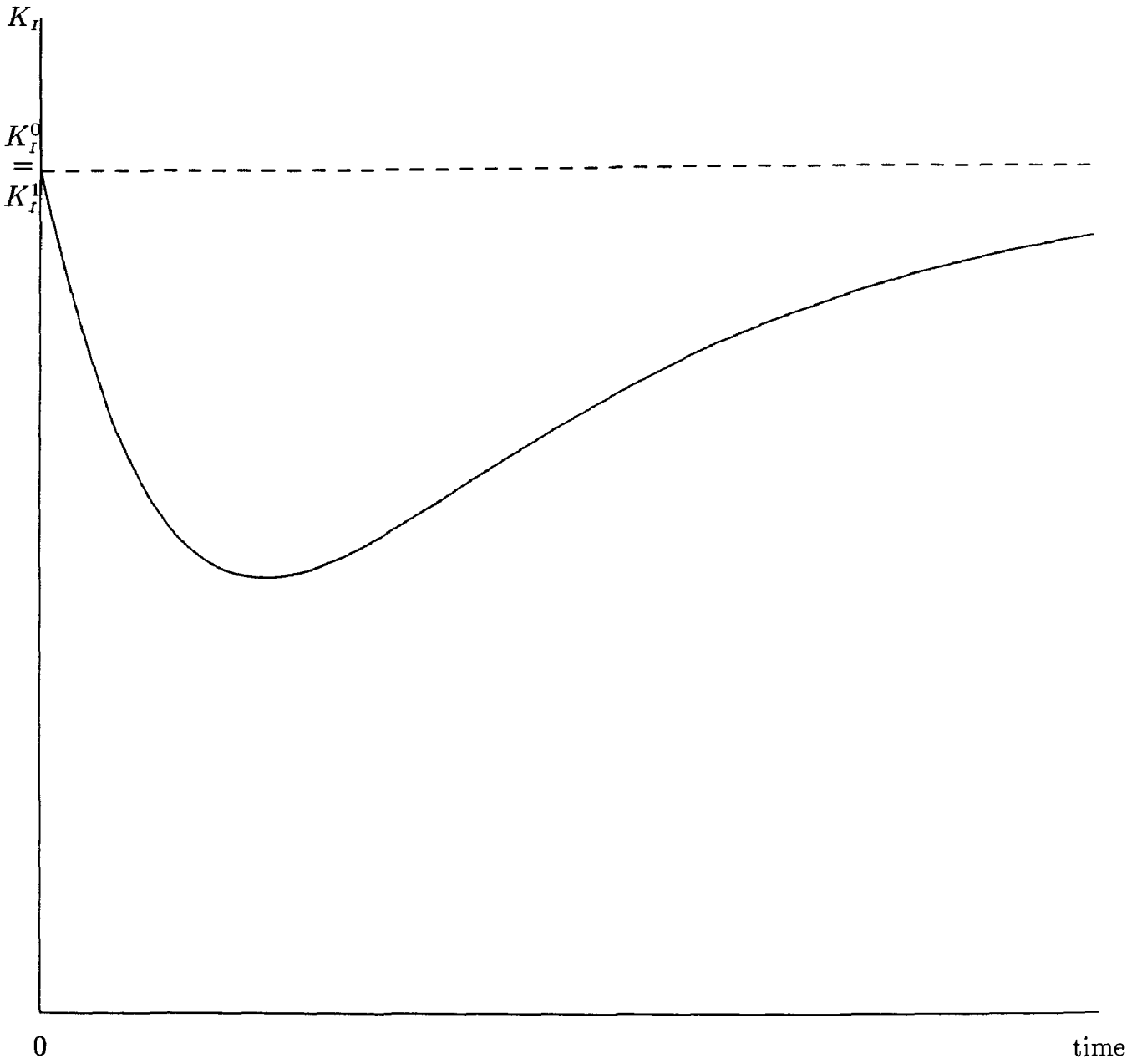


Figure 5: Adjustment of National Product.



0
Figure 6: Adjustment of Sector I 's Capital Stock.

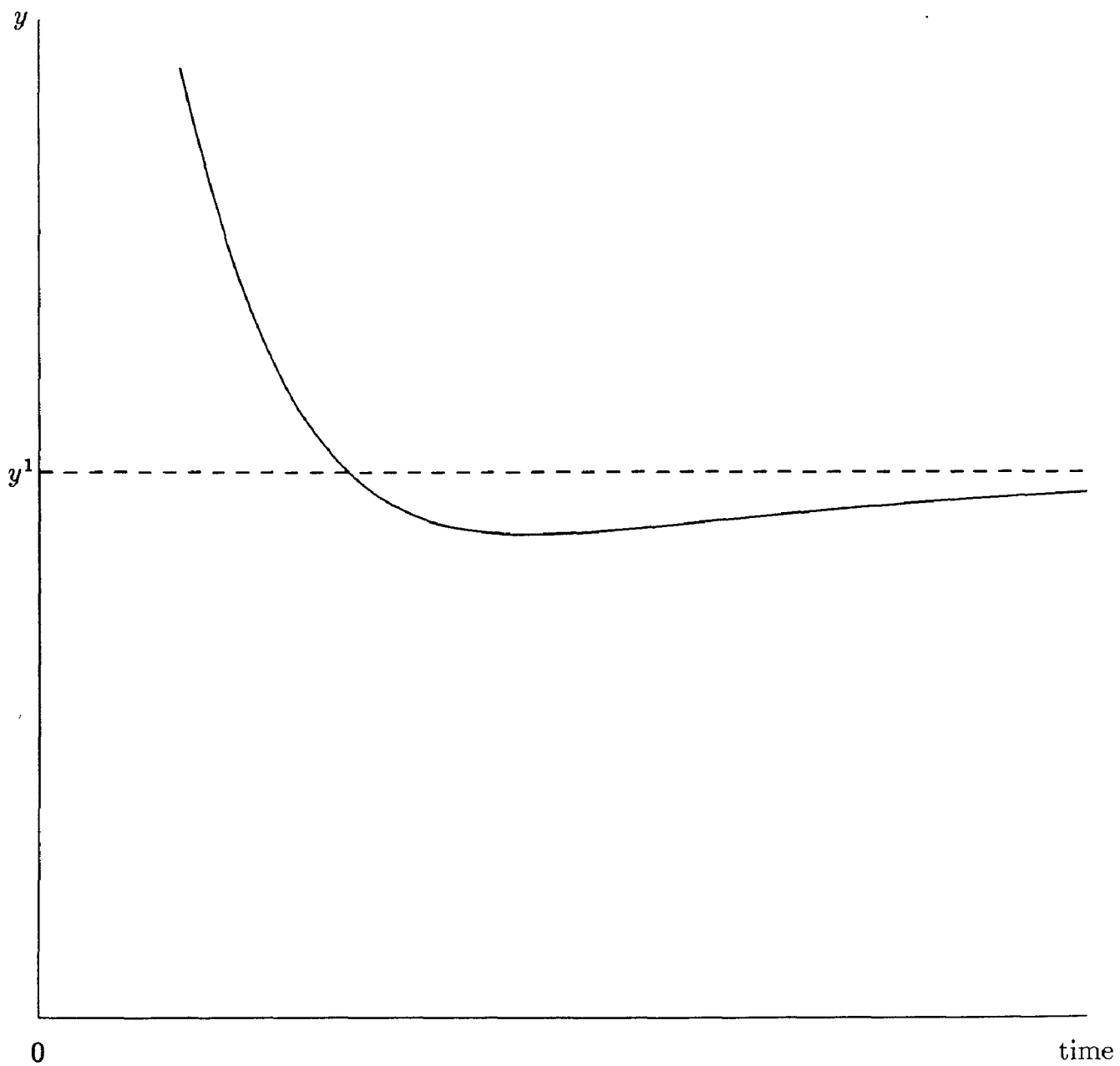


Figure 7: Adjustment of National Product.

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