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IS THERE A LONG-RUN TRADE-OFF BETWEEN INFLATION AND UNEMPLOYMENT?

by

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ABSTRACT

How are inflation and unemployment related in the long run? Are they negatively correlated, as in the so-called naive Phillips curve theories or uncorrelated, as in the neo-liberals' view or are they positively correlated as Friedman suggested in his Nobel lecture?

In this paper inflation is introduced into a general equilibrium search unemployment model. We show that it is possible to get either a negatively or a positively sloping long-run Phillips curve, all depending on the source of inflation.

Notation

w = wage

w_0 = the low wage

w_1 = the high wage

p = price

p_0 = the low price

p_1 = the high price

s = the rate of unemployment

μ = individuals per firm

γ = the frequency of (w_1, p_0) firms

k = optimal reservation income

Θ = dividends + transfer payment = numeraire

τ = the physical death risk per period

τ^* = $\tau/(1-\tau)$

b = unemployment compensation

TR = general transfer payment.

1. Introduction

One of the most discussed and analyzed questions in economics during the last two and a half decades is whether or not there is a trade-off between unemployment and inflation in a market economy. The issue originated in the correlation study by A.W. Phillips (1958) which found such a trade-off (negative correlation) for Great Britain for the period 1860-1958. Many studies, with different results, have been undertaken for various countries since then. For example Samuelson and Solow (1960) claimed such a trade-off for the US economy and presented it as the "menu" for politicians.

The idea of a trade-off between unemployment and inflation was strongly questioned in a famous presidential address by Milton Friedman at the AEA meeting December 29, 1967 (Friedman, 1968). Friedman's message was that the central theory of economics could not support the view that a change in the general price level could have any influence on the real variables of the economy, unemployment for instance, in the long run.

Robert Lucas addressed the question in his famous article "Expectations and the Neutrality of Money" (Lucas 1972).

We have examined the question of a trade-off between unemployment and inflation in a version of the Albrecht-Axell-Lang general equilibrium model of search unemployment with endogenous inflation (Albrecht-Axell-Lang, 1984, for short AAL, 1984). In the present paper inflation is generated in the

economy via increases in transfer payments to individuals that are financed by Central Bank.

Our results are that long-run general equilibrium unemployment will decrease if transfer payments are equally distributed to all individuals. If, instead, transfer payments are paid only to high-income individuals, then the rate of unemployment will increase. We have also analyzed transfer payments to the unemployed, i.e., an unemployment subsidy. The result in this case is most surprising. As unemployment compensation increases from zero, inflation goes up (of course) and unemployment goes down, as in the case with general transfers; but, after unemployment compensation exceeds a certain amount, further increases imply decreases in both inflation and unemployment.

These results must be understood by recognizing that inflation and unemployment are both endogenous variables in an economy. The Phillips-curve question is hence a question whether two endogenous variables change in the same or in opposite directions in response to a shift in exogenous variables. The answer to such a question must of course in general depend on the source of the change, i.e., on which parameter(s) or exogenous variable(s) shifted.

We have in this analysis introduced increases in three different transfers payments, which are not financed by taxes, but with new printed money. This, of course, gives raise to an increase of inflation. The unemployment will decrease or increase, depending on to whom the transfer payments

are paid. The important conclusion is that a question like the Phillips-curve question in general has no unambiguous answer.

2. The Model

The model used is the model of "General equilibrium wage and price distributions" which is presented in detail in AAL, 1984. We have supplemented the model here to include endogenous inflation. First, we describe how unemployment is determined.

In the economy one homogeneous commodity is produced and consumed. There is one homogeneous factor of production, labor. The product is produced by firms using labor, and all firms have the same constant returns production function.[1]

When individuals are born, they have neither a job nor a shop to purchase in. They start their lives by drawing a wage offer at random (from an urn of wage offers) and a price offer at random from another urn of price offers. The distributions of price and wage offers are known to the individuals.

Each individual faces a death risk of τ per period, and τ is constant through life. The individual compares the expected lifetime real consumption from starting to work at the offered wage and consuming at the offered price with the expected lifetime real consumption from continued search. If the wage he draws is very high and/or the price

he draws is very low, he starts to work and becomes employed, otherwise he rejects both offers and continues to search so long as the expected value of accepting the offers falls below the expected value of further search.

If there is price and wage dispersion in the general (Nash) equilibrium there will be endogenous unemployment in this economy. The size of this unemployment is of course determined by the endogenous shapes of the wage and price distributions.

The existence of a stable price and wage dispersion equilibrium is proved in AAL (1984). To see the mechanism, let us briefly explain the situation of the firm.

A firm, facing searching individuals as above, has a negatively sloped product demand curve and a positively sloped labor supply curve. A searcher will with greater probability accept a low price than a high price. Likewise a searcher will with greater probability accept a high wage than a low wage.

If a firm sets a low price, the demand is high. But in order to produce a large quantity, it has to attract many workers; i.e., it has to offer a high wage. It will thus produce and sell a large quantity but at a small profit margin per unit. Another strategy that gives the same profit is to set a high price, giving rise to a low demand. The firm then requires relatively few workers and can offer a relatively low wage. The profit for

these latter firms with a low volume and high margin can be the same as the profit for the high volume/low margin firms because the profit margin per unit is big (high price low wage) which compensates the smaller quantity.

We show in AAL (1984) that there exists such a price-wage dispersion Nash equilibrium. In particular, we show that there exists an equilibrium with just two wages (w_0 and w_1) and two prices (p_0 and p_1). The optimal strategy of a firm is then to charge either p_0, w_1 or p_1, w_0, and these both give the same profit.

3. Inflation

In this paper we introduce inflation into the AAL, 1984 model. Before describing how this is done however, we note the fundamental difference between a "currency reform" and a "genuine inflation". Knut Wicksell explained this in his book "Lectures in Political Economy, II" (1906, 5th issue 1966, Gleerups, English edition 1935):

> "Hume's well-known fiction of our waking up one morning to find double the number of shillings and sovereigns in our pockets, whilst everything else remains unchanged, may seem quite appropriate, but suffers from the defect that it is not a simplification of reality - which is permissible - but relates to a purely paradoxical case, which in the nature of things never can occur." (Wicksell, 1935, p.160.)

An inflation must, according to Wicksell, be explained in its dynamic process. A currency reform

inflation is not an acceptable source of inflation. Sources of inflation could be, according to Wicksell, new gold findings, excess public spending - especially for financing wars - and banking lending rates below the natural rate of interest.

The Wicksell writings concentrated mainly on this third alternative, but the general conclusion is that inflation can appear and persist if and only if there is a sector in the economy that has expenditures greater than its revenues with no other sector running a corresponding budget surplus.

In our model inflation is introduced as the effect of the excess of government expenditures over tax revenues, i.e., a public deficit, or more correctly, public excess spending. The model incorporates this idea in the following way. The government pays transfer payments to individuals. In each period, firms' total revenues are distributed to the individuals as wages and dividends. These incomes are used in the next period together with the transfer payments (financed not by taxes but by loans in the Central Bank) to buy what is produced. Hence, firms' revenues will consist of both wages and dividends from the last period and the current period transfer payment. This comes in as revenues for firms and is redistributed as wages and dividends, which are of course higher than those of the previous period. These new higher wages and dividends are then used together with the new transfer payments in the next period to buy that period's production. All this creates a cumulative inflation process which goes on so long

as the government keeps on paying out transfer payments, financed by the Central Bank.

What is the result of this concerning the so-called Phillips-curve question - how will the two endogenous variables unemployment and inflation develop in the long run? It depends on the design of the transfer payments. We have run three experiments: One with a general transfer to all individuals, one with transfers only to high income individuals, and one with transfers only to the unemployed. The "Phillips curve" will appear in quite different shapes in these three experiments (see Figures 1-3 and Tables 1-3).

4. The Formal Model

The basic model (without inflation) is derived in AAL, 1984 and the details are not repeated here. The interested reader has to consult that article.

Here we give a short recapitulation of the equations of the model together with an explanation of the dating of the price and wage variables to take inflation into account.

Individuals search for a high wage in the labor market and for a low price in he product market. They terminate search when they find a wage and price combination fulfilling the reservation real income requirement. The required real income $k = (w+\theta)/p$, where w is wage, θ is dividend and p is price, satisfies the following equation in a two-point equilibrium:

$$\frac{k}{\tau} = \theta\left(\frac{\gamma}{p_0} + \frac{1-\gamma}{p_1}\right) + \frac{1-\tau}{\tau}\,\gamma^2\,\frac{w_1+\theta}{p_0} +$$

$$+ \frac{1-\tau}{\tau}\,(1-\gamma^2)\,k, \qquad (1)$$

where τ is the physical death risk, θ the dividend, γ the frequency of (w_1, p_0)-firms, p_0 and p_1 the low and the high price, respectively, and w_0 and w_1 the low and the high wage, respectively.

Inflation is introduced with the "cash-in-advance" assumption (see Lucas, 1980). Any worker-consumer who is employed will get his wage and dividend payment in period t. Hence, the wage is indexed as w_t and the dividend as θ_t. He will buy the product using all his "cash" in period t+1, i.e., at price p_{t+1}.

This means that equation (1) now reads

$$\frac{k}{\tau} = \theta_t\left(\frac{\gamma}{p_{0,t+1}} + \frac{1-\gamma}{p_{1,t+1}}\right) + (1-\gamma^2)\,\frac{1-\tau}{\tau}\,k +$$

$$+ \gamma^2\,\frac{1-\tau}{\tau}\,\frac{w_{1,t}+\theta_t}{p_{0,t+1}} \qquad (2)$$

An equilibrium condition is that profit be the same for the two firm strategies. The two possible firm strategies are setting price = p_0 and wage = w_1 or setting price = p_1 and wage = w_0. The equilibrium condition that profits should be the same at the two strategies implies that

$$(p_0-w_1)\,q(p_0) = (p_1-w_0)\,q(p_1) \qquad (3)$$

where $q(p)$ is quantity demanded at price p.

However, $q(p_0) = \ell(w_1)$

and $q(p_1) = \ell(w_0)$ [1]

where $\ell(w)$ is the labor supply faced by a firm setting wage w.

Hence

$$(p_0-w_1)\,\ell(w_1) = (p_1-w_0)\,\ell(w_0)$$

and since

$$\ell(w_0) = \mu s\,\frac{1-\tau}{\tau}\,\gamma$$

$$\ell(w_1) = \mu s\,\frac{1-\tau}{\tau},$$

where μ is individuals per firm and s is the rate of unemployment, the equal profit condition reads:

$$(p_1-w_0)\,\gamma = p_0-w_1. \qquad (4)$$

Since the date of the receipt and the wage payment for the firm should be the same, the dated version of equation (4) reads:

$$(p_{1,t}-w_{0,t})\,\gamma = p_{0,t}-w_{1,t}. \qquad (5)$$

For the two possible strategies (p_0,w, and p_1,w_0) we have product demand

$$q(p_0) = \frac{\mu s}{p_0}\left[\theta + \frac{1-\tau}{\tau}\left((1-\gamma)(w_0+\theta) + \gamma(w_1+\theta)\right)\right]$$

$$q(p_1) = \frac{\mu s}{p_1}\left[\theta + \frac{1-\tau}{\tau}\,\gamma(w_1+\theta)\right]$$

and labor supply

$$\ell(w_0) = \mu s \frac{1-\tau}{\tau}\gamma$$

$$\ell(w_1) = \mu s \frac{1-\tau}{\tau}.$$

Equating product demand and labor supply,[2]

$$\theta + \frac{1+\tau}{\tau}\gamma\ (w_1+\theta) = \frac{1-\tau}{\tau}\gamma p_1 \qquad (6)$$

and

$$\theta + \frac{1-\tau}{\tau}\left((1-\gamma)(w_0+\theta) + \gamma(w_1+\theta)\right) = \frac{1-\tau}{\tau}p_0 \qquad (7)$$

Rewriting (6) and (7) with dating (note that wage and dividends (w_t and θ_t) that are paid in period t are spent in period t+1 at the prices in that period, p_{t+1}) we get:

$$\theta_t + \frac{1-\tau}{\tau}\gamma(w_{1,t}+\theta_t) = \frac{1-\tau}{\tau}\gamma\ p_{1,t+1} \qquad (8)$$

$$\theta_t + \frac{1-\tau}{\tau}(1-\gamma)(w_{0,t}+\theta_t) + \frac{1-\tau}{\tau}\gamma(w_{1,t}+\theta_t) =$$

$$= \frac{1-\tau}{\tau}p_{0,t+1}. \qquad (9)$$

Further, in equilibrium with optimal sequential search, profit maximization requires that the real income from the two "middle" wage-price combinations ((w_0, p_0) and (w_1, p_1)) should both equal the optimal reservation income (k), determined in equation (2). Again, prices are dated one period ahead of wages and dividends. That is,

$$\frac{w_{1,t}+\theta_t}{p_{1,t+1}} = k \qquad (10)$$

and

$$\frac{w_{0,t}+\theta_t}{p_{0,t+1}} = k. \qquad (11)$$

The dividend θ is uniformly distributed among individuals and hence equals profit per firm times individuals per firm. Since we want to introduce inflation in this economy by means of transfer payments we change the interpretation of θ. From now on θ is non-work income, or dividends, plus transfers from the government.

The profit per firm is the same for (p_0, w_1)- and (p_1, w_0)-firms. Hence, without transfer payment we have profit

$$\pi = (p_0 - w_1)\, q(p_0).$$

Since

$$q(p_0) = \ell(w_1) = \mu s \frac{1-\tau}{\tau}$$

and dividend per individual is profit per firm (π) times firms per individual ($1/\mu$) we get after some manipulation (with dating)

$$\theta_t = (p_{0,t} - w_{1,t}) \frac{1}{\frac{\tau}{1-\tau} + \gamma(2-\gamma)} + TR \qquad (12)$$

where TR is a general transfer payment. (Note that s, the unemployment rate is $\tau/[1-(1-\tau)(1-\gamma)^2]$ (see AAL, 1984)).

Finally we define the per period inflation factor Q by

$$Q = \frac{\theta_{t+1}}{\theta_t} \tag{13}$$

(Note that θ_t is the numeraire.)

We look at the steady state equilibrium where all "prices" (i.e., prices, wages, and dividends) are escalated with the same factor Q. Hence we can express, for instance, p_{t+1} as Qp_t.

Introducing unemployment compensation b, substituting $Qp_{0,t}$ and $Qp_{1,t}$ for $p_{0,t+1}$ and $p_{1,t+1}$ and surpressing the time index we have, summing up, the following seven equations:

(i) The optimal reservation income

$$\frac{k}{\tau} = (\theta+b)\left(\frac{\gamma}{Qp_0} + \frac{1-\gamma}{Qp_1}\right) + (1-\gamma^2)\,\frac{1-\tau}{\tau}\,k + \\ + \gamma^2\,\frac{1-\tau}{\tau}\,\frac{w_1+\theta}{Qp_0} \tag{2'}$$

(ii) The equal profit condition

$$(p_1-w_0)\,\gamma = p_0-w_1 \tag{5'}$$

(iii) and (iv) The sale-production constraints

$$\theta + b + \frac{1-\tau}{\tau}\gamma(w_1+\theta) = \frac{1-\tau}{\tau}\gamma\, Qp_1 \qquad (8')$$

$$\theta + b + \frac{1-\tau}{\tau}(1-\gamma)(w_0+\theta) + \frac{1-\tau}{\tau}\gamma(w_1+\theta) = \frac{1-\tau}{\tau}Qp_0 \qquad (9')$$

(v) and (vi) The profit maximization conditions

$$\frac{w_1+\theta}{Qp_1} = k \qquad (10')$$

$$\frac{w_0+\theta}{Qp_0} = k \qquad (11')$$

(vii) The determination of non-work income

$$\theta = (p_0 - w_1 - b\frac{\tau}{1-\tau})\frac{1}{\frac{\tau}{1-\tau} + \gamma(2-\gamma)} + TR \qquad (12')$$

Hence we have seven equations and the following eight unknowns; γ, k, w_0, w_1, p_0, p_1, θ and Q. One of those has to be chosen as a numeraire. We have chosen θ (the choice is of course completely arbitrary).

The system is solved numerically after some minor simplifications. The simplified system is presented in the appendix. The only exogenous parameter (besides the policy parameters b and TR) is the death risk τ. We have set τ to 0.01 throughout.

5. Inflation and Unemployment: the Experiments

We have undertaken three experiments which will generate permanent inflation in this economy.

We have introduced transfer payment which are not financed by taxes, but corresponds to a public expenditure surplus, financed in the Central Bank (and creates inflation). The transfers (b,TR) are given to:

(1) All individuals (TR)
(2) The workers with high income
(3) The unemployed (b).

We get the following results:

If inflation is generated by transfer payment to all individuals, the rate of unemployment will go down.

If we get inflation because of transfers only to the high income individuals, the rate of unemployment will instead increase.

Finally, if inflation is caused by transfer payments to the unemployed, the rate of unemployment will go down - hence a negatively sloping Phillips curve. However, when the unemployment subsidy exceeds a certain level, further increases in transfers to the unemployed will lead to decrease both in unemployment and inflation. The explanation is as follows.

When the transfer payment to the unemployed is introduced, the unemployed searchers will become more selective in their search; they will reject a low wage offer that they without unemployment compensation would have accepted. The firms that offered the low wage now have to increase their wage offers in order to attract any workers. Hence, their profits will decrease (cost has increased) and they will be inclined to change strategy to become high wage firms instead. Some of them will do so, and the frequency of high wage firms will increase.

But then the probability for a searcher to find the most attractive offers (high wage and low price) increases. The average time for search unemployment then goes down - the unemployment rate goes down. (Note that the only combination of price and wage offer that is rejected is the low wage and the high price.)

However, since this increase in transfers to the unemployed is financed in the Central Bank, the inflation rate goes up. But if the unemployment rate at the same time goes down, the number of individuals receiving this transfer payment decreases. When unemployment compensation exceeds approximately 1.5 times the dividend payment, the decrease in the unemployment rate is large enough to reduce the total amount of real unemployment compensation. Therefore further increases in unemployment compensation decrease <u>both</u> unemployment <u>and</u> inflation.

Thus, the long-run Phillips curve could be negatively or positively sloped depending on the source of the change in the endogenous variables inflation and unemployment.

Conclusion

Is there a long-run trade-off between inflation and unemployment? In this paper we have argued that the question is somewhat too imprecise to make good sense. Indeed, both inflation and unemployment are endogenous variables of the economy, and thus they are related only via the policy parameters, or exogenous variables of the economy. As we have seen, within the model we have studied, the relation between unemployment and inflation could be very different (positively or negatively correlated) depending on the way a government's excess spending is used.

Table 1 **Long-run inflation and unemployment. General transfer payment financed in Central Bank**

Frequencies of high wage %	w_0	w_1	p_0	p_1	Unemployment %	Inflation %	Unemployment compensation	General transfer payment
12.17	1.87	2.75	3.00	3.92	4.23	0.00	1.00	0.00
12.54	1.91	2.74	2.99	3.85	4.11	1.54	1.00	0.05
12.95	1.94	2.74	2.97	3.77	4.00	3.11	1.00	0.10
13.38	1.98	2.73	2.96	3.70	3.88	4.72	1.00	0.15
13.86	2.01	2.72	2.94	3.63	3.76	6.36	1.00	0.20
14.38	2.05	2.71	2.93	3.56	3.64	8.05	1.00	0.25
14.96	2.08	2.70	2.91	3.49	3.51	9.78	1.00	0.30
15.60	2.11	2.68	2.89	3.42	3.39	11.56	1.00	0.35
16.32	2.14	2.67	2.86	3.34	3.25	13.39	1.00	0.40
17.14	2.17	2.65	2.84	3.27	3.12	15.28	1.00	0.45
18.07	2.20	2.63	2.81	3.19	2.98	17.24	1.00	0.50
19.15	2.23	2.61	2.78	3.12	2.83	19.28	1.00	0.55
20.43	2.25	2.59	2.75	3.03	2.67	21.41	1.00	0.60
21.97	2.26	2.56	2.71	2.95	2.51	23.67	1.00	0.65
23.87	2.27	2.52	2.66	2.86	2.34	26.09	1.00	0.70
26.33	2.27	2.47	2.60	2.75	2.16	28.74	1.00	0.75

Figure 1 **Long-run inflation and unemployment. General transfer payment financed in Central Bank**

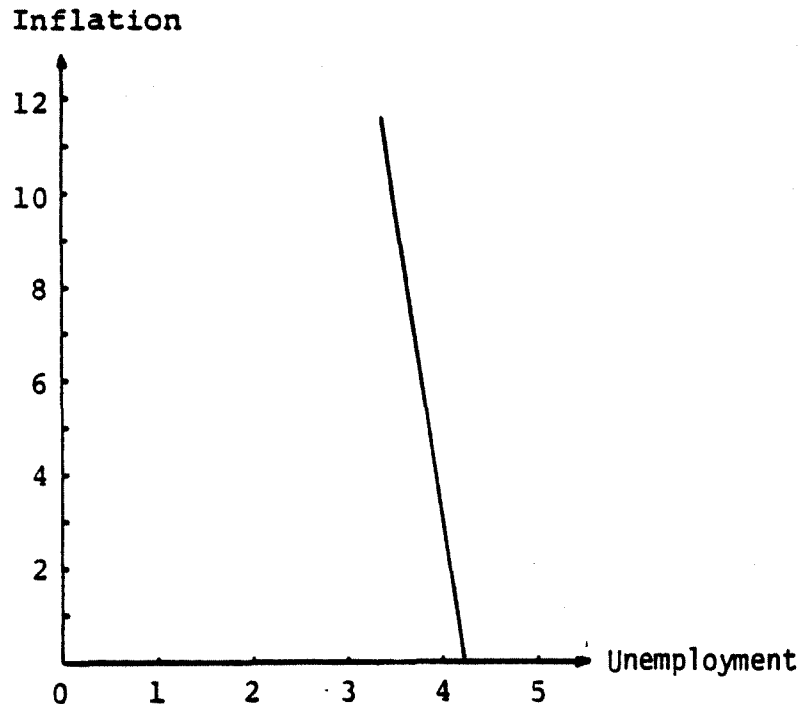


Table 2 **Long-run inflation and unemployment. Transfer payment to the high income (w_1) workers, financed in Central Bank**

Frequencies of high wage %	w_0	w_1	p_0	p_1	Unemployment %	Inflation %	Unemployment compensation	Transfer payment
12.17	1.87	2.75	3.00	3.92	4.23	0.00	1.00	0.00
11.89	1.85	2.71	2.95	3.90	4.31	0.78	1.00	0.05
11.63	1.82	2.66	2.90	3.87	4.40	1.58	1.00	0.10
11.37	1.79	2.62	2.85	3.85	4.49	2.39	1.00	0.15
11.13	1.76	2.57	2.80	3.83	4.58	3.22	1.00	0.20
10.89	1.73	2.53	2.75	3.81	4.67	4.06	1.00	0.25
10.66	1.70	2.48	2.70	3.78	4.76	4.92	1.00	0.30
10.44	1.67	2.44	2.65	3.76	4.85	5.80	1.00	0.35
10.23	1.64	2.39	2.60	3.74	4.94	6.70	1.00	0.40
10.02	1.61	2.34	2.56	3.71	5.03	7.62	1.00	0.45
9.82	1.53	2.30	2.51	3.69	5.13	8.56	1.00	0.50
9.62	1.55	2.25	2.46	3.66	5.22	9.52	1.00	0.55
9.43	1.52	2.21	2.41	3.64	5.31	10.51	1.00	0.60
9.24	1.49	2.16	2.36	3.61	5.41	11.52	1.00	0.65
9.06	1.45	2.11	2.31	3.59	5.51	12.55	1.00	0.70
8.88	1.42	2.07	2.26	3.56	5.61	13.61	1.00	0.75

Figure 2 **Long-run inflation and unemployment. Transfer payment to the high income (w_1) workers, financed in Central Bank**

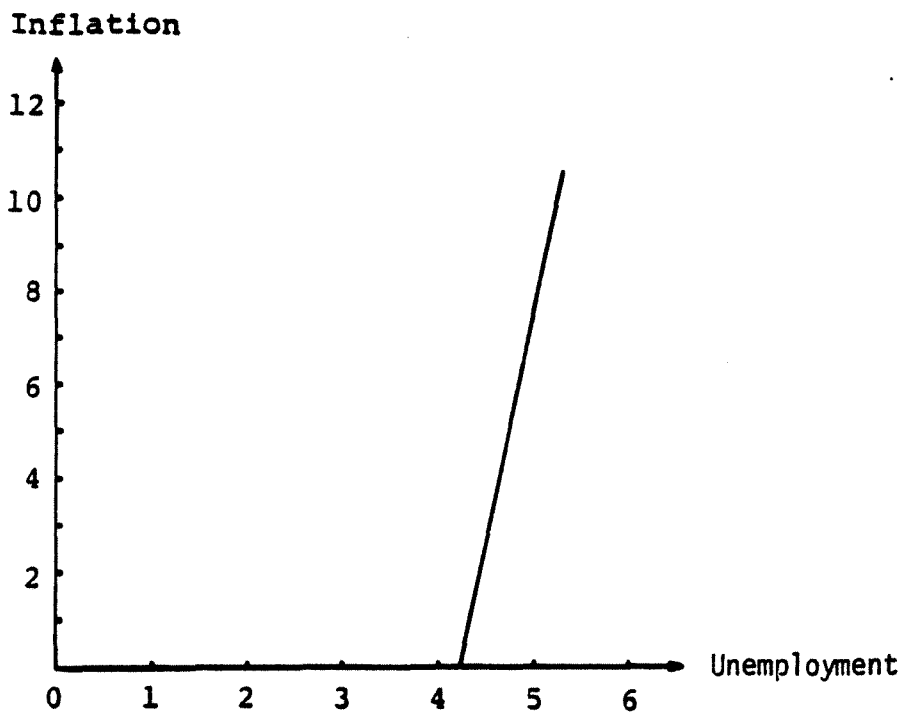
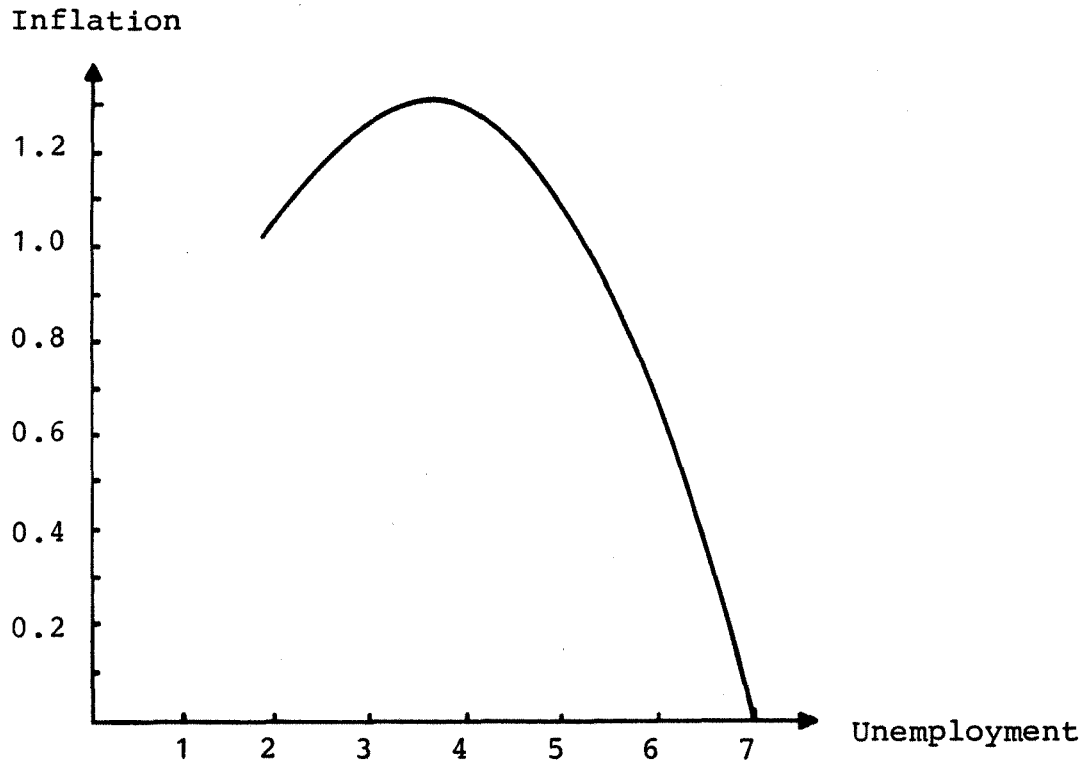


Table 3 **Long-run inflation and unemployment. Transfer payment to the unemployed (UI-compensation), financed in Central Bank**

Frequencies of high wage %	w_0	w_1	p_0	p_1	Unemployment %	Inflation %	Unemployment compensation	General transfer payment
6.97	0.00	0.93	1.07	2.07	6.97	0.00	0.00	0.0
9.99	0.95	1.83	2.03	2.95	5.05	0.87	0.50	0.0
12.48	1.90	2.75	2.99	3.86	4.13	1.27	1.00	0.0
14.53	2.82	3.63	3.91	4.74	3.61	1.31	1.50	0.0
16.35	3.72	4.50	4.81	5.62	3.25	1.30	2.00	0.0
18.02	4.60	5.36	5.70	6.48	2.98	1.27	2.50	0.0
19.56	5.47	6.21	6.58	7.33	2.78	1.24	3.00	0.0
21.01	6.33	7.05	7.44	8.17	2.61	1.21	3.50	0.0
22.39	7.17	7.88	8.28	8.99	2.47	1.18	4.00	0.0
23.70	8.01	8.69	9.12	9.81	2.36	1.15	4.50	0.0
24.96	8.83	9.50	9.94	10.62	2.25	1.13	5.00	0.0
26.17	9.64	10.29	10.76	11.42	2.17	1.11	5.50	0.0
27.34	10.44	11.08	11.56	12.21	2.09	1.08	6.00	0.0
28.47	11.24	11.86	12.36	12.99	2.02	1.06	6.50	0.0
29.57	12.02	12.63	13.14	13.76	1.96	1.05	7.00	0.0
30.65	12.79	13.39	13.92	14.52	1.90	1.03	7.50	0.0

Figure 3 **Long-run inflation and unemployment. Transfer payment to the unemployed (UI-compensation), financed in Central Bank**



APPENDIX

In the system of equations (2'), (5'), (8'), (9'), (10'), (11'), (12') we have eliminated the variable k from equation (2') using equations (10') and (11'). Equations (8') and (9') have been somewhat rearranged. We then get the following system of six equations:

$$(\theta+b)\left(\frac{1-\gamma}{w_1+\theta} + \frac{\gamma}{w_0+\theta}\right) + \frac{1-\tau}{\tau}\gamma^2\frac{w_1-w_0}{w_0+\theta} - 1 = 0 \qquad (A1)$$

$$(p_1-w_0)\gamma - p_0+w_1 = 0 \qquad (A2)$$

$$\theta + b + \frac{1-\tau}{\tau}\gamma(w_1+\theta-Qp_1) = 0 \qquad (A3)$$

$$(1-\gamma)(w_0+\theta) - Qp_0+\gamma Qp_1 = 0 \qquad (A4)$$

$$p_0(w_1+\theta) - p_1(w_0+\theta) = 0 \qquad (A5)$$

$$(p_0-w_1-b\frac{\tau}{1-\tau}) - (\theta-TR)\left[\frac{\tau}{1-\tau} + \gamma(2-\gamma)\right] = 0 \qquad (A6)$$

When transfers are given to high-income workers, w_1 is replaced by w_1 + transfers in equations (A1), (A3), (A4) and (A5). b = 0 in (A6) in case (3).

NOTES

[1] We assume constant returns to scale and the product unit is defined as the output of one unit of labor per unit of time.

[2] The argument that the firm produces to meet its product demand is as follows: q is decreasing function of p, ℓ is increasing function of w. If p and w are such that $q(p) > \ell(w)$ profit could be increased by increasing p or decreasing w. If p and w are such that $q(p) < \ell(w)$ profit could be increased by decreasing p or increasing w.

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