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Inflationary effects of administrative price increases

by

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1. Introduction

The first oil shock of 1973 presented an analytic problem to economists who up to this point were used to thinking of most shocks as coming from the demand side. Shocks to aggregate demand are not the only source of economic fluctuations. If fluctuations in economic activity emanate from the supply side, a higher rate of inflation is associated with a higher rate of unemployment and often with decreasing output. The analytic problem of the 1973 oil shock was the explanation of the simultaneous existence of high inflation and recession.

A *supply shock* is a shock to the economy that alters the costs of producing goods and services and, as a result, the prices that firms charge. Because supply shocks have a direct impact on the price level, they are also called *price shocks.*

Thus, an adverse supply shock yields an increase in the aggregate price level as it pushes up costs and prices. These are several examples of adverse supply shocks:

- A major oil producer, exercising its monopoly power can raise the world price of oil.
- Aggressiveness of trade union can push up wages and the prices of goods produced by union workers.
- A natural disaster (drought, flood, etc.) can destroy crops and the reduction in the food supply pushes up food prices.
- A government of a country in transition to market economy can administratively introduce higher prices of resources, for instance energy, to reduce subsidies, in order to bring the domestic prices to the world's price level, and to repair its budget.

In this paper, we examine the short term inflationary effects of a single governmentally administered shock increase of prices. This increase is carried out by the government which, while controlling aggregate demand has a difficult choice between two options. The first option is to hold aggregate demand constant. In this case output and employment will decrease and prices will grow. Prices may eventually fall, but not necessarily to the initial level, because real adjustments are slow, the adaptation of capital shock to the higher price of energy for instance. The cost of this process is a painful recession. The second option is to expand aggregate demand in defense of the falling output. Although government may be lucky enough to maintain the output level and the full employment (the level of *natural unemployment*)[1], the price level will be permanently higher. Also, in the presence of inefficient adjustments there might be a decrease in output and in employment.

There are multiple effects of a price shock. If, for instance, the prices of fuel and energy are raised, then on the one hand the prices of many other products will increase, and the aggregate price level will rise. This should lower, at least temporarily, the demand for fuel and energy and also bring down the aggregate demand level. On the other hand, in the long run, new, less energy intensive technologies should be introduced in response to higher energy prices. It has been observed in the countries of Western Europe and in the USA after the oil crises of 1970s. In Poland (and in other Central and Eastern European countries) new energy saving technologies have not been introduced, in spite of several shock increases in the prices of energy, gas and coal since 1989. Thus, technology has been changing very slowly in the transition period of Polish economy. Also, no substantial changes in demand for fuels and energy have been observed.

Therefore, in our analysis of short term inflationary effects of a price shock, administered by the government, we assume constant technology and examine primarily the "cost-pushed" inflation, which is presently prevailing in the Poland's transitional economy. Trade unions in Poland are still very strong. A price rise invites wage demands and as time passes it brings wage increases, which, once granted, tend to be irreversible. In the process of the transformation and privatization of the economy a tendency to maintain, and even increase profits is quite natural. Higher profits, together with increasing wages, induce higher costs and, as a result, might lead to a spiraling inflation.

The government has the possibility to control the situation by an appropriate indexation of income (wages and profits), but this is a very "delicate" matter. By increasing aggregate demand the government would like to prevent the reduction of output, but too high indexation might lead to exceesively high aggregate demand and thus to permanently high inflation. Due to imperfect long run capital adjustments it might lead to falling output and increasing unemployment

1 The natural level of unemployment corresponds to the natural level of ouput – the level at which the economy's resources are fully employed.

(see Fig.1). There is another tricky question as to whether the price shocks are permanent or transitory. In the paper we try to give answers to the above questions.

There is theoretical literature related to economics of inflation, for instance Jackman, Mulvey, Trevithick (1981), or the paper of Drudi and Giordano (1994), who investigate price versus productivity indexing in a model of monetary policy with wage bargaining. They argue that productivity indexing alone guarantees price and employment stability, provided the government credibility is high and the unions bargaining power is not too high. Under such conditions the optimal degree of price indexation is zero. It would be interesting to find out if these analytical conclusions are borne out by events in the Polish economy. In our current analysis of supply shocks in transitional Polish economy we assume productivity coefficients to be constant, and investigate only cost pushed inflation.

An interesting analysis, both theoretical and experimental, of aggregate supply shocks' contribution to price and output dynamics is given in Henin and Collard (1994).

There are papers published in Poland, related to our investigations which present analysis of inflationary effects of administrative price rises of resources (Borzym and Borysiewicz, 1991, Misiąg, 1987), and the consequences of changes in the exchange rate on inflation (Borzym and Borysiewicz, 1991, Piotrowski, 1989). However, their analyses are rooted in the old financial regulations, no longer valid after 1990. Especially in Misiąg's paper, the analysis is designed for planned economy. For instance imports, and the share of administrative prices in all prices are defined as exogeneous, production dynamics is independent of production costs, etc.

They all analyze inflation over a single period of time, from t to $t+1$. We apply a different methological approach, and investigate, over many periods, both the distribution of inflation, and accumulated inflation resulting from an administrative price rise. Thus, we find out, using quantitative methods, whether such price shock is transitory or persistent.

Our analysis is based on a dynamic, recursive, vector equation of prices, which depends on prices in previous time instances. One period delay is assumed between product prices and prices of cost factors. The wages and acquired profits are indexed with one period delay or instantaneously with increased prices of intermediate products and resources. This relation is derived from the balance equation defined for each column of the I-O matrix. It assumes the form of a linear control operator. The spectral radius (absolute value of the maximal eigenvalue) of the control matrix determines stability of inflation process. If the shock-driven inflation decreases with time, the accumulated inflationary effect can be calculated.

Using Polish data we analyze three scenarios of the price induced inflationary mechanism:

- when wages and profits stay constant; then the resulting inflation is min-

imum;

- when wages and profits increase – instantaneously or with a delay.

An impact of wage indexation on accumulated inflation is analyzed. It is shown that there exists a critical value of indexation for which the accumulated inflation, induced by a price shock, is constantly growing, and for large initial price rises administered by the government it can be explosive. Thus, even small government mistakes related to the scale of price increases and to the level of indexation of wages can result in high and permanent inflation. They might also lead to lower output and higher unemployment, but it is only discussed briefly in section 4, and will be analyzed in more detail in a separate paper.

2. Cost–pushed inflation

As discussed in the Introduction, *cost-pushed inflation* prevails in the transition period in the post-communist economies. We analyze an n-sector economy in which sector j produces homogeneous j-th product, $j = 1, \ldots, n$. We assume that the production technology of the j-th product does not change and that the A matrix of Input-Output coefficients is constant during our analysis.

Based on Input-Output analysis we define the total production costs of the j-th product X_j as a function of intermediate products, production factors – labor and capital, relative factor prices, and profit realized in the j-th sector. Thus, for the j-th column of the Input-Output matrix we have the balance equation:

$$X_j = \sum_{i=1}^{n} X_{ij} + K_j + V_j + m_j, \; j = 1, \ldots, n \tag{1}$$

where:

X_j value of output of the j-th product,

$\sum_i X_{ij}$ costs of intermediate material inputs, $i = 1, \ldots, n$, utilized for production of the j-th product, $j = 1, \ldots, n$,

K_j costs of capital inputs needed for production of the j-th product,

V_j wages in the sector producting the j-th product,

m_j profit acquired in the j-th sector.

Introducing prices, wages, productivity and efficiency ratios, we can rewrite equation (1) as:

$$p_j Q_j = Q_j \sum_{i=1}^{n} p_i a_{ij} + pk_j a_j^k Q_j + pv_j a_j^v Q_j + \pi_j Q_j, \tag{2}$$

where:

$a_{ij} = Q_{ij}/Q_j$ is the ratio of material inputs of the i-th product utilized in production of a unit of the j-th product,

p_j unit price of the product j,
Q_j output of the product j, in physical units,
a_j^k ratio of capital efficiency (amount of capital used for production of a unit of the j-th product),
pk_j unit price of capital in sector j,
a_j^v ratio of labor efficiency (the number of workers or amount of labor-hours, needed for production of a unit of product j),
pv_j a unit wage in sector j,
π_j profit rate in sector j.

Price level p_j, $j = 1, \ldots, n$, can be easily determined from the cost equation (2) by dividing its both sides by Q_j. Assuming that producers of the j-th product change its price with a one period delay relative to the change in prices of capital, labor and intermediate products, we obtain:

$$p_j^t = \sum_{i=1}^{n} p_i^{t-1} a_{ij} + pk_j^{t-1} a_j^k + pv_j^{t-1} a_j^v + \pi_j^{t-1}, \tag{3}$$

Then, changes in prices (the price dynamics) can be described by the following equation:

$$\Delta p_j^t = \sum_{i=1}^{n} \Delta p_i^{t-1} a_{ij} + \Delta pk_j^{t-1} a_j^k + \Delta pv_j^{t-1} a_j^v + \Delta \pi_j^{t-1}, \tag{4}$$

where $\Delta p_j^t = p_j^t - p_j^{t-1}$, $j = 1, \ldots, n$, and Δp_j^t denotes a change in prices of product j in the period between time t and $t-1$. At initial period $t = 0$ (the base year of our analysis) we have a vector of prices $[p_1^0, \ldots, p_j^0, \ldots, p_n^0]$. The price shock in the economy is defined as the change in prices in the first period $\Delta p_i^1 = p_i^1 - p_i^0$, $i \in \{1, \ldots, n\}$. Consequences of this price shock are observed in consecutive periods $t = 2, \ldots, k, \ldots$ The time period $\Delta t = 1$ of about one week can be interpreted as the time elapsing between the announcement of new prices and their application in trade transactions.

3. Accumulated inflation induced by price shocks

We could investigate the consequences of an earlier rise in prices of selected material inputs, products and services at any time t, but in this paper we estimate the inflation accumulated over infinite time which results from the initial price shock. A shock increase in the prices of two products i and k, Δp_i^{t-1}, Δp_k^{t-1}, $i, k \in \{1, \ldots, n\}$ alters the costs in sectors producing these products and, as a result, with a one period delay it alters the prices of other products $j = 1, \ldots, n$. Such price shocks occur when the government administers higher prices of energy or of coal, for instance. They belong to a general class of adverse supply shocks. These shocks can have either permanent or transitory effects on the overall inflation in the economy.

We consider three cases of propagation of the inflationary effects of a shock increase of prices of selected goods and services.

In the first scenario we assume that the change in price of the j-th product in (4) results only from the change of prices of intermediate products p_i, while no changes are observed in the price of capital, the unit wage, and the rate of profit:

$$\Delta pk_j^t,\ \Delta pv_j^t,\ \Delta\pi_j^t,\ \text{for } j = 1,\ldots,n,\ \text{and for all } t = 1,2,\ldots$$

In this unrealistic case, in which a rise in the prices of materials and resources affects neither wages nor profits, nor costs of capital, we estimate the absolute *minimum cost-pushed* inflation resulting from a prior shock increase of prices. Equation (4) assumes the form:

$$\Delta p_j^t = \sum_{i=1}^{n} \Delta p_i^{t-1} a_{ij},\ j = 1,\ldots,n. \tag{5}$$

In the second scenario we assume that the increase in wages and profits occurs simultaneously with the administered new prices of selected products and resources.

We assume that the incomes in sector j change proportionally to the changes in the price of the j-th product, and that this proportion does not change over time.

$$w_j^t = \frac{\Delta pv_j^t a_j^v + \Delta\pi_j^t}{\Delta p_j^t} = w_j,\ \forall t = 0,1,\ldots$$

As long as less than half of the Polish economy is privatized and the lobby of the trade unions is very strong, we can accept such an assumption. This does not change the qualitative results of our investigations but only clarifies the presentation. In the current analysis we do not investigate relationships between wages and profits and therefore they can either be constant or vary over time. It does not affect our analysis. Equation (4) assumes the form:

$$\Delta p_j^t = \sum_{i=1}^{n} \Delta p_i^{t-1} \bar{a}_{ij} + \Delta p_j^{t-1} w_j,\ j = 1,\ldots,n. \tag{6}$$

where $\bar{a}_{ij} = a_{ij} + a_{ij}^k$, and a_{ij}^k is a ratio of capital, coming from sector i, utilized in production of a unit of product j.

In the third scenario we assume that the increase in wages and profits is delayed relative to the administered new prices of resources and occurs simultaneously with the announcement of a new price of the product j. In this case the cost inflationary spiral, induced by an increase of income, is evolving slower than in the second scenario. Equation (4) assumes the form:

$$\Delta p_j^t = \sum_{i=1}^{n} \Delta p_i^{t-1} \bar{a}_{ij} + \Delta p_j^t w_j,\ j = 1,\ldots,n. \tag{7}$$

In order to simplify the presentation we can apply matrix notation. The price dynamics equations can be rewritten as below.

In the first scenario:

$$\Delta P_t = A' \Delta P_{t-1}, \tag{8}$$

where:

A constant matrix of Input-Output coefficients a, of dimension $[n \times n]$,

A' transpose of matrix A,

ΔP_t vector of dimension $[n \times 1]$, defined for time t, whose components Δp^t determine a change in prices of product j.

In the second scenario:

$$\Delta P_t = [\bar{A}' + W] \Delta P_{t-1}, \tag{9}$$

where W denotes a diagonal matrix of dimension $[n \times n]$ with nonzero elements w_i on the principal diagonal, $\bar{A} = A + A^k$, and A^k is a square matrix with elements a_{ij}^k, $i, j = 1, \ldots n$.

In the third scenario:

$$\Delta P_t = [I - W]^{-1} \bar{A}' \Delta P_{t-1}, \tag{10}$$

as from equation (7) we have

$$\Delta p_j^t = \frac{1}{1 - w_j} \sum_{i=1}^{n} \Delta p_i^{t-1} \bar{a}_{ij}, \; j = 1, \ldots, n.$$

Thus, we can define a recursive vector equation for prices:

$$\Delta P_t = R \Delta P_{t-1}, \tag{11}$$

where R is a linear control operator. The matrix R of dimension $[n \times n]$ assumes the following form in consecutive cases of our analysis:

Scenario No. I:

$$R = A' \tag{12}$$

Scenario No. II:

$$R = \bar{A}' + W \tag{13}$$

Scenario No. III:

$$R = [I - W]^{-1} \bar{A}' \tag{14}$$

Applying the recursive equation (11) we can determine the price increase at time t, ΔP_t, as a function of the initial shock price increase ΔP_1. The

inflationary effects ΔPS, accumulated over time, and induced by the initial shock price increase can be described as:

$$\Delta PS = \sum_{t=1}^{\infty} \Delta P_t = [I + R + R^2 + \ldots + R^k + \ldots]\Delta P_1. \tag{15}$$

When the accumulated inflationary effects ΔPS induced by the shock price ΔP_1 decrease over time, i.e. when the matrix R to the power k converges to zero as $k \to \infty$ (or when the spectral radius of matrix R is less than one) then the infinite sequence $I + R + R^2 + \ldots + R^K + \ldots$ converges to the matrix $[I - R]^{-1}$, as:

$$I + R + R^2 + \ldots + R^K + \ldots = [I - R]^{-1} \tag{16}$$

when $\lim_{k\to\infty} R^K = 0$.

Then, from (15), the accumulated inflationary effect ΔPS resulting from the shock price increase ΔP_1 can be estimated as:

$$\Delta PS = [I - R]^{-1}\Delta P_1. \tag{17}$$

The eigenvalues of a square $[n \times n]$ matrix R are the roots of its characteristic polynomial $p(z) = \det(zI - R)$. The set of these roots, called spectrum, is denoted by $\lambda(R)$. Absolute value of the maximum eigenvalue, $\lambda_r = \max_i |\lambda_i|$, $\lambda_i \in \lambda(R)$, $i = 1, \ldots, n$, is called the *spectral radius*. If λ_r is less than one we have convergence in (16) and ΔPS decays in time. If λ_r is greater than one, the value of expression (15) is growing and the accumulated inflation is permanently increasing. Then, equation (16) do not hold.

We analyze the impact of wage indexation on the accumulated inflation in the second and third scenarios, when the incomes increase together with the price of material inputs and resources. Then, the linear control operators (13) and (14) assume the form:

$$R = A' + \gamma W \tag{18}$$

$$R = [I - \gamma W]^{-1}\bar{A}', \; 0 < \gamma < 1, \tag{19}$$

where γ is an indexation parameter. It plays a crucial role in the analysis of inflationary effects induced by a shock increase of prices. There exists a critical value of γ, above which the spectral radius of matrix R is greater than one. As a result, the accumulated inflationary effect ΔPS is permanent and growing explosively. Thus, inflation can grow infinitely, other elements of the model being constant.

4. Sensitivity analysis

The matrix $[I - R]^{-1}$ of (10) has a very interesting economic interpretation. It is a measure of inflationary sensitivity of the economy to shock price increases in various sectors of the economy. $[I - R]^{-1}$ represents the relationship between the inflationary effects accumulated over time, ΔPS, resulting from the initial shock price increase ΔP_1, and this initial shock (see (10)).

If we want to measure accumulated inflation in a single sector i, when the shock impulses can come from all sectors $j = 1, \ldots, n$, then

$$\Delta PS_i = \sum_{j=1}^{n} Z_{ij} \Delta P_{1j} \ (i = 1, \ldots, n). \tag{20}$$

where $Z = [I - R]^{-1}$.

If we want to measure inflatioon in the sector i, resulting from a single price shock of a sector j^* $(\forall j \neq j^* \ \Delta P_{1j} = 0)$, then

$$\Delta PS_i = Z_{ij^*} \Delta P_{ij^*} \ (i = 1, \ldots, n). \tag{21}$$

Thus, we have

$$Z_{ij} = \frac{\Delta PS_i}{\Delta P_{1j}}, \tag{22}$$

where Z_{ij} is the inflationary sensitivity ratio, which yields an increase of prices in sector i, resulting from a single shock price rise in sector j. The j-th column of the matrix Z determines inflationary sensitivity of consecutive sectors to a shock increase of prices in the j-th sector.

One could also define a ratio of inflationary sensitivity to a price shock resulting from sector j, for the whole economy:

$$\bar{Z}_j = \frac{\sum_{i=1}^{n} \omega_i Z_{ij}}{\sum_{i=1}^{n} \omega_i}, \tag{23}$$

where the weights ω_i represents the output of the i-th sector.

The ratio $\bar{Z}_j$ defines the average inflation in the economy, accumulated over time, and resulting from an initial price rise in sector j.

Based on the above analysis we have carried out computations in order to find out which of the sectors is the most sensitive to price shocks, and which one contributes the most to inflation in other sectors of the economy.

5. Experimental results for the Polish economy

We assume disaggregation of the Polish economy into the following 15 sectors: (1) fuel & energy, (2) metallurgy, (3) electromachinery, (4) chemistry, (5) mineral industry, (6) timber & paper industry, (7) light industry, (8) food processing

Indexation parameter γ	λ_r – spectral radius of matrix R		
	Scenario I	Scenario II	Scenario III
0.00	0.6021	–	–
0.80	–	0.9590	0.9369
0.85	–	0.9844	0.9786
0.87	–	0.9947	0.9967
0.88	–	0.9998	1.0061
0.89	–	1.0049	1.0158
0.90	–	1.0101	1.0256
1.00	–	1.0620	1.1406

Table 1. The spectral radius of matrix R as a function of indexation parameter γ.

industry, (9) other industries, (10) construction, (11) agriculture, (12) forestry, (13) transportation & telecommunication, (14) trade, (15) other branches. The data are taken from the Input-Output Tables of 1988, published by the Central Statistical Office.

Based on (17) we investigate the propagation of inflation induced by the initial shock price increase in one of the 15 sectors of the economy. In all three scenarios discussed earlier we compute the eigenvalues of matrix R and determine its spectral radius. We apply the singular value decomposition method for computation of eigenvalues. Values of spectral radii are presented in Table 1.

In the first scenario, when the incomes (wages and profits) do not change, the spectral radius is $\lambda_r = 0.6$, and the inflation decays in about ten periods ($k = 10$).

This situation is illustrated in Fig.1, oversimplified but consistent with the macroeconomic theory of adverse supply shocks. In the literature, a supply shock is a shock to economy that alters the costs of producing goods and services and, as a result, the prices that firms change (Blanchard and Fischer, 1989). The price p_1 determines the short run aggregate supply curve (SRAS1), while p_2p_1 obtained in result of a shock increase of prices of intermediate products or resources defines SRAS2. As can be deduced from (3), p does not depend on output. The long-run aggregate supply (LRAS) curve is vertical, and changes in aggregate demand affect only the price level. The aggregate demand curve (AD1) crosses SRAS1 in point K.

In the first case the aggregate demand is held constant, and the economy moves from point K to L, as an adverse supply shock pushes up costs and prices. We have a combination of increasing prices and falling output. Eventually the prices fall and the economy should return to the initial point K (natural output and unemployment level). However, in real life, the supply shock may lower the

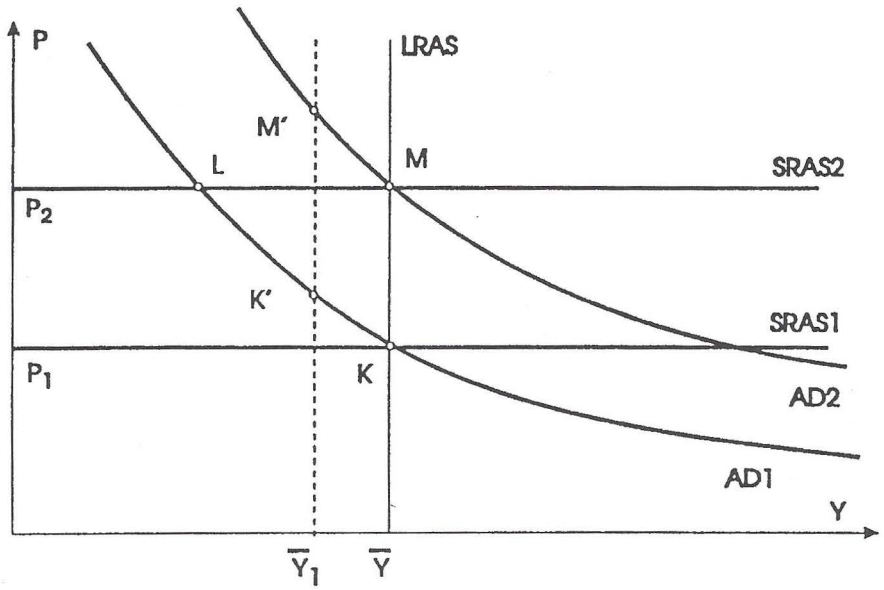

Figure 1. An adverse supply shock

natural level of output, and cause the prices to fall, but only to the point K', as both capital and labor are affected. In addition, aggregate demand can increase, when the government reacts by increasing incomes, to prevent a reduction of output. This policy, however, yields a permanently higher level of prices – point M in Fig. 1.

In scenarios II and III we analyze the case in which the aggregate demand changes, due to changes of incomes (the long-run aggregate supply can also change when Δpk_j changes, i.e. investment, and thus output might decrease when the unit cost of capital decreases). The cost of such a policy might be the increase in prices to the level of point M' and a decrease in output.

For both scenarios II and III we computed spectral radii of matrix R for various indexation parameters $\gamma \in [0, 1]$. In Table 1, values of λ_r are computed for indexation parameters ranging from 0.8 to 1.0. The values of λ_r are close to 1, and for a critical value of γ, equal to 0.88 for scenario II and 0.87 for scenario III they exceed one. This means that the accumulated inflation, induced by an adverse supply shock, is growing. Thus, a shock increase of administered prices, accompanied by the indexation of wages and profits to a level higher than 0.88 percent of the increased price level, yields inflation, which is not decaying, does not stabilize, but accumulates increasingly. The total inflationary effects cannot be estimated, as the inflation grows to infinity.

Even when the indexation reaction of the government is only 80 percent, the

Initial price shock	Resulting accumulated inflation [%]						
	Scenario I		γ	Scenario II		Scenario III	
	energy	economy		energy	economy	energy	economy
10	12.7	2.2	0.5	20.2	4.8	14.8	3.5
			0.8	34.8	13.7	19.9	7.8
20	25.5	4.3	0.5	40.4	9.7	29.6	7.1
			0.8	69.6	27.3	39.8	15.7
40	50.9	8.6	0.5	80.8	19.3	59.1	14.2
			0.8	139.2	54.6	79.6	31.3
60	76.4	12.9	0.5	121.2	29.0	88.7	21.2
			0.8	208.8	81.9	118.4	47.0
80	101.8	17.2	0.5	161.6	38.7	118.3	28.3
			0.8	278.3	109.2	159.3	62.6

Table 2. Accumulated inflation (increase in percent) in fuel and energy sector and in the whole economy, resulting from a shock increase of prices for fuel and energy.

Sector of origin of the shock price rise	Average accumulated inflation in the economy				
	Scenario I	Scenario II		Scenario III	
		$\gamma = 0.5$	$\gamma = 0.8$	$\gamma = 0.5$	$\gamma = 0.8$
fuel & energy	2.20	4.93	13.85	3.61	7.91
metallurgy	1.69	3.41	8.60	2.84	6.31
electromachinery	2.89	5.96	15.42	4.29	8.48
chemistry	1.14	2.39	6.13	1.73	3.45
mineral industry	0.57	1.15	2.77	0.85	1.64
timber & paper ind.	0.58	1.19	3.04	0.91	1.90
light industry	1.03	1.93	4.35	1.40	2.42
food industry	1.33	1.70	2.41	1.49	1.95
residual industries	0.51	1.06	2.56	0.75	1.35
construction	1.40	2.41	4.93	1.73	2.71
agriculture	2.67	4.45	7.98	3.47	5.17
forestry	0.15	0.36	1.06	0.15	0.55
transport & telecommunication	1.41	3.13	8.84	2.18	4.45
trade	1.50	3.37	9.70	2.15	4.08
other branches	0.58	1.07	2.46	0.84	1.62

Table 3. Average accumulated inflation in the economy (in percent) induced by a shock price rise of 10 percent in a single sector.

inflationary effects of the shock price rise of energy and fuels by 40 percent yields very high inflation in the economy equal to 54.6 percent (139.2 percent price rise in the fuel and energy sector), when the wages are indexed simultaneously with the increase of administered prices. These figures are lower when the indexation is delayed in scenario III. Table 2 presents inflationary effects of shock increases of prices of fuel and energy ranging from 10 percent to 80 percent for two indexation parameters: 0.5 and 0.8. Indexing above 0.88 might bring exploding inflation when the initial price increase is high.

In Table 3 we present the inflation accumulated in the economy, induced by the 10 percent shock increase of prices, administered in consecutive sectors. All three scenarios are presented. The 10 percent price rise in the electromachinery sector yields the highest accumulated inflation of 2.89 percent, in the first scenario of no rise in incomes and with no indexation. When the indexation is instantaneous (the second scenario), the accumulated inflation is 5.96 percent for the indexation parameter 0.5, and 15.42 percent for the indexation parameter 0.8. When the indexation is applied with a one period delay relative to price shock (third scenario), these figures are lower and equal 4.29 percent, and 8.48 percent respectively. The price shock in the fuel and energy sector also brings very high sectoral and overall inflation in the economy. A price increase in this sector contributes the most to price increases of products in sectors of: fuel and energy, metallurgy, mineral industry, transportation and chemistry. The weakest influence of the shock prise rise in the fuel and energy sector is observed in trade, light industry and in forestry. Price shocks in the sectors of agriculture, metallurgy, telecommunication and transportation and in trade also substantially contribute to the overall inflation.

We recall that the spectral radius of matrix R is less than one for both the second and the third scenarios, when the indexation parameter is 0.8. This means that the numbers given in Table 3 represent inflation, which stabilizes over time. It is permanent unless other economic fluctuations occur. But increasing the indexation parameter above 0.88 will yield a permanently growing inflation.

The presented results demonstrate that the inflationary effects induced by an initial price shock grow when the income indexation parameter γ grows, and when the initial price shock grows. The lowest inflation is observed in scenario I, in which incomes are fixed. Then, the inflationary effects due to shock increase in prices of resources are transient. For instance, the accumulated inflation resulting from a 10% price increase of goods in fuel and energy sector amounts to 2.2% (Table 3). A price increase of 80% results in 17% inflation in the economy. The highest accumulated inflation results from price shocks when the incomes indexation (of wages and profits) is instantaneous with the shock price rise of resources, i.e. in scenario II. It is absolutly evident for higher values of indexation parameter. For instance for $\gamma = 0.8$ the price rise of 20% in the energy sector results in 70% of accumulated inflation. The increase of 40% in the energy sector yields three digit inflation in the economy.

6. Conclusions

We have analyzed the impact of adverse price shocks and of income indexation on the accumulated inflation in the Polish economy and in its 15 sectors. Our method allows investigations of inflationary effects for any disaggregation of the economy, provided data is available. The presented analysis makes it possible to identify the sectors in the economy which are the most sensitive to price shocks, and in which shock increase of prices administered by government contributes the most to the overall inflation, and to inflation in individual sectors. These sectors include: electromachinery industry which produces machines and tools, agriculture, fuel and energy, steel industries which produces resources and food products, and trade and transportation which produces services.

Price shocks or adverse supply shocks administered by a government, when combined with inappropriate indexation are very dangerous to the economy. They might result in high and permanent inflation, falling output and rising unemployment when the government indexes incomes too highly. As discussed in section 4, even small mistakes of few percent in the indexation parameter will lead to permanently growing inflation. Then, the only way to decrease prices might be to bring down aggregate demand, and the demand for selected products. But the costs of this operation will be long lasting unemployment and recession. This is true when labor efficiency, material coefficients and capital productivity do not change over time. While in Poland over 1991-1993 both material coefficients and capital productivity were stable (Felbur, Waźniewski, 1994), the labor efficiency increased substantially. Investigations should be carried out to include such efficiency variability in supply shocks analysis. It can be concluded from our analysis that cost-pushed inflation cannot be separated from demand inflation. Quantitative analysis of inflation and recession dynamics will be the subject of a separate study.

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References

BLANCHARD O., FISHER S., (1989) *Lectures on Macroeconomics.* The MIT Press, Cambridge.

BORZYM K., BORYSIEWICZ J., (1991) Model symulacyjny badania skutków zmian parametrów sterujących w gospodarce polskiej PROGCEN, PROGCEN Simulation Model for Analysis of Changes in Macroeconomic Parameters, IKiCHZ Report No 27, Warsaw.

CICHOCKI K., (1992) From Stabilization to Growth: The Case of Poland, and International Comparisons, Mimeo, Princeton University; 1994, From Stabilization to Growth: A Discussion of the Polish and other Experiences, in: *Systems Analysis and Decision Support in Economics and Technology*, R. Kulikowski, K. Szkatuła, J. Kacprzyk, (Eds.), Omnitech Press, Warszawa, pp. 56-72.

DRUDI F., GIORDANO R., (1994) Optimal Wage Indexation in a Reputational Model of Monetary Policy Credibility, paper presented at the European Economic Association Conference, Mastricht 2-5 September 1994.

FELBUR S., WAŻNIEWSKI P., (1994) Zmiany produkcji a efektywność gospodarowania, Efficiency and Changes in Production, Gospodarka Polski w procesie Transformacji 1993, IRiSS Report, Warsaw, pp. 102-118.

HÉNIN P. Y., COLLARD F., (1994) The Contribution of Aggregate Demand and Supply Shocks to Output and Price Dynamics: A Comparative Assesment, paper presented at the European Economic Association Conference, Mastrickt 2-5 September 1994.

(1988) Input-Output Tables, The Central Statistical Office.

JACKMAN R., MULVEY C., TREVITHICK J., (1981) *The Economics of Inflation*, Basil Blackwell, Oxford.

LEONTIEF W., (1951) *The Structure of the American Economy 1919-1939*, Oxford University Press, New York.

MISIĄG W., (1987) Analiza skutków zmian cen urzędowych – model MCEN, The MCEN Model – for Analysis of Administratively Introduced Price Changes, *Przegląd Statystyczny*, No **2**, pp. 155-166.

PIOTROWSKI Z., (1989) Wpływ zmian kursu walutowego na ceny krajowe, Contribution of the Exchange Rate on the Level of Prices, IKCHZ, Warsaw.

WORONIECKA I., (1994) Próba oszacowania skumulowanego efektu inflacyjnego jednorazowej podwyżki cen na surowce i materiały, Estimation of Accumulated Inflation, Induced by a Shock Price Increase of Resources, in: *Modelowanie i komputerowe wspomaganie decyzji gospodarczych*, A. Straszak, Z. Nahorski (Eds.), PTBOiS, IBS PAN, AON, WAT, Warsaw, pp. 45-63.