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# The Impact of Raw Materials Prices on the Interest Rate*

By Johann Graf Lambsdorff[1]

## 1. Introduction

The market for raw materials can be regarded as highly sensitive to political forces. Warfare, disputes over property rights, questions of international coordination and the building of cartels are important factors of influence which are typically regarded exogenous to macroeconomic analysis. Although it is acknowledged that the question of causality between macroeconomic aggregates (such as production and commodity prices) and raw materials prices is still open to debate,[2] this paper concentrates on one side of this causality: The question of how raw materials prices are impacting on the macroeconomy.

The macroeconomic influence of raw materials prices has first been investigated after the embargo of the OPEC-countries in 1973 considerably increased oil prices. There is consensus among economists that an increase of raw materials prices leads to stagflation, i.e. rising commodity prices and decreasing production and income in industrial countries. The same consensus cannot be found with respect to the (nominal) interest rates. In simulation studies involving various macroeconometric models (Hickman 1987, 159) reports about 4 studies to favor decreasing interest rates and 9 to argue on behalf of increasing interest rates in response to rising raw materials prices. The economic modeling in (Phelps 1978, 210) and (Wilcox 1983, 46) also brings about a negative correlation between the two variables. Likewise, the emphasis on recessive demand side effects in (Sachs 1982) and (Hamilton 1988) implies an oversupply on the capital market with decreasing interest rates, although this is not explicitly stated there. In contrast to such conclusions other contributions emphasize supply side effects and argued in favor of a positive correlation.

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2 See e.g. (Hooker 1996) and (Hamilton 1996).

The principal contribution of this paper is to develop a macroeconomic model which consistently incorporates the manifold influences raw materials prices exert on the economy. Crucial determinants are kept variable, such as the elasticity of substitution, returns to scale, wage rigidity and the capital stock. This allows us to derive robust conclusions which are valid for a broad range of different economies. Also, this approach allows for many conclusions for macroeconomic modelling which lie beyond the scope of this paper. Only minor restrictions are needed to keep the model manageable and the outcome understandable. By doing so the paper will shed light on the relationship between interest rates and raw materials prices and present theoretical arguments for a positive correlation between the two.

The paper is organized as follows. Section 2 lists the potential impact of raw materials prices on the interest rate, section 3 develops a model which allows for a comparison of the multitude of these effects. Making use of a CES-production function, the model puts special emphasis on deriving the supply side and consistently incorporating the demand side into the analysis. Above this, particular precaution is taken to formulate an adequate model for the world economy as opposed to a small open economy. While incorporating a variable capital stock, our final results turn out to be close to a simple Keynesian model.

Our proposition is that rising raw materials prices will lead to an excess demand on the capital market and to rising interest rates. Section 4 concludes by presenting a possible application of our findings, referring to central bank policies. Some economists propose an interest rate target for central bank policies in contrast to money stock targeting. This is justified if output stability is preferred to price stability. Rising raw materials prices lower production and raise the commodities price index and the interest rate. Interest rate targeting now requires an expansionary monetary policy, raising output and the price level. Whereas output fluctuations are subsequently stabilized, the volatility of the price level will inevitably increase.

## 2. Identifying Channels of Influence

The interest rate is determined on the capital market, bringing into equilibrium macroeconomic savings and investments.[3] Determining interest rate reactions thus requires determining the effects of raw materials prices on

[3] Given the Keynesian approach taken here and its focus on a liquidity preference theory of interest rates, a rising interest rate has a direct negative effect on investments. To a lower extent, savings are affected negatively via the Keynes-effect on output.

savings and investments. A variety of such impacts can be found in the literature. These can be subsumed under the following descriptions:[4]

*Scale Effect on Savings:* Rising raw materials prices raise the costs of production and induce a reduction of the production level. Less income is generated in the production process, lowering the level of savings according to the marginal propensity to save.

*Scale Effect on Investments:* Investments can be assumed to depend on current or on future production levels. With production costs rising and the production level decreasing due to increased raw materials prices also investments will be lowered.

*Cross-Price Effect:* The input of raw materials is lowered in reaction to rising raw materials prices. This may impact on the marginal returns to capital. Whereas (Tatom 1991) and (Hutchison 1991) propose that substitution possibilities (although limited) imply a positive cross-price elasticity the opposite is expressed by (Wilcox 1983, 47), (Hamilton 1988) and (Phelps 1978, 210). They argue that the marginal returns to capital are lowered as a consequence of limited substitution possibilities. We may hence either obtain a positive or a negative cross-price effect on the capital stock.

*Income-Shift Effect:* Rising raw materials prices shift income from industrial countries to raw materials exporting countries. Assuming exports of the commodity to be exogenous, this reduces total demand on the international commodity market. Given a certain production level this increases savings.[5]

*Inflation Expectations Effect:* Rising commodity prices as a response to increasing raw materials prices may lead to expectations of rising inflation. Investments may increase due to decreasing real interest rates.[6]

We will argue that while the scale effect on savings dominates the scale effect on investments there are no convincing reasons to assume the existence of an income-shift effect and a cross-price effect. This leads straightforward to the conclusion of a rising nominal interest rate in response to rising raw materials prices. An increase of the nominal interest rate might be further fuelled temporarily by the inflation expectations effect.

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4 See (Rasche and Tatom 1981, 10) and (Herberg, Hesse and Schuseil 1982, 113) for som of the macroeconomic effects mentioned.

5 This effect corresponds to what is the "demand effect" in the commodity market, see (Sachs 1982, 245) and (Tatom 1991, 5). (Hutchison 1991, 11) and (Hickman 1987, 139) point to the fact, that income is only shifted. The term "income-shift effect" appeared more appropriate therefore. The rise of savings occurs on the part of the raw materials exporters. These savings are channeled back into the capital markets. This has been called *financial recycling* by (Corden and Oppenheimer 1976, 30).

6 This effect is also mentioned in (Hutchison 1991, 15).

## 3. The Model

The following model presumes a bipartite world: An industrialized region faces a raw materials exporting region. The production of the industrial countries is dependent on the import of raw materials whereas the exporters of raw materials do not own facilities for producing the commodity and import the commodity from the industrialized countries.

### 3.1. The Supply Side

Central to our investigation is the use of a rather general production function for the industrial countries' commodity. We will assume a CES-production function, which is known to incorporate a Cobb-Douglas and a limitational production function as special cases. By doing so we do not restrict the model to a specific value for the elasticity of substitution nor a particular value for the returns to scale. The advantage of this general approach is to derive results which are robust to a large variety of macroeconomic situations:

(1) $$Q = (\alpha_1 N^{-\rho} + \alpha_2 R^{-\rho} + \alpha_3 K^{-\rho})^{-\frac{\mu}{\rho}},\ \rho > 0,\ 0 < \mu < 1,\ \alpha_1 + \alpha_2 + \alpha_3 = 1^7.$$

$Q$ is the total real gross production (quantity) of the industrial countries, $N$ indicates labor, $R$ the imported raw material and $K$ physical capital. The elasticity of substitution $\sigma$ is determined by $\rho$ according to $\sigma = \frac{1}{1+\rho}$. Since $\rho > 0$ the analysis presupposes $\sigma < 1$, i.e. the realistic assumption of a low elasticity of substitution of the input factors. Given the conditions of perfect competition, we will determine production ($Q$) as a function of the factor prices. The optimality conditions are:[8]

(2) $$\mu\alpha_1 \frac{Q^{1+\frac{\rho}{\mu}}}{N^{1+\rho}} = \frac{W}{P}\ ,$$

(3) $$\mu\alpha_2 \frac{Q^{1+\frac{\rho}{\mu}}}{R^{1+\rho}} = \frac{P_R}{P}\ ,^{9}$$

7 The term $\mu$ represents the returns to scale, see (Bhandari and Turnovsky 1984, 172) and (Varian 1984, 30). A more complicated model has been introduced by (Marston and Turnovsky 1985) which includes domestic value-added instead of labor into the function, whereas value-added is determined by a Cobb-Douglas-function, incorporating labor and capital. Extensions like this however do not contribute further to our analysis.

8 See (Lambsdorff 1994, 28–29).

9 Since raw materials are denominated in dollars, for countries other than the USA there has to be the exchange rate considered, see (Bhandari 1981, 335–336), (Bhan-

(4) $$\mu\alpha_3 \frac{Q^{1+\frac{\rho}{\mu}}}{K^{1+\rho}} = \frac{P_K}{P} \ .$$

Apparently, factor inputs in relation to overall production are negatively associated with the relative factor prices. In order to smoothly incorporate the supply side into demand side conditions, we impose the extreme assumption that physical capital is fully depreciated in the course of the production process. This can be justified by assuming the relevant period to be sufficiently long. Certainly, this restriction appears to be rather strong. However, it must be valued against the standard short-term macroeconomic assumption of a constant capital stock. Such a model would not allow substitution between capital and raw materials and thus neglect potentially important effects of raw materials price changes. At the same time, our results can largely be reproduced under the assumption of a constant capital stock.[10] Thus, while our results are also valid in the short-term with a constant capital stock, the incorporation of substitution possibilities makes our model more fruitful for our special purpose.

Since only one product is produced, the price of the physical capital equals that of the commodity ($Q$). However, we assume that producers' liquidity constraints force them to finance the capital stock via the capital market and that the acquisition of capital takes place one period in advance of production. With a price level in period t, $P_t$, and an interest rate, $i_t$, the real costs of capital in period 0 are: $\frac{P_{K,0}}{P_0} = (1 + i_{-1}) \frac{P_{-1}}{P_0} = (1 + i_{-1})(1 - \pi_0)$, with $\pi_t = \frac{P_t - P_{t-1}}{P_t}$ being the rate of inflation with respect to the current price level. Determining the optimal level of physical capital in period 1, the producers will form expectations concerning the inflation rate, denoted by an asterisk. Assuming zero inflation at the outset this implies for period 1: $d\left(\frac{P_K}{P}\right) = di - (1 + i_0)d\pi^*$. Note, that this notation introduces a dynamic element into our static analysis: Changes of the price level in period 1 will affect the real costs of capital. However, this dynamic element is exogenous to our static model.

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dari and Turnovsky 1984, 156), (Jarchow 1992, 2) and (Wohltmann 1993, 558). However, given assumptions of symmetry for the industrial countries, the exchange rate does not react to raw materials price changes and can be omitted in the equation. The opposite opinion was expressed in (Bhandari 1981, 346). But embedded into a two or three country model, his conclusion proves to be wrong, see (Wohltmann 1993, 24) and (Lambsdorff 1994, 60).

[10] Introducing the standard assumption that long-term considerations determine capital demand, all other functions remain the same. It can easily be seen that the crucial results remain unaffected.

Dividing (2) and (4) by (3), we obtain the ratio between the input factors:

$$N = \left(\frac{\alpha_1}{\alpha_2}\frac{P_R}{W}\right)^{\sigma} R \tag{5}$$

$$K = \left(\frac{\alpha_3}{\alpha_2}\frac{P_R}{P_K}\right)^{\sigma} R\,. \tag{6}$$

According to the appendix, the inital values for the factor supplies are given by $N_0 = \mu^{\sigma}\alpha_1^{\sigma}Q_0^{\sigma+\frac{1-\sigma}{\mu}}$, $R_0 = \mu^{\sigma}\alpha_2^{\sigma}Q_0^{\sigma+\frac{1-\sigma}{\mu}}$, $K_0 = \mu^{\sigma}\alpha_3^{\sigma}Q_0^{\sigma+\frac{1-\sigma}{\mu}}$, and we obtain the supply function:

$$(1-\mu)dQ = -N_0(dW - dP) - R_0(dP_R - dP) - K_0(di - (1+i_0)d\pi^*)\,.^{11} \tag{7}$$

Not surprisingly, the supplied quantity of the commodity depends negatively on real factor prices. The higher the returns to scale ($\mu$) the stronger the reaction of the production level. Solving (4) for $K$ and taking the total differential, we obtain:

$$dK = -\sigma\mu^{\sigma}\alpha_3^{\sigma}Q^{\sigma+\frac{1-\sigma}{\mu}}(1+i_0)^{-\sigma-1}d(P_K/P) + \mu^{\sigma}\alpha_3^{\sigma}(1+i_0)^{-\sigma}\left(\sigma+\frac{1-\sigma}{\mu}\right)Q_0^{\sigma+\frac{1-\sigma}{\mu}-1}dQ\,.$$

Inserting for $K_0$, this yields:

$$dK = -\gamma(di - (1+i_0)d\pi^*) + b\,dQ \qquad \text{with} \tag{8}$$

$$\gamma = \frac{\sigma K_0}{1+i_0}, \quad b = \frac{K_0}{Q_0}\left(\sigma + \frac{1-\sigma}{\mu}\right).$$

Note here, that a rise of the real raw materials price $\left(\frac{P_R}{P}\right)$ negatively affects the production level. Irrespective of the precise value of the elasticity of substitution we therefore obtain a negative impact on the level of the capital stock. Apart from this effect via the production level there is no direct cross-price effect between raw materials prices and the capital stock. Surely, substitution possibilities will affect the *ratio* between raw materials and capital according to (6). But, given a production level Q, rising raw materials prices reduce $R$ to such an amount, that $K$ remains constant. Therefore, (Tatom 1991, 7) is simply wrong when he states that if „the elasticity of substitution between energy and some other resources is positive, a rise in

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[11] Comparable results can be found in (Bruno and Sachs 1979), (Bhandari and Turnovsky 1984, 173), (Nandakumar 1988) and (Wohltmann 1993). Similar results can be obtained using a Cobb-Douglas production function, see (Jarchow 1992, 3).

the price of energy raises the employment of the other resource." Since the CES-production function does not bring about a direct cross-price effect, we are forced to delete this influence from our analysis.[12] While this effect was not obtained, equation (8) contains the scale effect on investments and will allow for the analysis of the inflation expectations effect.

### 3.2. The Demand Side

Equilibrium on the commodity market is given if production ($Q$) equals world demand:

$$Q = C_i(Y_i) + C_r(Y_r) + K + G.$$

The total differential is:

$$dQ = c_i dY_i + c_r dY_r + dK + dG,$$

$$\text{with} \quad c_i = \frac{\partial C_i}{\partial Y_i},\ c_r = \frac{\partial C_r}{\partial Y_r}\ .$$

The consumption of the industrial countries ($C_i$) is supposed to be determined by the industrial countries' gross domestic product ($Y_i$).[13] Similarly, the consumption of the raw materials exporters ($C_r$) is determined by their income level ($Y_r$). Raw materials exporters are assumed not to own facilities for producing the commodity. Thus, their consumption ($C_r$) can only be satisfied by importing industrial products. Overall government expenditure by industrial countries is given by $G$.

$K$ refers to industrial countries' investments. In order to make the endogenous capital stock manageable we introduced the crucial assumption that the period is long enough for full depreciation of the capital stock. Therefore, capital demand and the capital stock ($K$) are identical and the capital demand function is determined by equation (8). The intra-industrial trade of commodities is not considered in this model, since all trade relations are canceled out by aggregation. This simplifies the model as compared to sin-

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[12] Note in passing that a positive cross-price elasticity between raw materials prices and physical capital would increase capital demand in response to rising raw materials prices. Our proposition, i.e. that rising raw materials prices bring about an excess demand in the capital market, would be further supported by this line of argument. However, a negative cross-price-elasticity would imply the opposite.

[13] Gross domestic product $Y_i$ equals the real domestic factor incomes (labor, capital and profit incomes), gross of depreciation. This follows from the profit function $H = PQ - WN - P_R R - P_K K \Rightarrow Q - R\frac{P_R}{P} = Y_i = HP + N\frac{W}{P} + K\frac{P_K}{P}$.

gle country models.[14] The real income of the raw materials exporters is given by $Y_r = \frac{P_R}{P} R$. Solving (3) for $R$ and inserting this, we obtain:

$$(1) \qquad Y_r = \left(\frac{P_R}{P}\right)^{1-\sigma} \mu^{\sigma} \alpha_2^{\sigma} Q^{\sigma + \frac{1-\sigma}{\mu}}.^{15}$$

By definition, industrial gross production corresponds to the sum of the income of industrial countries and the value of factor imports: $Q = Y_i + \frac{P_R}{P} R = Y_i + Y_r$, yielding $dY_i = dQ - dY_r$. Taking this into account and inserting (8), we can rewrite the demand side:

$$(10) \qquad dQ = (c_i + b)dQ - (c_i - c_r)dY_r - \gamma(di - (1 + i_0)\pi^*) + dG.$$

Usually it is argued that raw materials price increases have a negative effect on demand in the commodity market.[16] Referring to equations (10) and (9) we can now investigate this. At first, the elasticity of substitution has to be smaller than unity, since only in this case there is a positive reaction of the income of raw materials exporters to increases of the raw materials price, as shown in function (9).[17] Second, the commodity demand can increase or decrease, depending on the marginal propensities to consume in the industrial and raw materials exporting countries. A decrease is obtained only, if the marginal rate of consumption of the raw materials exporters is lower than that of the industrialized countries.[18] Particularly this last assumption is questionable.[19] Without sound evidence to the contrary we

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14 See (Bhandari 1981), (Bhandari and Turnovsky 1984) and (Jarchow 1992). It has been proposed by (Hickman 1987, 140) that a demand shift may also result from recessive developments in non-OPEC countries. Surely, such an argument has to be analyzed within a broader model. The aggregation of all industrial countries is the simplest form to disprove this idea

15 Compare this to (Bruno and Sachs 1985, 90). With the exception of (Bhandari and Turnovsky 1984, 155 – 156), and (Wohltmann 1993) only few investigations make the effort to consistently translate supply side conditions into the demand side, as is presented here. Necessarily, the elasticity of substitution between raw materials and the domestic input factor will affect the demand side.

16 E.g. this is stated by (Hamilton 1996), (Hamilton 1988), (Tatom 1991, 3), (Hutchison 1991, 8 – 9) and (Herberg et al. 1982, 113).

17 The assumption of a low elasticity of substitution is agreed upon by most analysts. E.g. (Findlay and Rodriguez 1977, 209) proceed as far as assuming the elasticity to be zero and make use of a limitational production function. Still there is evidence for substitution possibilities. But (Bhandari 1982, 164) and (Herberg et al 1982, 112) point out that these possibilities are rather small.

18 The rational behind this goes as follows: Rising raw materials prices raise the expenditures for imported raw materials, given the elasticity of substitution to be rather small. This shifts income from the industrial countries to the raw materials exporters. If these have a lower marginal rate of consumption, aggregate consumption declines.

19 Some arguments with respect to the short term had been put forward in (Hickman 1987, 139) who argues that the decline in domestic expenditures may not be im-

should restrict ourselves to assume the same marginal rate of consumption for both regions – just as it is standard to assume the same marginal propensities to consume for different sources of income (labor, capital and profit). At least, any theory which disapproves with this approach should provide clear evidence why certain regions in the world are likely to behave differently. Assuming $c = c_i = c_r$ it becomes evident that the shifting income does not result in an income shift effect on the commodity market as described before. Rather, the decreasing domestic demand is offset by rising exports of the commodity to the owners of raw materials. This brings about the simple demand function:

$$dQ = (c+b)dQ - \gamma(di - (1+i_0)d\pi^*) + dG\,. \tag{11}$$

We impose the standard macroeconomic assumption that absorption is smaller than one: $1 - b - c > 0$. As opposed to (Phelps 1978, 210), (Gordon 1975), (Wilcox 1983), (Hickman 1987, 138) and (Herberg et al. 1982, 113) raw materials price changes leave the IS-curve unaffected.[20]

### 3.3. Theoretical Conclusions

Before analyzing the effects of raw materials price changes, the model has to be completed by adding the money market and the labor market. Labor is an input factor to the production of the commodity. The nominal wage ($W$) is assumed to be determined according to the following wage rule:

$$W = (1-\tau) + \tau P, \quad 0 \leq \tau \leq 1.$$

Depending on $\tau$, the model allows for different degrees of wage rigidity. Nominal wage rigidity is indicated by $\tau = 0$, whereas real wage rigidity is given by $\tau = 1$. This approach guarantees the robustness of our results to different macroeconomic parameters. Also, an impact of production ($Q$) on the wage level can be incorporated into the model without affecting the results.

mediately offset by the respending of the augmented OPEC proceeds on exports. According to (Hutchison 1991, 13) the OPEC needed 4 years following the 1973-74 oil price hike and 2 years after 1978-80 to return to a balanced current account. Particularly when focusing on the longer term, the assumption of asymmetric rates of consumption appear implausible. For further empirical evidence see (Fabritius and Petersen 1981) and (Lambsdorff 1994, 78 – 80).

20 Observe that with a level of tax revenues given by $T$ the demand side implies $S_{pr} = K + BD$, i.e. gross world private savings to equal gross private investments plus the government deficit ($BD = G - T$). Full depreciation of the equilibrium (private) capital stock implies net investments to be zero and net private savings to equal the government deficit.

For the sake of simplicity we left out this aspect. The total differential of the labor supply is:

$$(12) \qquad dW = \tau dP.$$

The money market, i.e. the market for liquidity in the industrial countries, is represented by:

$$\frac{M}{P} = kQ - li.$$

This presupposes that the demand for money is determined by the total gross production ($Q$) and not only by the industrial countries income ($Y_i$).[21] This seems to be reasonable since liquidity is necessary for all turnovers on the commodity market and likewise all incomes resulting from the production of $Q$.[22] We apply the typical assumption that the cost of liquidity is determined by the nominal rather than the real interest rate. The money supply is determined exogenously. The initial money supply and the price level are standardized to 1.[23] The total differential of the money market with a constant money supply is:

$$(13) \qquad dM - dP = kdQ - ldi.$$

We further assume raw materials prices to be fixed exogenously. To be realistic here, we acknowledge that they may not only be determined exogenously but also react, for example, to world demand. Incorporating such a feed-back effect into this model would somewhat dampen the impact of exogenous shifts of the raw materials prices. Yet, the crucial results remain unaffected and for the sake of simplicity we omitted this aspect.

The four equations for the supply side (7), the labor market (12), the money market (13) and the demand side (11) are now matched by the four endogenous variables $dQ, dP, di$ and $dW$. The total system of equations can be rewritten in matrix form:

$$\begin{bmatrix} 1-\mu & -N_0 - R_0 & K_0 & N_0 \\ 0 & -\tau & 0 & 1 \\ k & 1 & -l & 0 \\ 1-c-b & 0 & \gamma & 0 \end{bmatrix} \begin{bmatrix} dQ \\ dP \\ di \\ dW \end{bmatrix} = \begin{bmatrix} -R_0 dP_R + K_0(1+i_0)d\pi^* \\ 0 \\ dM \\ dG + \gamma(1+i_0)d\pi^* \end{bmatrix}.$$

21 This approach dominates in the literature except for (Findlay and Rodriguez 1977, 152).

22 This assumes raw materials to be paid in the currency of the industrial countries.

23 The standardization does not restrict the model to specific economic situations. For an illustration see (Lambsdorff 1994, 21 and 143).

The determinant is:

$$D = (1-\mu)\gamma + (N_0 + R_0)[\gamma k + l(1-c-b)] - K_0(1-c-b) - N_0\tau[\gamma k - l(1-c-b)]$$

$$= (1-\mu)\gamma - K_0(1-c-b) + (N_0(1-\tau) + R_0)[\gamma k + l(1-c-b)].$$

We require for stability purposes $\frac{1-\mu}{K_0} > \frac{1-c-b}{\gamma}$. This correlates to the standard assumption that the interest rate affects the demand side to a higher degree than the supply side, with the latter impact often assumed to be zero in macroeconomic analysis.[24]Therefore, the determinant is positive. Applying Cramer's rule, we obtain:

$$di = \underbrace{\frac{R_0(1-c-b)}{D}}_{>0} dP_R + \underbrace{\frac{-(N_0(1-\tau) + R_0)(1-c-b)}{D}}_{<0} dM$$

$$+ \underbrace{\frac{1 + k(N_0(1-\tau) + R_0)}{D}}_{>0} dG + \underbrace{\frac{\gamma - K_0(1-c-b) + \gamma k(N_0(1-\tau) + R_0)}{D}}_{>0;\,<1}(1 + i_0)d\pi^*.$$

Since raw materials are an input to the production of the industrial product, raw materials price increases lead to rising production costs. This lowers production, resulting in an excess demand on the commodity market. In response to this, the commodity price will rise and the nominal wage will be adjusted according to the wage rule. Given a fixed nominal money supply, the rising price level brings about an excess demand in the money market and the interest rate will increase. This increase will finally lower aggregate investment, bringing about equilibrium in the commodity market.

Equilibrium in the commodity market also implies equilibrium in the capital market, since the demand for capital corresponds to the demand for investments in the commodity market. On the other hand, the supply of capital corresponds to savings, i.e. the difference between income and consumption.[25] Total real income is determined by the income of the industrial countries ($Y_i$) plus the income of the raw materials exporters $\left(\frac{P_R}{P}R\right)$. Savings therefore amount to: $S = Y_i + \frac{P_R}{P}R - C_i - C_r$, and with $Q = Y_i + \frac{P_R}{P}R$ we obtain $dS = (1-c)dQ$. Apparently, savings are only determined by the

24 Inserting for $\gamma$ this yields $\sigma\frac{1-\mu}{1+i_0} > (1-c-b)$. With $\sigma$ decreasing and $\mu$ and $(1-c-b)$ rising this may be violated. In that case the negative slope of the IS-curve, which is standard to macroeconomic analysis, is not obtained. This result points to another fruitful contribution of this model: macroeconomic stability cannot be obtained if constant returns to scale, an elasticity of substitution close to zero or very high nominal interst rates are given.

25 Taxes are assumed to be fixed and not further considered here.

production level. Hence, a decreasing production level lowers overall savings (scale effect on savings). This finding contrasts to the aforementioned arguments of a direct impact of raw materials prices on the IS-curve.

On the other hand, investments are lowered also by the decreasing production level, which corresponds to a decrease of the demand for capital by $bQ$ (scale effect on investments). Yet, since $b < 1 - c$ this effect is smaller than the decrease of savings. The assumption $b < 1 - c$ may appear ad hoc at this stage but should be valued against the fact that with $b$ approaching $1 - c$ the demand side multiplier approaches infinity, i.e. an autonomous increase of demand brings about an unrealistic infinite demand side expansion. The assumption thus follows standard Keynesian modeling and is even more general than most models which assume $b$ to be zero.

Thus, our findings show that the scale effect on savings dominates the scale effect on investments. Concerning an income-shift effect, we can argue according to subsection 3.2. Increasing earnings of the raw materials exporters – which are only obtained with an elasticity of substitution below unity – will increase their savings. Still this increasing income matches with a decreasing income of the industrial countries. An increase of the propensity to save can be obtained only if raw materials exporters have a higher marginal rate of savings than the industrial countries – an assumption which can be doubted for good reasons.

The model has been formulated to determine an equilibrium in period 1. This implies expectations of inflation to be zero. However, the rise in the price level may be assumed to continue in the future. A rational for this may be that expansionary fiscal and monetary policies are expected, imposed to counter the recession. Expectations of inflation may also persist if the adjustment process is not completed in period 1. E.g. we may assume the adjustment of wages to be incomplete, i.e. $\tau$ to be small initially and to increase in period 2. We incorporated this inflation expectations effect by exogenously considering the influence of expected inflation. Nominal interest rates turn out to be positively dependent on expected inflation.[26] The existence of this effect will certainly depend on the goals and credibility of existing institutions and the speed of the adjustment process. Insofar, we do not provide unambiguous evidence that this effect exists. But, by including this effect separately into our model we show that the positive correlation between raw materials prices and interest rates arises as a result of a permanent excess demand in the capital market, independent of potential dynamic elements.

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26 The Fisher-effect proposes the influence of expected inflation on the nominal interest rate to be equal to one. The effect obtained here is smaller, since liquidity preference is determined by the nominal interest rate.

The proposition derived from our theoretical considerations is that nominal interest rates will react positively to raw materials price increases, indicating excess demand in the capital market.

## 4. Conclusion

Making use of a CES-production function which incorporates labor, capital and raw materials, we presented a model for the world economy. Particular emphasis has been put to consistently formulating the demand side of the world economy and including an endogenous capital stock. This model allowed for an investigation of different influences of raw materials prices on the international capital market. It turned out that a rise of the raw materials price brings about an excess demand in the international capital market, since a scale effect on savings dominates a scale effect on investment. This may be strengthened temporarily by an inflation expectations effect, whereas a direct cross-price effect has not been obtained. Only as special assumptions are introduced, a countervailing impulse may exist: If raw materials can only imperfectly be substituted *and* raw materials exporters have a higher marginal rate of savings than the industrial countries we obtain an income-shift effect which increases savings. There is no convincing evidence for the existence of such an effect.

Hence, the fact that banks were highly in search for debtors after the big oil price shocks does not imply excess savings at that time. Instead, the international decrease of savings was accompanied by a shift of savings to the raw materials exporters. The search for debtors merely reflects the institutional adjustment which accompanied the shift and the necessary *"financial recycling"*.

One consequence of these findings concerns central bank policies. In case of interest rate targeting, rising raw materials prices – which bring about a rise in the interest rate – force for an upward adjustment of the money supply. Such a monetary policy raises the commodities price level and production. At the same time, rising raw materials prices increase the commodities price level and lower production. Taking together these two effects, interest rate targeting stabilizes the effect on production but worsens fluctuations of the price level. Using an interest rate target therefore is particularly recommendable if the central bank prefers price variation to output variation.[27] Crucial to this consequence has been our result that an increase in

[27] This is not to say that interest rate targeting is always a superior measure for stabilizing output. As was shown already by (Poole 1970) in a model with constant prices the effects of instability in the monetary sector are better smoothed by fixing the interest rate, while fixing the money stock is preferable in case of demand side fluctuations.

raw materials prices – which is often noted as a typical supply shock for macroeconomic analysis – is not ambiguous in its effect on the interest rate but clearly brings about an increase of this variable.

## 5. Appendix

From (1) we obtain:

$$Q^{-\frac{\rho}{\mu}} = \alpha_1 N^{-\rho} + \alpha_2 R^{-\rho} + \alpha_3 K^{-\rho} .$$

Inserting (5) and (6), this yields:

$$Q^{-\frac{\rho}{\mu}} = \left[\alpha_1 \left(\frac{\alpha_1}{\alpha_2}\frac{P_R}{W}\right)^{-\sigma\rho} R^{-\rho} + \alpha_2 R^{-\rho} + \alpha_3 \left(\frac{\alpha_3}{\alpha_2}\frac{P_R}{P_K}\right)^{-\sigma\rho} R^{-\rho}\right].$$

Since $\sigma\rho = 1 - \sigma$, this yields:

$$Q^{-\frac{\rho}{\mu}} = \left[\alpha_1^{\sigma} W^{1-\sigma} P^{\sigma-1} + \alpha_2^{\sigma} P_R^{1-\sigma} P^{\sigma-1} + \alpha_3^{\sigma} P_K^{1-\sigma} P^{\sigma-1}\right] \alpha_2^{1-\sigma} P_R^{\sigma-1} P^{1-\sigma} R^{-\rho} .$$

Since $-\rho = \frac{1-\sigma}{\sigma}$ it follows:

(14) $$PQ^{\frac{1}{\mu}} = \left[\alpha_1^{\sigma} W^{1-\sigma} P^{\sigma-1} + \alpha_2^{\sigma} P_R^{1-\sigma} P^{\sigma-1} + \alpha_3^{\sigma} P_K^{1-\sigma} P^{\sigma-1}\right]^{-\frac{1}{\rho}} \alpha_2^{-\sigma} P_R^{\sigma} P^{1-\sigma} R .$$

This equation relates $R$ and $Q$, given optimal ratios of the input factors. Inserting (5) and (6) into the profit function, $H = PQ - WN - P_R R - P_K K$, we obtain:

$$H = PQ - \left[W \left(\frac{\alpha_1}{\alpha_2}\frac{P_R}{W}\right)^{\sigma} + P_R + P_K \left(\frac{\alpha_3}{\alpha_2}\frac{P_R}{P_K}\right)^{\sigma}\right] R$$

$$= PQ - \left[\alpha_1^{\sigma} W^{1-\sigma} P^{\sigma-1} + \alpha_2^{\sigma} P_R^{1-\sigma} P^{\sigma-1} + \alpha_3^{\sigma} P_K^{1-\sigma} P^{\sigma-1}\right] \alpha_2^{-\sigma} P_R^{\sigma} P^{1-\sigma} R .$$

Solving (14) for $\alpha_2^{-\sigma} P_R^{\sigma} P^{1-\sigma} R$ and inserting this, we obtain:

$$H = PQ - \left[\alpha_1^{\sigma} W^{1-\sigma} P^{\sigma-1} + \alpha_2^{\sigma} P_R^{1-\sigma} P^{\sigma-1} + \alpha_3^{\sigma} P_K^{1-\sigma} P^{\sigma-1}\right]^{1+\frac{1}{\rho}} PQ^{\frac{1}{\mu}} ,$$

and profit maximization yields:

$$\frac{dH}{dQ} = P - \frac{1}{\mu}\left[\alpha_1^{\sigma} W^{1-\sigma} P^{\sigma-1} + \alpha_2^{\sigma} P_R^{1-\sigma} P^{\sigma-1} + \alpha_3^{\sigma} P_K^{1-\sigma} P^{\sigma-1}\right]^{1+\frac{1}{\rho}} PQ_0^{\frac{1}{\mu}-1} = 0 .$$

Since $\sigma - 1 = -\frac{1}{1+(1/\rho)}$, we rewrite:

$$\mu^{\sigma-1}\left[\alpha_1^\sigma W^{1-\sigma}P^{\sigma-1} + \alpha_2^\sigma P_R^{1-\sigma}P^{\sigma-1} + \alpha_3^\sigma P_K^{1-\sigma}P^{\sigma-1}\right] = Q^{\left(\frac{1}{\mu}-1\right)(\sigma-1)}. \tag{15}$$

Assuming $P, W, P_R$ and also $P_{-1}$ to be 1 at the outset, the real factor prices amount to $\frac{W_0}{P_0} = \frac{P_{R,0}}{P_0} = 1$ and $\frac{P_{K,0}}{P_0} = 1 + i$. Approximating (15) by taking the total differential, we obtain:[28]

$$\left(\frac{1}{\mu} - 1\right)(\sigma - 1)Q_0^{\left(\frac{1}{\mu}-1\right)\sigma - \frac{1}{\mu}}dQ =$$

$$\mu^{\sigma-1}\left[\alpha_1^\sigma(1-\sigma)(dW - dP) + \alpha_2^\sigma(1-\sigma)(dP_R - dP) + \alpha_3^\sigma(1-\sigma)(1+i)^{-\sigma}d(P_K/P)\right].$$

According to (2), (3) and (4) the initial values for labor, raw materials and capital are $N_0 = \mu^\sigma \alpha_1^\sigma Q_0^{\sigma + \frac{1-\sigma}{\mu}}$, $R_0 = \mu^\sigma \alpha_2^\sigma Q_0^{\sigma + \frac{1-\sigma}{\mu}}$, $K_0 = \mu^\sigma \alpha_3^\sigma Q_0^{\sigma + \frac{1-\sigma}{\mu}}$. Considering this in addition to $d(P_K/P) = di - (1 + i_0)\pi^*$, the supply function is:

$$(1-\mu)dQ = -N_0(dW - dP) - R_0(dP_R - dP) - K_0(di - (1+i_0)d\pi^*). \tag{16}$$

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[28] Typically, the first-order approximation is conducted by log-linearizing and a first-order Taylor approximation, see (Bhandari 1981), (Bhandari 1982, 271–272), and (Bhandari and Turnovsky 1984, 155). Making use of a total differential leaves the results unaffected.

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## Zusammenfassung

Bei dem Versuch, den Zusammenhang zwischen Rohstoffpreisen und dem (nominalen) Zinsniveau zu beleuchten, wird die Vielfalt der Einflüsse von Rohstoffpreisen auf die Wirtschaft untersucht anhand eines Keynesianischen Modells, welches einen endogenen Kapitalstock, Vorprodukte und eine CES-Produktionsfunktion berücksichtigt. Im Gegensatz zu uneindeutigen Resultaten der bisherigen Literatur erlaubt dieser Ansatz, einen positiven Zusammenhang zwischen Zinsniveau und Rohstoffpreisen nachzuweisen. Eine Schlußfolgerung hieraus ist, daß Zentralbanken eine Zinsfixierungspolitik dann betreiben sollten, wenn eine Stabilisierung des Sozialprodukts gegenüber einer Stabilisierung des Preisniveaus bevorzugt wird.

## Abstract

In an attempt to shed light on the relationship between raw materials prices and (nominal) interest rates the multitude of effects of raw materials price shifts on the economy are analyzed with the help of a Keynesian macroeconomic model, incorporating an endogenous capital stock, intermediate imports and a CES-production function. In contrast to ambiguous results to be found in the literature this allows us to argue in favor of a positive impact of raw materials prices on the interest rate. A conclusion is that a central bank should target the interest rate in case output stability is preferred over price stability.

*Keywords: Raw materials; Capital stock; CES-production function; Cross-price-elasticity; Savings; Investments; Supply shocks; Interest rate targeting.*

*JEL-Klassifikation: F40, E52*