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Dynamic Effects of Raw Materials Price Shocks for Large Oil-Dependent Economies

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Abstract

The paper analyzes the dynamic effects of anticipated price increases of imported raw materials upon two large open economies. It is assumed that the economies have an asymmetric macroeconomic structure on the supply side and are dependent upon a small third country for oil or raw materials imports. The dynamic behavior of several macroeconomic variables is discussed under alternative scenarios. We first assume that oil is priced in dollars. Thereafter, we investigate the impacts of oil price shocks on the domestic and the foreign economy if oil imports are denominated in terms of domestic currency (Euro) rather than US dollars. It is shown that with domestic-currency denominated oil the stagflationary effects of oil price increases upon both the domestic and foreign economy are reduced. The paper also discusses several monetary policy responses to oil price shocks.

JEL classification: E63, F41, Q43
Keywords: oil price shocks, international policy coordination, time inconsistency, currency denomination

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1 Introduction

This paper deals with the macroeconomics of oil price shocks[1] and analyzes the dynamic effects of anticipated price increases of raw materials imports upon two large open economies. It is assumed that the domestic and the foreign economy are symmetric on the demand side but have an asymmetric macroeconomic structure on the supply side. For the production of their respective final good imported inputs are necessary. Both economies are dependent upon a small third country for raw materials imports (like crude oil). We can identify the small oil-exporting country with the OPEC nations and the domestic and the foreign economy with the European Monetary Union and the USA respectively. It is assumed that the dependency upon oil imports is stronger for the domestic than the foreign economy and that oil imports are priced in terms of the foreign currency (dollars). We then discuss the dynamic effects of anticipated oil price shocks upon several domestic and foreign macroeconomic variables like real output, inflation rate, real interest rate and terms of trade. The theoretical analysis is motivated by the substantial increase in oil prices in recent years.[2] The discussion is based on a macrodynamic model of two large open oil-dependent economies. The model stands in the Mundell/Fleming/Dornbusch/Phillips tradition and generalizes similar models of Bhandari (1981) and Turnovsky (1986) to the case of large oil-dependent economies. The paper first analyzes the dynamic effects of oil price shocks, if raw materials imports are denominated in terms of the foreign currency. We then investigate the impacts of such price increases under alternative currency denomination of oil imports. It is shown that the decision of the OPEC nations to denominate their oil exports in terms of Euro rather than US dollars reduces the stagflationary effects of oil price increases upon both the domestic and foreign economy. Besides the discussion of the two polar cases of either foreign- or domestic-currency denominated oil the paper also analyzes a combination of these cases where a fixed proportion of raw materials imports is priced in dollars while the rest is denominated in terms of Euro.

The paper also investigates the consequences of alternative degrees of wage indexation. It is analyzed to what extent the dynamic effects of oil price shocks depend upon the wage adjustment scheme in the domestic and the foreign economy. We also discuss the effects of various monetary policy rules that could be employed by the domestic and the foreign economy in an effort to reduce or neutralize the potentially disruptive effects of oil price shocks. In what follows we use the terms oil imports and raw materials imports interchangeably. The implications of this paper go well beyond the role of imported raw materials in an open economy. In fact, it can also be applied to all intermediate goods produced and used for domestic production.

The paper is organized as follows: Section 2 describes the dynamic model of two large oil-dependent economies. Section 3 analyzes the dynamic effects of anticipated oil price

[1] An overview is given in Jones, Leiby and Paik (2004).

[2] The average monthly US dollar price of crude oil (simple average of Dubai, Brent and WTI) has risen from a low of 10.41 per barrel in December 1998 to a peak of 32.33 per barrel in November 2000. Meanwhile, the price has fallen to a low of 18.52 US$/bbl in December 2001, to start rising afterwards to an all-time high of 46.87 US$/bbl in October 2004 (cf. IMF (2004)).

increases. It is assumed that for both countries oil imports are denominated in terms of the foreign currency (US dollars). In section 4 the case of domestic-currency denominated oil is discussed. We analyze the question whether both economies can be better insulated against oil price shocks if the currency denomination of international raw materials trade changes from US dollars to Euro. Section 4 also considers a combination of theses two polar cases. It is assumed that oil imports are denominated in terms of a fixed weight basket of the domestic and foreign currency. Section 5 discusses the consequences of alternative degrees of wage indexation while section 6 analyzes various monetary policy responses to oil price shocks. In particular the problem is analyzed whether an international coordination of monetary policy is able to avoid adjustment dynamics of all endogenous variables, i.e. to stabilize the macroeconomic variables at their respective steady state level. Section 7 summarizes the main results. At the end the paper includes an extensive mathematical appendix, where the analytical solution to the dynamic macroeconomic model is presented.

2 The Model

We consider two large open economies which are of equal size in the initial steady state. Both countries use imported oil from a third small country for the production of their respective domestic outputs. The following notation is employed: Dots denote time derivatives and overbars indicate steady state values. All variables – except for the interest rates i and i^* – are logarithmized. Variables with a $*$ describe foreign variables while variables without $*$ stand for domestic variables. The model is described by the following set of equations:

$$q = (a_0 + a_1 y - a_2(i - \dot{p}^c)) + g + (c_0 - c_1 y + c_2 y^* - c_3 \tau) \tag{1}$$

$$q^* = (a_0 + a_1 y^* - a_2(i^* - \dot{p}^{*c})) + g^* - (c_0 - c_1 y + c_2 y^* - c_3 \tau) \tag{2}$$

$$\tau = p - (p^* + e) \tag{3}$$

$$m - p^c = l_0 + l_1 q - l_2 i \tag{4}$$

$$m^* - p^{*c} = l_0 + l_1 q^* - l_2 i^* \tag{5}$$

$$i = i^* + \dot{e} \tag{6}$$

$$p^c = \alpha p + (1-\alpha)(p^* + e) \qquad (0.5 < \alpha < 1) \tag{7}$$

$$p^{*c} = \alpha^* p^* + (1-\alpha^*)(p - e) \qquad (0.5 < \alpha^* < 1) \tag{8}$$

$$y = q - \psi(p_R^* + e - p) - d_0 \tag{9}$$

$$y^* = q^* - \psi^*(p_R^* - p^*) - d_0 \tag{10}$$

$$\dot{p} = \mu \dot{w} + (1-\mu)(\dot{p}_R^* + \dot{e}) \qquad (0 < \mu < 1) \tag{11}$$

$$\dot{p}^* = \mu^* \dot{w}^* + (1-\mu^*)\dot{p}_R^* \qquad (0 < \mu^* < 1) \tag{12}$$

$$\dot{w} = \pi + \delta(q - \overline{q}) \tag{13}$$

$$\dot{w}^* = \pi^* + \delta^*(q^* - \overline{q}^*) \tag{14}$$

$$\pi = \beta \dot{m} + (1-\beta)\dot{p}^c \qquad (0 \leq \beta \leq 1) \tag{15}$$

$$\pi^* = \beta^* \dot{m}^* + (1-\beta^*)\dot{p}^{*c} \qquad (0 \leq \beta^* \leq 1) \tag{16}$$

$$\overline{q} = f_0 + f_1\overline{\tau} + f_2(\overline{p - (p_R^* + e)}) \tag{17}$$

$$\overline{q}^* = f_0^* - f_1^*\overline{\tau} + f_2^*(\overline{p^* - p_R^*}) \tag{18}$$

where q = real output, y = real income, i = nominal interest rate, $i - \dot{p}^c$ = real interest rate, g = real government expenditure, p = domestic price of domestic output, τ = final goods terms of trade, e = nominal exchange rate (domestic currency price of foreign currency), m = nominal money stock, w = nominal wage rate, p^c = consumer price index, π = augmentation term in the Phillips curve, p_R^* = US dollar price of imported raw materials or other intermediate goods, $p - (p_R^* + e)$ = intermediate goods terms of trade, $p_R^* + e - p$ = real factor price of imported intermediate goods; a_0, c_0, d_0, l_0, f_0, f_0^* = autonomous shift terms; a_1, a_2, c_1, c_2, c_3, l_1, l_2, ψ, ψ^*, δ, δ^*, f_1, f_1^*, f_2, f_2^* = positive model parameters (which can be interpreted as elasticities or semi-elasticities).

Equations (1) and (2) are IS equations and describe goods market equilibrium in the respective economy. This requires real output to be equal to the sum of real private absorption (first expression in brackets), real government expenditure and the difference between real exports and imports of final goods (second expression in brackets). Real private absorption is assumed to depend positively on income and negatively upon the real interest rate.[3] As in Turnovsky (1986) the real interest rate is computed using the inflation rate based on the (rationally anticipated) consumer price index. International trade in final goods (trade balance without imports of raw materials) depends upon domestic and foreign income and the final goods terms of trade (defined in (3)). The IS equations are assumed symmetric so that in the trade balance $c_1 = c_2$ holds and corresponding effects across the two economies are identical.

Equations (4) and (5) are standard equations and reflect money market equilibrium. Money demand is assumed to depend on real output rather than real income which is considered a more appropriate measure of the volume of transactions. We assume symmetric money demand functions. The nominal money stock is deflated by the consumer price index defined in (7) and (8) respectively to allow for the fact that in open economies money is also used for the purchase of imported goods. Equation (6) is the uncovered interest parity condition and describes perfect substitutability of domestic and foreign bonds. The domestic interest rate may deviate only by the rationally anticipated rate of depreciation $\dot{e}$ from the foreign interest rate.

Equation (9) (and similar (10)) links domestic production with real income or gross national product. The difference between real output and income results from real intermediate imports. Real imports of raw materials (or more generally: intermediate goods)

[3] In discrete time *New Neoclassical New Keynesian synthesis* models, private absorption does not only depend positively on the current income, but also depends positively on past and/or expected future income (see, for example, Fuhrer and Moore (1995), Clarida, Gali and Gertler (1999), King (2000) or McCallum (2001)). In deterministic continuous time models (like ours) private absorption only depends on the current income.

can be expressed in non-logarithmized form as the product of the real price of raw materials ($P_R^* \cdot E/P$) and physical imports R (where capital letters refer to natural variables and imports of raw materials are denominated in terms of the foreign currency). If there is no possibility of substituting labor or capital for oil in the production process there must be a proportional relationship between the quantity R and the level of domestic production Q of the form $R = \kappa Q$ $(0 < \kappa < 1)$. In this case a logarithmic-linear approximation of the relationship between the natural variables Y and Q leads to equation (9) where ψ is of the form $\kappa/(1-\kappa)$ provided that the initial value of the intermediate goods terms of trade $P/(P_R^* \cdot E)$ is normalized to unity. If alternatively a CES production function is assumed which allows for factor substitution between labor and oil, the constant ψ depends on the elasticity of substitution between the factors of production and upon the share of imported inputs in aggregate production (Bhandari and Turnovsky, 1984).[4] An analogue equation holds for the relationship between foreign production and foreign income where the real factor price for oil is now given by $p_R^* - p^*$. If we identify the foreign economy with the USA and the domestic economy with the European Monetary Union (EMU) it is reasonable to assume $\psi > \psi^*$, i.e. that the dependency on oil imports is greater for EMU than for the USA.[5]

The equations (11) and (12) describe price adjustment in the domestic and foreign economy respectively. In both countries the inflation rate is determined by a weighted average of nominal wage inflation and the rate of change of the domestic price of raw materials imports. The corresponding weights μ and $1-\mu$ reflect the average share of wage and raw materials costs respectively in the overall variable costs of a representative firm. The expression $1-\mu$ can be interpreted as a measure of the degree of openness of the domestic economy on the supply side, while the parameter $1-\alpha$ in the price index definition (7) reflects the openness of the domestic economy with respect to the large open *foreign* economy on the demand side (Bhandari and Turnovsky, 1984). We assume $\alpha < \alpha^*$ and $\mu < \mu^*$ so that the domestic economy has a greater degree of openness both on the demand and supply side. The equations (11) and (12) are dynamic versions of mark-up pricing rules which are widely used in applied and theoretical economics (Bhandari, 1981).

Equations (13) and (14) describe the dynamics of wage adjustment which take the form of an augmented Phillips curve (Buiter and Miller, 1982). The augmentation term is according to (15) and (16) a fixed weight linear combination of the trend and core rate of inflation, the first given by the growth rate of money supply and the second by the (rationally anticipated) inflation rate based on the consumer price index.[6] In the special

[4] Now ψ is of the form $(1-\mu)(1-\sigma)/\mu$ where σ is the elasticity of substitution between labor and oil and where μ and $1-\mu$ measure the share of labor and imported inputs in gross output respectively.

[5] In addition to the oil *dependency*, i.e. the ratio of net oil imports to GDP, the oil *intensity*, i.e. the ratio of oil consumption to GDP, is greater for the EMU than for the USA (Anderton, di Mauro and Moneta (2004)). Note that our model assumption regarding the dependency of the two large open economies on imported raw materials produced only by a third small country leads to an identity of these concepts.

[6] The formulation of the inflation dynamics can also be interpreted as a special type of a continuous time hybrid Phillips curve. In a discrete time model, the hybrid Phillips curve formulation allows inflation to depend on expected future and lagged inflation (see, for example, Gali and Gertler (1999)). Instead of a backward-looking element in the hybrid Phillips curve, we model a dependency of the inflation dynamics on the trend inflation rate given by the growth rate of money supply.

case $\beta = 1$ and a given growth rate of money supply the wage adjustment mechanism is consistent with nominal wage rigidity (van der Ploeg, 1990). In the other polar case $\beta = 0$ the growth rate of the real wage rate $\dot{w} - \dot{p}^c$ only depends on the output gap $q - \overline{q}$ so that real wage rigidity occurs if the parameter δ equals zero. We assume asymmetric wage adjustment dynamics across the two large open economies. In the EMU the degree of wage indexation is typically greater than in the USA; we therefore assume $\beta < \beta^*$ (cf. Manasse, 1991, OECD, 2000).

The last two equations (17) and (18) describe long run aggregate supply functions. In the long run, assuming labor market equilibrium where labor demand is a negative function of the producer and labor supply a positive function of the consumer real wage rate and, in addition, assuming a perfectly elastic raw materials supply, output supply depends positively on the final and intermediate goods terms of trade.[7] Since the domestic economy is assumed stronger oil-dependent than the foreign economy the parameter f_2 is typically greater than f_2^*.

In the following we will show that as a result of the assumed asymmetries on the supply side anticipated oil price increases generate adjustment dynamics and steady state effects which differ considerably across the two economies. In particular it will be demonstrated that in the long run the stagflationary effects of oil price shocks are stronger for the domestic than for the foreign economy.

The dynamic behaviour of the complete world system (1)-(18) can be described by a third-order dynamic system. In the case of positive growth rates of domestic and foreign money supply the dynamics of the system can be summarized conveniently in terms of real liquidity and real competitiveness (Buiter and Miller, 1982). According to the decomposition method by Aoki (1981) and its generalization by Fukuda (1993) we use the state variables l^s, l^d and τ, where

$$l^s = (m - p) + (m^* - p^*), \qquad l^d = (m - p) - (m^* - p^*) \tag{19}$$

Both the sum and the difference of domestic and foreign real liquidity are backward-looking or predetermined variables (containing the sluggish price variables p and p^*), while the terms of trade τ is a forward-looking or jump variable which moves discontinuously whenever the nominal exchange rate jumps. Note that the inflation rates $\dot{p}$ and $\dot{p}^*$ are jump variables as well that can adjust instantaneously although the adjustment of wages and prices is sluggish. The state space representation of the model and the solution time path of the state vector $(l^s, l^d, \tau)'$ are provided in the mathematical appendix. In general it is not possible to decompose the dynamics of the whole system into an aggregate and a difference system wich can be solved independently.[8] Nevertheless, the state space form of

[7] A more detailed theoretical derivation of the role of the terms of trade in aggregate supply is given in Devereux and Purvis (1990). The supply equations (17) and (18) can also be derived by assuming long run static price and wage equations of the form $\overline{p} = \mu\overline{w} + (1-\mu)(p_R^* + \overline{e})$, $\overline{p}^* = \mu^*\overline{w}^* + (1-\mu^*)p_R^*$, $\overline{w} = \overline{p}^c + \delta\overline{q}$, $\overline{w}^* = \overline{p}^{*c} + \delta^*\overline{q}^*$. In this case the parameters f_1, f_2, f_1^*, f_2^* are of the form $f_1 = (1-\alpha)/\delta$, $f_2 = (1-\mu)/(\mu\delta)$, $f_1^* = (1-\alpha^*)/\delta^*$, $f_2^* = (1-\mu^*)/(\mu^*\delta^*)$ where $f_2 > f_1$ and $f_2^* > f_1^*$.

[8] This is only the case if the supply side of the world system is symmetric ($\psi = \psi^*$, $\mu = \mu^*$).

the model exhibits saddle point stability. The system matrix has a positive determinant and the number of stable eigenvalues (two) coincides with the number of predetermined state variables (cf. Buiter, 1984, Turnovsky, 2000).[9] In the following we assume that at time $t = 0$ the world economy is in steady state. At time 0 a once-and-for-all increase in the price of imported raw materials ($dp_R^* > 0$) is anticipated to take effect at some future time $T > 0$. For example, we can assume that the OPEC credibly announces in $t = 0$ a permanent price increase of crude oil to happen at the future date $T > 0$. The following chapter discusses the dynamic effects of such an oil price shock upon the EMU and the USA. In particular, the anticipation effects of announced oil price increases are analyzed.

3 Dynamic Effects of an Oil Price Increase

We first consider the *long run* or *steady state* effects of a unit increase in the dollar price of OPEC oil, p_R^*.[10] The steady state effects of this disturbance result from the equilibrium condition $\overline{\dot{\tau}} = 0 = \overline{\dot{l}^s} = \overline{\dot{l}^d}$ for the state space representation of the dynamics of the world system. The equilibrium condition implies that in line with monetarism the long run producer and consumer price inflation as well as the rate of depreciation $\dot{e}$ are only determined by the rate of domestic and foreign monetary growth ($\overline{\dot{p}} = \overline{\dot{p}^c} = \dot{m}$, $\overline{\dot{p}^*} = \overline{\dot{p}^{*c}} = \dot{m}^*$, $\overline{\dot{e}} = \dot{m} - \dot{m}^*$). This implies that an oil price shock of the form $dp_R^* > 0$ can only cause *temporary* inflation in the domestic and foreign economy. On the other hand, a rise in the price of oil leads to a *permanent* change in the level of the state variables τ, l^s and l^d. If we assume that the nominal money stock is constant in both economies ($\dot{m} = \dot{m}^* = 0$) the foreign price shock leads to a permanent increase in domestic producer price level ($d\overline{p} > 0$) which is stronger than the rise in foreign price level ($d\overline{p} > d\overline{p}^*$). This implies that there is a fall both in the steady state level of aggregate real money stock ($d\overline{l}^s < 0$) and the real money stock differential ($d\overline{l}^d < 0$) and a reduction in domestic real money supply which is stronger than the decrease in foreign real money stock ($d(\overline{m - p}) < d(\overline{m^* - p^*})$).[11] Correspondingly, the nominal exchange rate, i.e. the domestic currency price of foreign currency, increases in the long run ($d\overline{e} > 0$). Under the *fairly* weak necessary and sufficient condition

$$(1 - a_1 + 2c_1)(f_2 - f_2^*) > (a_1 - 2c_1)(\psi - \psi^*) \tag{20}$$

the long run rise in the price differential $p - p^*$ is greater than the steady state depreciation of the domestic currency so that the domestic final goods terms of trade $\tau(= p - p^* - e)$

[9] Note that the stable eigenvalues of the system decrease in absolute terms if the degree of supply-side openness (i.e., $1 - \mu$) increases. For very large (empirically irrelevant) values of $1 - \mu$ the number of stable eigenvalues is smaller than the number of predetermined state variables so that the saddle point stability gets lost (cf. Turnovsky (2000), p. 147 (Proposition 5.3)).

[10] The steady state system is presented in the appendix, Section A. The initial steady state of the state vector $x = (l^s, \tau, l^d)'$ is denoted by $\overline{x}_0$, the new steady state by $\overline{x}_1$.

[11] The decline of the equilibrium real money stock implies in isolation a rise in the steady state value of the nominal interest rate. Since in long run equilibrium $\overline{i} = \overline{i}^* + \dot{m} - \dot{m}^*$ and $(\overline{i - \dot{p}^c}) - (\overline{i - \dot{p}^{*c}}) = (1 - (\alpha + \alpha^*))\overline{\tau} = 0$ holds, it follows that the long run change of all nominal and real interest rates coincides if there is no monetary growth (i.e., $\dot{m} = \dot{m}^* = 0$). Several numerical simulations show that the oil price shock causes an increase in the equilibrium values of domestic and foreign interest rate. For large values of the interest-rate *semi*-elasticity of money demand l_2 the increase in $\overline{i}$ and $\overline{i}^*$ is weak.

permanently increase ($d\overline{\tau} > 0$). Generally, the steady state effect of the price shock $dp_R^* > 0$ on the domestic terms of trade τ is not uniquely determined. This can be illustrated in a $\overline{\tau}/(\overline{q}-\overline{q}^*)$-diagram (cf. figure 1) which contains the difference of the long run IS equations ($\overline{IS}-\overline{IS}^*$), i.e.

$$(1-a_1+2c_1)(\overline{q}-\overline{q}^*) = -(2c_3-(a_1-2c_1)\psi)\overline{\tau}+2c_0 + g - g^* - (a_1-2c_1)(\psi-\psi^*)(\overline{p_R^*-p^*}) \quad (21)$$

and the corresponding difference of the long run aggregate supply functions ($\overline{AS}-\overline{AS}^*$), i.e.

$$\overline{q}-\overline{q}^* = f_0 - f_0^* + (f_1+f_1^*+f_2)\overline{\tau} - (f_2-f_2^*)(\overline{p_R^*-p^*}) \quad (22)$$

The demand-side equilibrium curve $\overline{IS}-\overline{IS}^*$ has a negative slope provided that $2c_3 > (a_1-2c_1)\psi$ holds.[12] On the other hand, the supply-side curve $\overline{AS}-\overline{AS}^*$ is positively sloped in $\overline{\tau}/(\overline{q}-\overline{q}^*)$-space. Since an increase in the US dollar price of imported raw materials is

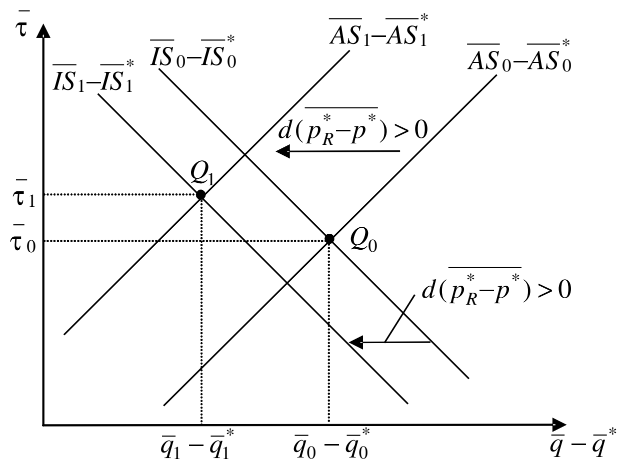

Figure 1: Steady state effects of the input-price increase

accompanied by a less than equivalent rise in the equilibrium foreign price level ($dp_R^* > d\overline{p}^*$) the long run foreign real price of raw materials inputs rises ($d(\overline{p_R^*-p^*}) > 0$). Due to our assumptions $\psi > \psi^*$, $f_2 > f_2^*$ this induces a shift both of the demand and supply curve to the left (see figure 1).[13] If inequality (20) holds the long run supply curve $\overline{AS}-\overline{AS}^*$ moves further to the left than the long run demand curve $\overline{IS}-\overline{IS}^*$. In this case a long run real appreciation of the domestic currency occurs ($d\overline{\tau} > 0$) although the nominal exchange rate permanently increases ($d\overline{e} > 0$). Figure 1 also illustrates that irrespective of the sign of the change of domestic final goods terms of trade there is always a fall in

[12]Note that the assumption of a normal reaction of the domestic trade balance against the USA to changes in the final goods terms of trade τ (i.e., $c_3 > 0$) is not sufficient for a negative slope, since an increase in τ raises due to $y = q + \psi\tau - \psi(p_R^*-p^*) - d_0$ national income and domestic private absorption holding other factors constant.

[13]The curve $\overline{IS}-\overline{IS}^*$ moves to the left since the rise in $\overline{p_R^*-p^*}$ leads to a stronger reduction in domestic than in foreign income and absorption respectively.

the long run output differential $\overline{q} - \overline{q}^*$ so that $d\overline{q} < d\overline{q}^*$ holds. Under the weak assumption (20) the increase in the price of imported raw materials leads to a permanent reduction in foreign output ($d\overline{q}^* < 0$). Therefore, domestic real output also falls in the long run, and the output contraction is stronger in the domestic than in the foreign economy.[14] The intuitive reason is that the domestic economy is stronger oil-dependent than the foreign economy and that oil imports are priced in terms of the foreign currency (dollars). Due to the nominal depreciation of the domestic currency, the oil price shock $dp_R^* > 0$ must have stronger negative effects on the supply side of the domestic economy than upon the foreign economy.

As yet we have shown that in the long run a rise in the dollar-price of imported crude oil has stronger stagflationary effects in the EMU than in the USA and that the equilibrium nominal depreciation of the Euro is typically accompanied by a real appreciation of the domestic currency.[15] Although the increase in the steady state value of the terms of trade τ worsens the domestic real trade balance against the US, the stronger reduction of national than foreign income ($d\overline{y} < d\overline{y}^*$) in isolation leads to an improvement of the domestic equilibrium trade balance against the US so that the net effect is ambiguous. If the negative terms of trade effect on the domestic trade balance is not too large, the trade balance against the large foreign country *improves*.[16] A similar result holds if the equilibrium trade balance with respect to OPEC is considered. In logarithmic terms, the steady state change of domestic real imports of raw materials ($d\overline{im}_R$) is given by

$$d\overline{im}_R = d\overline{q} + (1 - \sigma)d(\overline{p_R^* + e - p}) \tag{23}$$

where σ is the elasticity of substitution between labor and oil.[17] While the domestic output contraction leads to an equivalent fall in $\overline{im}_R$ the rise in the real factor price of oil increases real raw materials imports. The net effect is therefore ambiguous in sign.[18] Several numerical simulations with realistic parameter values[19] illustrate that the output effect dominates the opposite real factor price effect so that $d\overline{im}_R$ is *negative* in general.[20] This implies that the equilibrium trade balance with respect to OPEC typically *improves*

[14]This result also holds in the case $d\overline{\tau}/dp_R^* < 0$. Due to the relationship $p_R^* - p^* = \tau + (p_R^* + e - p)$ the rise in the long run foreign real price of oil $(\overline{p_R^* - p^*})$ is stronger (weaker) than the rise of the corresponding domestic real factor price $(\overline{p_R^* + e - p})$ if $d\overline{\tau}/dp_R^* > 0 (< 0)$. Since $y - y^* = q - q^* + \psi\tau - (\psi - \psi^*)(p_R^* - p^*)$ and $\psi > \psi^*$, there is also a fall in the equilibrium income differential ($d(\overline{y - y^*}) < 0$). Note that the degree of output contraction strongly depends on the degree of oil-dependency of the economies. An increase in the degree of supply-side openness (i.e., a rise in $1 - \mu$) leads to a tightening of the contractionary output effects (cf. Bhandari and Turnovsky (1984)). Moreover, the inflationary effects due to the oil price shock are weaker but more persistent, if the degree of supply-side openness rises. See, for example, Romer (1993) for a general discussion of the openness-inflation relationship.

[15]Similar results for *small* open economies can be found in Bhandari (1981) and Bhandari and Turnovsky (1984).

[16]In Bhandari (1981) it is assumed that the terms of trade effect dominates the income effect so that the real trade balance with respect to the USA is worsened.

[17]In Bhandari and Turnovsky (1984) σ is equal to 0.33 while in Bhandari (1981) $\sigma = 0$. Since real exports of the domestic economy with respect to OPEC are negligible by assumption, the steady state change of the trade balance with respect to OPEC equals $-d\overline{im}_R$.

[18]Cf. Bhandari (1981).

[19]See footnote 37 for the parameter values used for numerical simulations of the model.

[20]The same holds for $d\overline{im}_R^*$, i.e. the steady state change of foreign real imports of raw materials.

so that the same holds for the overall trade balance of the domestic economy.[21]

Let us now consider the *dynamic* effects of an anticipated increase in the foreign price of raw materials imports for both the domestic and the foreign economy. If the OPEC credibly announces at $t = 0$ that at some future date T the price of crude oil will be raised, this on impact leads to a fall in the domestic final goods terms of trade τ, i.e. an immediate real and nominal depreciation of the domestic currency (cf. figure 2 at the end of this section).[22] After the initial jump the process of depreciation continues to hold during the entire period between the announcement and the implementation of the oil price increase. This is accompanied by a gradual rise in the domestic and a gradual fall in the foreign price level (figure 3). The divergent responses of domestic and foreign price level can be explained by the immediate domestic output increase and foreign output decrease which cause temporary wage and price inflation in the domestic and wage and price deflation in the foreign economy (figure 4). During the anticipation phase $0 < t < T$ the increase in the price differential $p - p^*$ is weaker than the rise in the nominal exchange rate e so that the terms of trade τ fall until the input price shock actually occurs. The exogenous price shock leads to a stronger rise of domestic than foreign price level and a reversal in the development of τ, i.e. a process of real appreciation which is accompanied by a further nominal devaluation of the domestic currency. During the course of adjustment, for sufficiently large $t > T$, a *delayed overshooting* of τ, e and $p - p^*$ takes place so that these variables have a *hump-shaped* adjustment for $t > T$ and converge from above to their respective new steady state level (cf. figure 2).[23] The announcement of a future oil price increase and the resulting real depreciation of the domestic currency on impact lead to a rise in domestic and a fall in foreign output so that the output differential $q - q^*$ is positive in the short run. This is accompanied by a positive difference of the income variables y and y^* (figure 5).[24] Thereafter, both difference variables start to decrease and change sign during the course of adjustment (i.e., $q < q^*$ and $y < y^*$ for t sufficiently large). After its initial increase domestic output begins to fall (figure 5). The reason is the rise of the domestic real factor price $p_R^* + e - p$ throughout the entire anticipation period (figure 6), which – in isolation – reduces national income and private absorption. In addition, the rise of the inflation rate based on the consumer price index, $\dot{p}^c$, is connected with a stronger increase of domestic nominal interest rate so that the domestic real interest rate also starts to increase after its initial fall (cf. figure 7) leading to a further reduction of private absorption. During the entire period between the announcement and the implementation of the oil price increase both the rise of the domestic real interest rate and domestic

[21] Several numerical simulations illustrate that there is also an improvement of the overall trade balance of the large foreign economy, although its bilateral trade balance with respect to the domestic economy deteriorates in general.

[22] The intuitive reason for the immediate rise of e is the stronger oil-dependency of the domestic economy. The public therefore expects that the domestic economy will be stronger hit by the oil price hike than the foreign economy.

[23] A delayed overshooting of exchange rates in response to monetary policy shocks was empirically found by, for example, Eichenbaum and Evans (1995).

[24] On impact, there is also a discontinuous decrease in the real interest rates $i - \dot{p}^c$ and $i^* - \dot{p}^{c*}$. Although the instantaneous reduction of the domestic real interest rate is smaller than the fall of the corresponding foreign variable, the output differential $q - q^*$ increases on impact.

real price of imported raw materials is stronger than the change of the corresponding foreign variables.[25] After the initial jump domestic output decreases therefore stronger than foreign output.[26]

At the date of implementation the increase of the nominal factor price leads to an equivalent rise of both the domestic and foreign real factor price (figure 6).[27] Since the domestic economy is – by assumption – stronger oil-dependent than the foreign economy, the domestic output contraction at time T is greater than the corresponding foreign output reduction.[28] For $t > T$ both output and income variables converge from above to their new (smaller) steady state levels (figure 5). Note that the contractionary real effects during the entire period after the implementation of the oil price increase are stronger for the domestic than the foreign economy. The same holds for the domestic and foreign price effects after time T. For any $t > T$ both the domestic price level p and price index p^c lie above their corresponding foreign price variables p^* and p^{*c} respectively (figure 3). This implies that for $t > T$ the stagflationary effects are stronger in the domestic than in the foreign economy. On the other hand, stagflationary outcomes in the sense of simultaneous output contraction and price increases do not occur during the anticipation phase. Domestic output rises on impact and lies above its initial steady state level in the short run. In the foreign economy a disinflationary process takes place throughout the time interval $0 < t < T$. A rise of the foreign price level only occurs after the implementation of the oil price increase.

Figure 8 illustrates the dynamic adjustment of domestic and foreign real oil imports. On impact, a rise in domestic real output and the domestic real factor price of oil takes place. On the other hand, foreign output is reduced on impact while the foreign real factor price initially remains constant. According to the import equations

$$im_R = q + (1 - \sigma)(p_R^* + e - p) \quad (24)$$

$$im_R^* = q^* + (1 - \sigma^*)(p_R^* - p^*) \quad (25)$$

this implies an increase in domestic real raw materials imports im_R while foreign real oil imports im_R^* decrease on impact. Since domestic real output is greater than its initial steady state level during the whole anticipation period and the real factor price $p_R^* + e - p$

[25] Note that the real interest rate differential $(i - \dot{p}^c) - (i^* - \dot{p}^{*c}) = (1 - (\alpha + \alpha^*))\dot{\tau}$ is positive since $\alpha + \alpha^* > 1$ and $\dot{\tau} < 0$ for $0 < t < T$. The same holds for the real factor price differential $(p_R^* + e - p) - (p_R^* - p^*) = -\tau$. While both the domestic and foreign real factor price increase during the entire anticipation period, the development of domestic and foreign real interest rate is of opposite direction. The foreign real interest rate $i^* - \dot{p}^{*c}$ decreases for $0 < t < T$. Similar results hold for corresponding nominal variables. During the anticipation period $0 < t < T$ the domestic price and wage inflation rates $\dot{p}$, $\dot{p}^c$ and $\dot{w}$ as well as the nominal interest rate i rise while the corresponding foreign variables fall.

[26] It is assumed that the terms of trade elasticity of the trade balance, c_3, is not too large, since otherwise $q - q^*$ could rise for $0 < t < T$. Note that for small values of the degree of supply-side openness a discontinuous *increase* in domestic and foreign output is possible at time T. This result holds since domestic and foreign real interest rate fall in T.

[27] It is assumed that the nominal exchange rate e only jumps at the date of anticipation.

[28] This result holds although domestic and foreign real interest rate decrease at time T discontinuously, and the fall of domestic real interest rate is larger than the fall of the corresponding foreign variable. If the degree of supply-side openness is small, a *rise* of real output at time T is possible.

increases further, im_R lies above its initial value for all $0 < t < T$. For im_R^* just the opposite holds ($im_R^* < \overline{im_R^*}$) although there is a moderate increase of the foreign real oil price $p_R^* - p^*$ due to the fall of the foreign price level p^*. The oil price shock in T leads to an equivalent rise in the real factor prices $p_R^* + e - p$ and $p_R^* - p^*$ so that im_R and im_R^* rise sharply in T.[29] This result holds although real output decreases in T. For $t > T$ the real factor prices and the output variables fall continuously leading to a gradual decline of domestic and foreign raw materials imports. At the end of the adjustment process im_R and im_R^* lie below their respective initial steady state level implying a long run *improvement* of the domestic and foreign trade balance with respect to OPEC. This result holds although there is a steady state rise in the real factor price of oil. The long run output contraction has a stronger (negative) effect on real oil imports than the opposing effect of the factor price increase. The realization of a once-and-for-all increase of the oil price only leads to a temporary rise of real oil imports of the EMU and the USA from the OPEC nations.

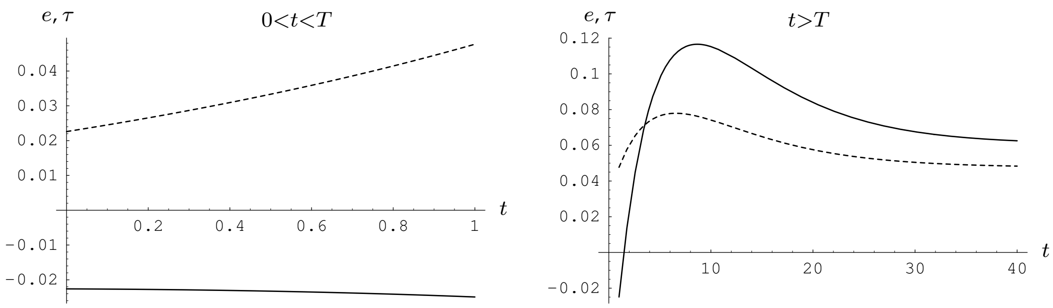

Figure 2: Response of nominal exchange rate e (**dotted line**) and terms of trade τ to an anticipated oil price shock (**solid line**) during the time span $0 < t < T = 1$ (**left**) and for $t > T = 1$ (**right**)

[29]Note that the jump in T does not depend on the value of T. This is a general result which holds for any jump variable of the whole model.

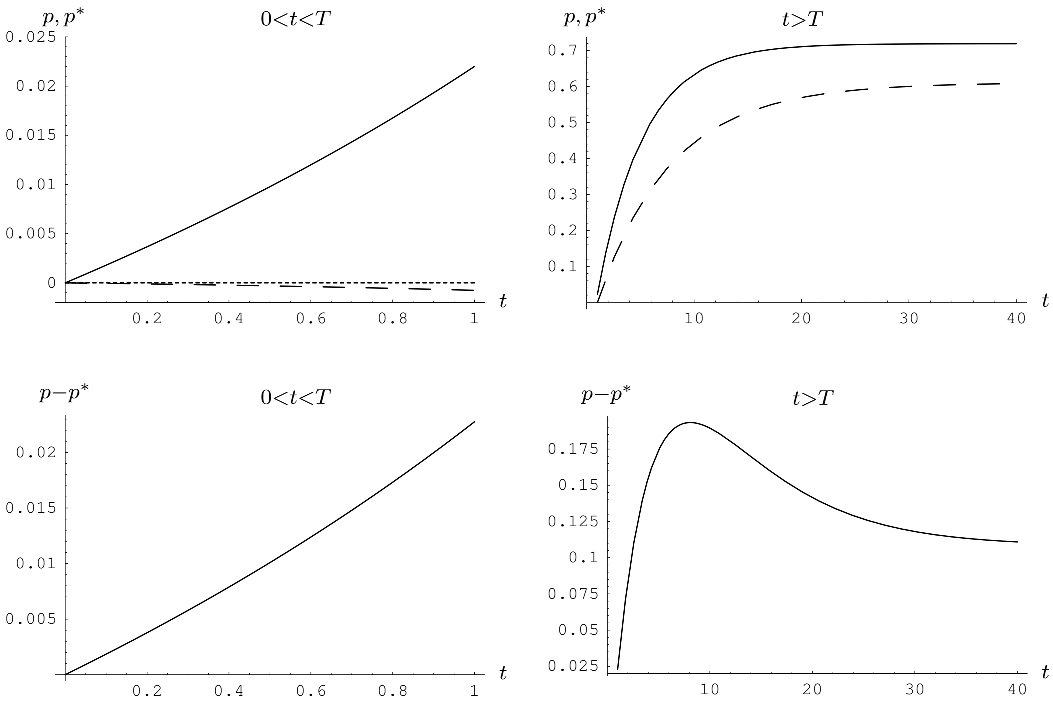

Figure 3: Response of domestic price level p (**solid line**), foreign price level p^* (**dashed line**) and price differential $p - p^*$ to an anticipated oil price shock, initial steady state $\overline{p}_0 = \overline{p}_0^*$ (**dotted line**)

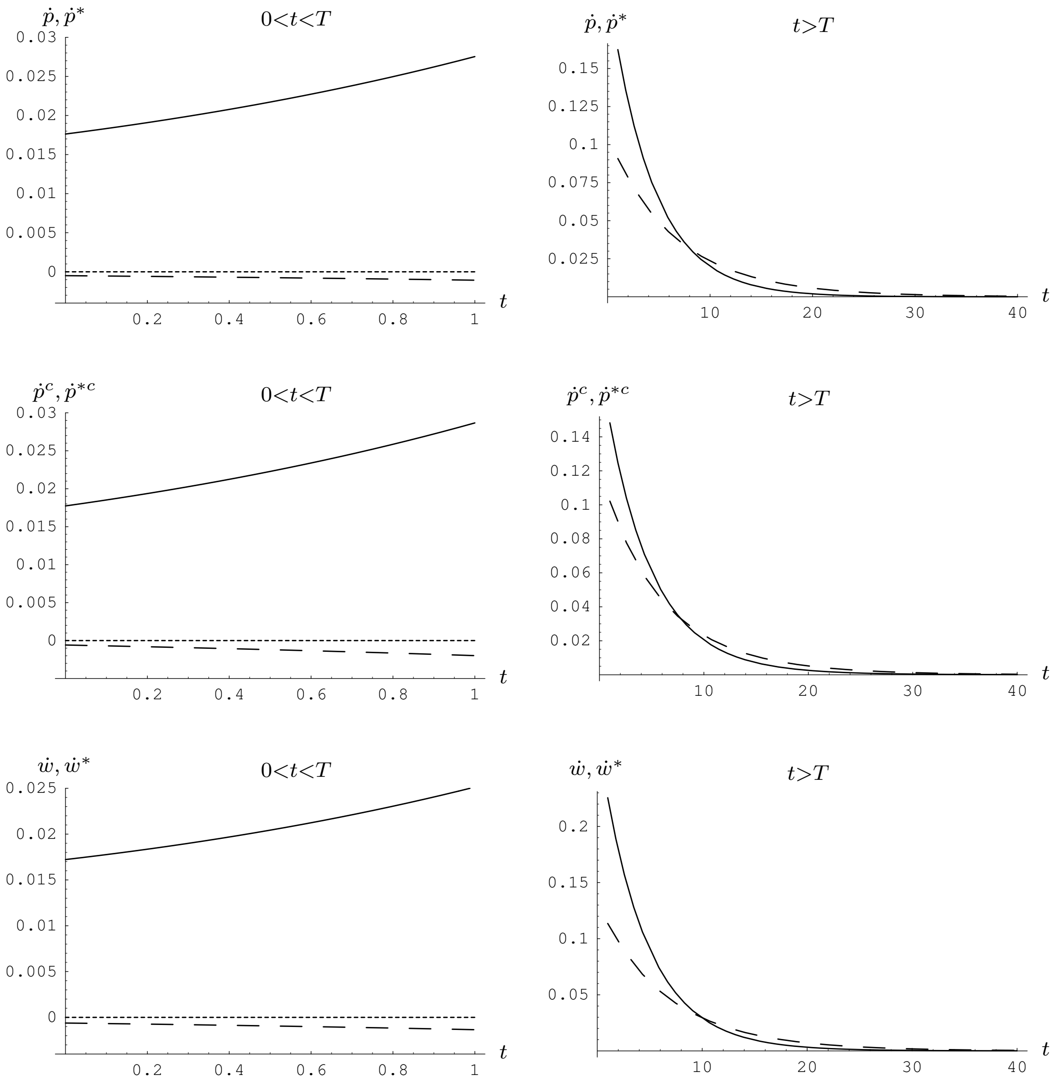

Figure 4: Response of domestic inflation rate $\dot{p}$, consumer price inflation rate $\dot{p}^c$ and wage inflation rate $\dot{w}$ (**solid lines**) and foreign inflation rate $\dot{p}^*$, consumer price inflation rate $\dot{p}^{*c}$ and wage inflation rate $\dot{w}^*$ (**dashed lines**) to an anticipated oil price shock , initial steady states (**dotted lines**)

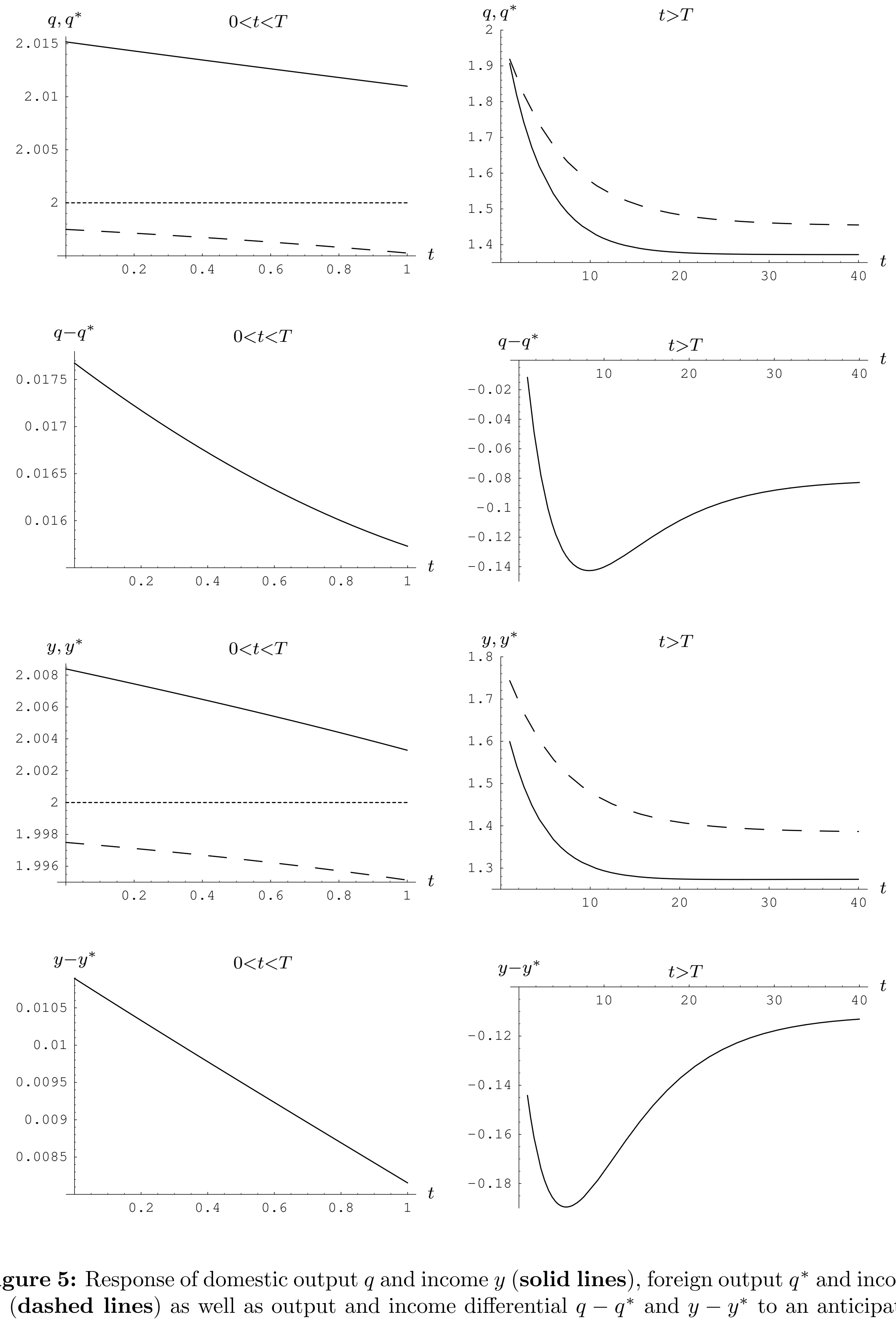

Figure 5: Response of domestic output q and income y (**solid lines**), foreign output q^* and income y^* (**dashed lines**) as well as output and income differential $q - q^*$ and $y - y^*$ to an anticipated oil price shock, initial steady states (**dotted lines**)

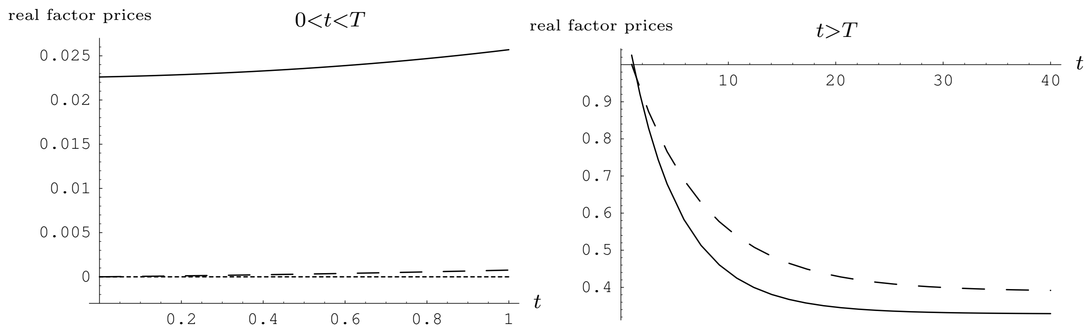

Figure 6: Response of domestic real factor price $p_R^* + e - p$ (**solid line**) and foreign real factor price $p_R^* - p^*$ (**dashed line**) to an anticipated oil price shock, initial steady state (**dotted line**)

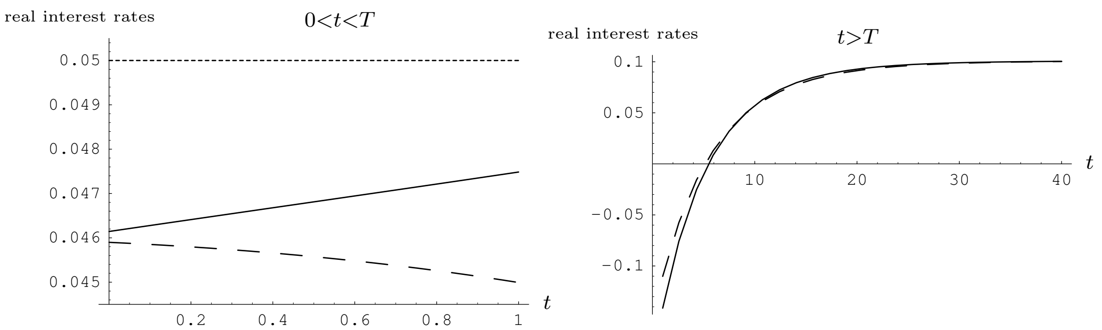

Figure 7: Response of domestic real interest rate $i - \dot{p}^c$ (**solid line**) and foreign real interest rate $i - \dot{p}^{*c}$ (**dashed line**) to an anticipated oil price shock, initial steady state (**dotted line**)

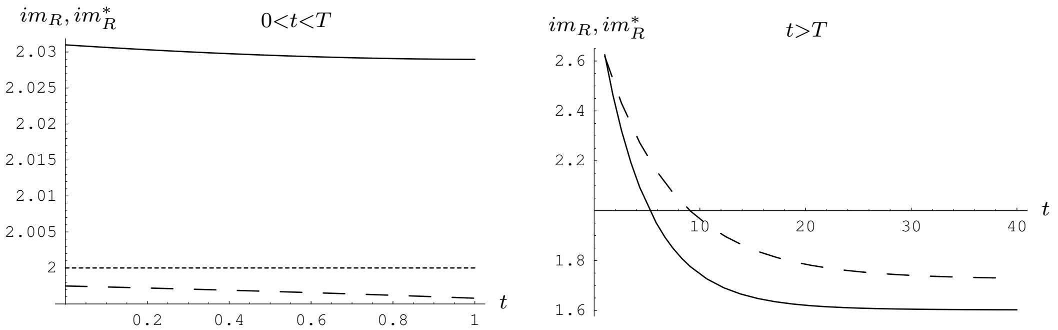

Figure 8: Response of domestic real oil imports im_R (**solid line**) and foreign real oil imports im_R^* (**dashed line**) to an anticipated oil price shock, initial steady state (**dotted line**)

4 Domestic-Currency Denominated Oil Imports

This section investigates the consequences of an increase of the price of crude oil imports being denominated in terms of domestic rather than foreign currency. The real domestic factor price of imported raw materials is now defined by $p_R - p$ where p_R is the exogenously given input price denominated in terms of Euro. The corresponding foreign real factor price of oil is given by $p_R - e - p^*$. An anticipated increase in the (domestic-currency) price of imported raw materials in qualitative terms generally has the same steady state effects as in section 3 (i.e. long run stagflation in both economies coupled with a long run rise in the nominal exchange and interest rate and the domestic terms of trade τ).

Several numerical simulations with plausible parameter values show that the steady state multipliers of an increase in p_R with respect to the real and nominal variables q, q^*, y, y^*, p, p^*, p^c, p^{*c}, i and i^* are *smaller* (in absolute terms) than the corresponding multipliers of a rise in p_R^*.[30] This implies that with domestic-currency denominated oil the long run stagflationary effects upon *both* economies are reduced.[31] If we identify the domestic economy with the EMU and the foreign economy with the USA we can say that both the EMU and the USA are better insulated against OPEC price shocks if oil imports are denominated in Euro rather than US dollars. Moreover, the rise in the equilibrium nominal exchange rate $\overline{e}$ and the domestic terms of trade $\overline{\tau}$ as well as the rise in the domestic and foreign real factor price of imported raw materials is weakened.[32] Since the long run output effect upon the steady state value of real oil imports dominates the opposing real factor price effect there is a long run reduction of real raw materials imports which is smaller when oil imports are priced in Euro rather than US dollars. This result holds for both the domestic and the foreign economy. The improvement of the bilateral trade balances of the domestic and foreign economy with respect to OPEC is therefore weakened.

Figure 9 at the end of the section shows the domestic and foreign output adjustment if imported raw materials are denominated in terms of domestic currency. Each figure also contains the output time path in case of foreign-currency denominated oil. With domestic-currency denominated oil the positive impact effect on domestic output q is reduced. The real depreciation of the domestic currency is now smaller, and the domestic real interest rate does not decrease but increases on impact.[33] After its initial jump real output q continues to rise during the entire anticipation period while it falls if oil imports are denominated in terms of US dollars. The reason for the opposite adjustment

[30] Formally, this follows from the fact that the determinant of the steady state matrix belonging to the state vector $(\overline{\tau}, \overline{l}^d, \overline{l}^s)'$ in absolute terms is considerably greater than the corresponding determinant in case of foreign-currency denominated oil imports.

[31] Cf. Bhandari (1981) for small open economies.

[32] Although $d\overline{p}|_{(D)} > d\overline{p}|_{(E)}$ and $d\overline{p}^*|_{(D)} > d\overline{p}^*|_{(E)}$ holds (where D and E denote the Dollar and Euro regime respectively), the steady state rise in the nominal exchange rate e leads to $d(\overline{p_R^* + e - p})|_{(D)} > d(\overline{p_R - p})|_{(E)}$ and $d(\overline{p_R^* - p^*})|_{(D)} > d(\overline{p_R - e - p^*})|_{(E)}$. Since the long run output supply according to (11) and (12) is much stronger dependent upon the intermediate than the final goods terms of trade (i.e., $f_2 > f_1$, $f_2^* > f_1^*$) it follows that in absolute terms $|d\overline{q}|_{(D)} > |d\overline{q}|_{(E)}$ and $|d\overline{q}^*|_{(D)} > |d\overline{q}^*|_{(E)}$.

[33] On the other hand, the domestic real factor price $p_R - p$ is now constant on impact (leaving private absorption unchanged) while with foreign-currency denominated oil $p_R^* + e - p$ rises on impact.

of q during the anticipation period is the different adjustment of the domestic real factor price. If oil imports are priced in Euro, the real factor price $p_R - p$ falls during the entire anticipation phase leading to a rise in national income and private absorption. With foreign-currency denominated oil just the opposite holds. The same arguments can be applied to the behavior of foreign output. After its initial (negative) jump which is greater in case of domestic-currency denominated oil, q^* behaves like q, i.e. increases until time T.[34] At the time T of the oil price increase and thereafter the adjustment of q and q^* is in qualitative terms the same as with foreign-currency denominated oil. After the discontinuous contraction at time T, the output variables q and q^* continue to fall. If the time span T between the anticipation and the realization of the oil price shock is sufficiently large then for any $t > T$, q and q^* lie above their corresponding values in the case of foreign-currency denominated oil.[35]

Now we consider the development of the inflation rates, $\dot{p}$ and $\dot{p}^*$ (figure 9). With domestic-currency denominated oil, the direct effect of the rate of depreciation $\dot{e}$ on the domestic inflation rate $\dot{p}$ vanishes (cf. equation (11)). On the other hand, the dynamic foreign price equation (12) now contains the term $\dot{p}_R - \dot{e}$ (instead of $\dot{p}^*_R$). Since $\dot{e}$ is positive throughout the entire anticipation phase it is obvious that for $0 < t < T$ the inflation rate in the domestic economy is reduced while the deflationary process in the foreign economy is reinforced.[36] At the date of implementation the discontinuous increase of both $\dot{p}$ and $\dot{p}^*$ is now smaller than with foreign-currency denominated oil. For $t > T$ the inflation rates $\dot{p}$ and $\dot{p}^*$ gradually decrease where the fall is slower than with US dollar denominated oil. This implies that for sufficiently large, but finite $t > T$ the inflation rates in the case of domestic-currency denominated oil may be slightly greater than with foreign-currency denominated oil (figure 9). On the other hand, for any $t > T$ the continuous increase of both the domestic and foreign price level after the implementation of the input price shock is weakened if oil imports are priced in Euro (figure 10).

As yet we have discussed the international effects of oil price shocks if either oil imports are completely priced in US dollars or in Euro. We have shown that OPEC´s decision to denominate their oil exports in terms of Euro rather than US dollars has the consequence that both the EMU and the USA are better insulated against oil price increases. The question arises whether a combination of these two polar cases may lead to a further reduction of the stagflationary effects of oil price disturbances.

If γ measures the share of imported raw materials imports which are denominated

[34] Note that the impact effect upon the output differential $q - q^*$ is again positive, but smaller compared with foreign-currency denominated oil. The differential output now continues to increase after its initial jump while it falls during the entire anticipation phase if crude oil is priced in dollars. The reason is that with domestic-currency denominated oil the output differential $q - q^*$ is a negative function of the domestic real factor price $p_R - p$ which falls for $0 < t < T$ since p rises during the entire anticipation period. The opposite holds if oil imports are priced in dollars. In this case $q - q^*$ is a negative function of the foreign real factor price $p^*_R - p^*$ which rises for $0 < t < T$ due to the deflationary process in the foreign economy during this time span.

[35] If T is sufficiently small then for small values of $t > T$ $q|_{(D)} > q|_{(E)}$ and $q^*|_{(D)} > q^*|_{(E)}$ holds. This is especially the case if $T = 0$, i.e., if the oil price shock is not anticipated.

[36] Analogous results hold for the domestic variables $\dot{p}^c$ and $\dot{w}$ and the corresponding foreign variables $\dot{p}^{*c}$ and $\dot{w}^*$.

in terms of dollars and $1-\gamma$ measures the share of domestic-currency denominated oil imports, then the dynamic price equations are of the following form:

$$\dot{p} = \mu\dot{w} + (1-\mu)\big(\gamma(\dot{p}_R^* + \dot{e}) + (1-\gamma)\dot{p}_R\big) \tag{26}$$
$$\dot{p}^* = \mu\dot{w}^* + (1-\mu^*)\big(\gamma^*\dot{p}_R^* + (1-\gamma^*)(\dot{p}_R - \dot{e})\big) \tag{27}$$

where $0 \leq \gamma, \gamma^* \leq 1$. The income equations (9) and (10) now contain the real factor price combination $\gamma(p_R^* + e - p) + (1-\gamma)(p_R - p)$ and $\gamma^*(p_R^* - p^*) + (1-\gamma^*)(p_R - e - p^*)$ respectively. The same holds for the long run aggregate supply functions (17), (18).

Tables 1 to 4 show the steady state effects of a simultaneous increase of the Dollar and Euro price of imported raw materials ($dp_R^* = dp_R = 1$) with respect to domestic and foreign real output and the price index for alternative combinations of γ and γ^*.[37] In each table the first column contains the values of γ^* while the first row contains alternative values of γ. It is obvious that for each of the four tables the minimum value (in absolute terms) is attained in case $\gamma = \gamma^* = 0$, i.e.[38]

$$|d\overline{x}|_{(\gamma,\gamma^*)=(0,0)} < |d\overline{x}|_{(\gamma,\gamma^*)\neq(0,0)} \qquad \text{for } \overline{x} \in \{\overline{q}, \overline{q}^*, \overline{p}^c, \overline{p}^{c*}\} \tag{28}$$

This implies that for both large open economies the *long run* stagflationary effects of materials price increases are minimized if all imports of raw materials or other intermediate goods are completely denominated in terms of Euro. Moreover, in this case the steady state increase of the domestic and foreign overall trade balance, which results from the long run reduction of real raw materials imports, is smallest. The reason is that for both economies the steady state decline in real oil imports is minimized if $\gamma = \gamma^* = 0$. There exists no combination of γ and γ^* for which the steady state change of raw materials imports is positive. Note that similar statements concerning the *impact* and short-run effects cannot be made.

On impact, the domestic output expansion is reduced if oil imports are priced in Euro, while foreign output contraction is reinforced.[39] After the impact phase up to time T there is a continuous increase of q and q^* if $(\gamma, \gamma^*) = (0,0)$, i.e., if oil imports are completely denominated in terms of Euro. On the other hand, during this time span there is a

[37] The simulations are based on the parameter values $a_1 = 0.8$, $a_2 = 1.0$, $c_1 = 0.2$, $c_3 = 0.3$, $\alpha = 0.75$, $\alpha^* = 0.8$, $l_1 = 1$, $l_2 = 1.5$, $\mu = 0.7$, $\mu^* = 0.8$, $\sigma = \sigma^* = 0.3$, $\psi = (1-\mu)(1-\sigma)/\mu = 0.3$, $\psi^* = (1-\mu^*)(1-\sigma^*)/\mu^* = 0.175$, $\delta = \delta^* = 0.2$, $f_1 = (1-\alpha)/\delta = 1.25$, $f_1^* = (1-\alpha^*)/\delta^* = 1$, $f_2 = (1-\mu)/(\mu\delta) = 2.14286$, $f_2^* = (1-\mu^*)/(\mu^*\delta^*) = 1.29$, $\beta = 0.2$, $\beta^* = 0.8$.

[38] Inequality (28) also holds for $\overline{x} \in \{\overline{y}, \overline{p}, \overline{p}^*, \overline{i}, \overline{i}^*\}$. It does *not* hold for $\overline{x} = \overline{y}^*$. In this case the minimum value of $|d\overline{y}^*|$ is reached if $(\gamma, \gamma^*) = (1,0)$ (i.e. if domestic (foreign) oil imports are completely priced in dollars (Euro)). The reason is that the steady state increase of the foreign real factor price combination $\gamma^*(p_R^* - p^*) + (1-\gamma^*)(p_R - e - p^*)$ is smallest if $(\gamma, \gamma^*) = (1,0)$. For the corresponding domestic factor price combination $\gamma(p_R^* + e - p) + (1-\gamma)(p_R - p)$ the weakest rise is given if $(\gamma, \gamma^*) = (0,1)$, while the greatest increase is attained if $(\gamma, \gamma^*) = (1,0)$. Since the same holds for the steady state change of the final goods terms of trade τ, the minimum value of $|d\overline{q}|$ ($|d\overline{q}^*|$) is generally *not* attained if $(\gamma, \gamma^*) = (0,1)$ ($(\gamma, \gamma^*) = (1,0)$). From an empirical point of view the combinations $(0,1)$ and $(1,0)$ are irrelevant.

[39] The numerical simulation shows that the immediate increase of q takes its maximum value in case $(\gamma, \gamma^*) = (1,1)$. The minimum value of q at time $t = 0$ is attained if $(\gamma, \gamma^*) = (0,0)$. Just the opposite holds for the short run decrease of q^*. It is minimized if $(\gamma, \gamma^*) = (1,1)$ and maximized if $(\gamma, \gamma^*) = (0,0)$. Similar results hold for the domestic and foreign inflation rates $\dot{p}^c$, $\dot{p}$, $\dot{p}^{c*}$ and $\dot{p}^*$.

contractionary process in both economies if $(\gamma, \gamma^*) = (1, 1)$ (cf. figure 9). Thus, if the anticipation period $(0, T)$ is sufficiently long then for sufficiently large $t < T$ the output variables q and q^* in case $(\gamma, \gamma^*) = (0, 0)$ must lie above their corresponding values in case $(\gamma, \gamma^*) = (1, 1)$. Because of this it is obvious that if a fixed proportion of oil imports is denominated in terms of US dollars and the other part in terms of Euro, and the time span between the anticipation and the implementation of the oil price shock is sufficiently small, then the output development in both economies must throughout the anticipation phase lie between the polar cases $(\gamma, \gamma^*) = (1, 1)$ and $(\gamma, \gamma^*) = (0, 0)$ (cf. figure 9 where the case $(\gamma, \gamma^*) = (0.5, 0.5)$ is illustrated). Similar results hold for the domestic and foreign price variables and the inflation rates.

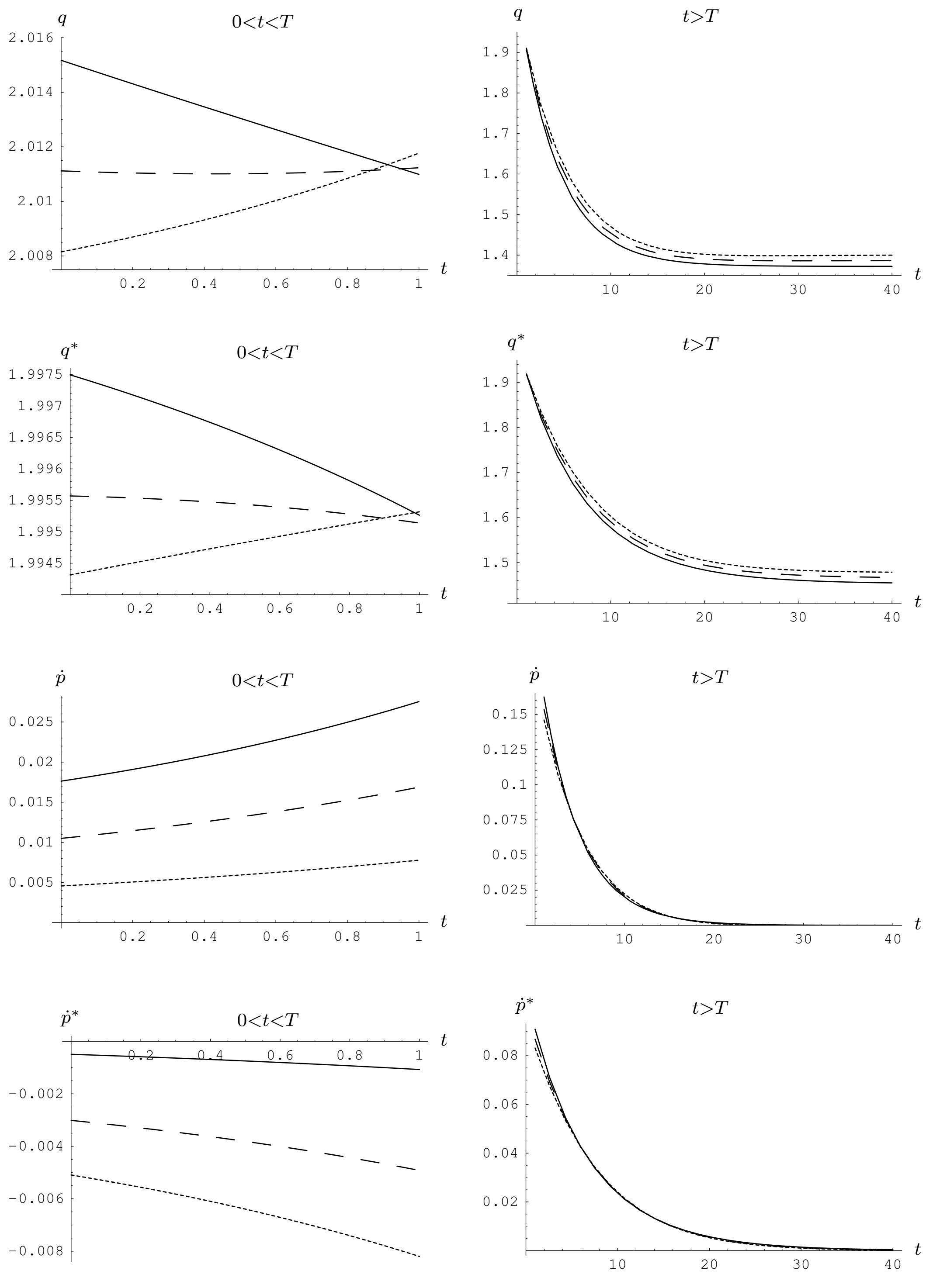

Figure 9: Response of domestic output q and inflation rate $\dot{p}$ and foreign output q^* and inflation rate $\dot{p}^*$ to an anticipated oil price shock for domestic-currency denominated oil (**dotted lines**), foreign-currency denominated oil (**solid lines**) and for the case $\gamma = \gamma^* = 0.5$ (**dashed lines**)

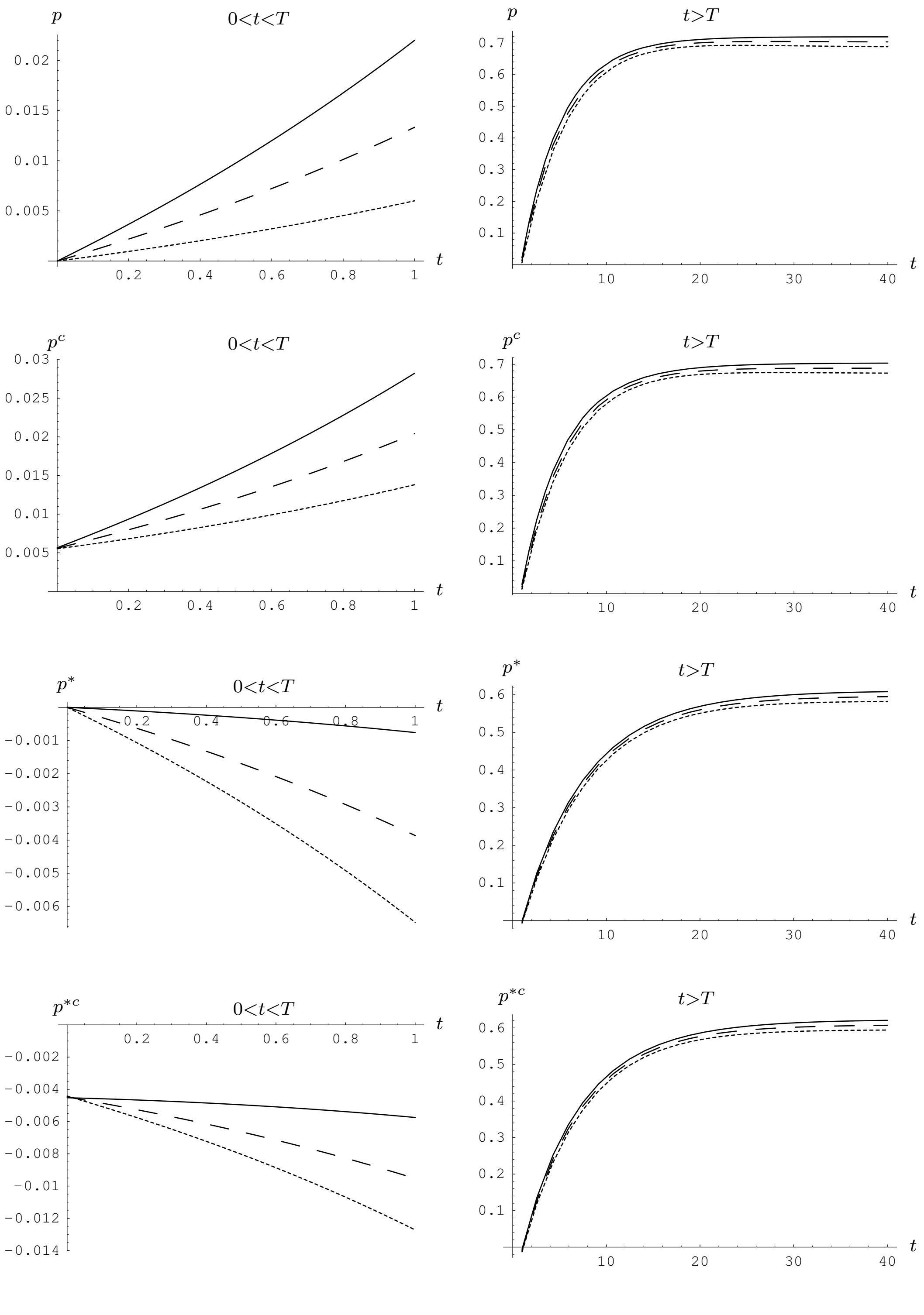

Figure 10: Response of domestic price level p, domestic consumer price index p^c, foreign price level p^* and foreign consumer price index p^{*c} to an anticipated oil price shock for domestic-currency denominated oil (**dotted lines**), foreign-currency denominated oil (**solid lines**) and for the case $\gamma = \gamma^* = 0.5$ (**dashed lines**)

Steady state change of domestic output

$\gamma^*\backslash\gamma$	0	0.25	0.5	0.75	1
0.0	-0.599297	-0.600651	-0.601872	-0.602979	-0.603987
0.25	-0.605052	-0.606179	-0.607189	-0.608098	-0.608922
0.5	-0.611679	-0.612496	-0.613221	-0.613871	-0.614455
0.75	-0.619393	-0.619782	-0.620125	-0.620429	-0.620701
1.0	-0.628485	-0.628281	-0.628103	-0.627947	-0.627809

Table 1: Steady state effects of $dp_R^* = dp_R = 1$ with respect to q for alternative combinations of γ and γ^*

Steady state change of foreign output

$\gamma^*\backslash\gamma$	0	0.25	0.5	0.75	1
0.0	-0.522044	-0.527387	-0.532206	-0.536574	-0.540551
0.25	-0.522357	-0.528039	-0.533128	-0.537712	-0.541862
0.5	-0.522717	-0.528783	-0.534173	-0.538995	-0.543332
0.75	-0.523137	-0.529642	-0.53537	-0.540452	-0.544992
1	-0.523632	-0.530644	-0.536753	-0.542123	-0.54688

Table 2: Steady state effects of $dp_R^* = dp_R = 1$ with respect to q^* for alternative combinations of γ and γ^*

Steady state change of domestic consumer price index

$\gamma^*\backslash\gamma$	0	0.25	0.5	0.75	1
0.0	0.672089	0.673949	0.675625	0.677145	0.678528
0.25	0.678159	0.679808	0.681284	0.682614	0.683818
0.5	0.685149	0.686503	0.687706	0.688781	0.689749
0.75	0.693285	0.694226	0.695054	0.695789	0.696446
1.0	0.702875	0.703234	0.703546	0.703821	0.704065

Table 3: Steady state effects of $dp_R^* = dp_R = 1$ with respect to p^c for alternative combinations of γ and γ^*

Steady state change of foreign consumer price index

$\gamma^*\backslash\gamma$	0	0.25	0.5	0.75	1
0.0	0.594836	0.600685	0.605959	0.610739	0.615092
0.25	0.595464	0.601668	0.607223	0.612228	0.616759
0.5	0.596188	0.60279	0.608658	0.613905	0.618627
0.75	0.597029	0.604086	0.610299	0.615812	0.620736
1.0	0.598021	0.605596	0.612196	0.617997	0.623136

Table 4: Steady state effects of $dp_R^* = dp_R = 1$ with respect to p^{*c} for alternative combinations of γ and γ^*

5 Alternative degrees of wage indexation

The dynamic adjustment paths presented in the last two chapters have been derived under the assumption that the degree of wage indexation is greater in the domestic than in the foreign economy ($1 - \beta > 1 - \beta^*$ or equivalently $\beta < \beta^*$). In this chapter we want to discuss the question to what extent the dynamic effects of oil price shocks depend upon the parameters β and β^*.[40] In what follows we only consider the two polar cases $(\beta, \beta^*) = (1, 1)$ and $(\beta, \beta^*) = (0, 0)$ which can be identified with nominal and real wage rigidity in both economies respectively. A variation of the parameter values of β and β^* does not change the steady state effects of raw materials price increases since the long run equilibrium of the world system is independent of β and β^*. Instead, it leads to changes in the dynamic effects, in particular at the date of anticipation and the date of implementation.

Firstly, we consider the output effects under the assumption that oil imports are completely denominated in terms of US dollars (cf. figure 11). On impact, the domestic output effect is stronger compared with the *B*enchmark scenario ($B : 0 < \beta < \beta^* < 1$) if *R*eal wage rigidity holds ($R : \beta = \beta^* = 0$), while it is weakened in the regime of *N*ominal wage rigidity ($N : \beta = \beta^* = 1$):

$$q(0+)|_R > q(0+)|_B > q(0+)|_N > \overline{q}_0 \tag{29}$$

Although at the date of anticipation the nominal and real depreciation of the domestic currency as well as the rise of the real factor price is stronger in regime N than in R, the fall of the real interest rate is strongest in R and weakest in N. Thus inequality (29) must hold if the semi-interest elasticity of private absorption is sufficiently high. An analogous rank order holds for foreign output whereby $q^*(0+)|_R > \overline{q}_0^*$ in general because of a strong fall of the foreign real interest rate in the regime of real wage rigidity. After the initial jump, q and q^* behave as in the benchmark case, i.e. they drop continuously. At the date of implementation there is a further output jump. In the case of nominal wage rigidity it is again negative (due to the sharp rise of the real factor price in T). But with real wage rigidity both the domestic and foreign output *increase* in T which is a consequence of the strong fall of the real interest rate. In regime R the expansionary interest rate effect dominates the opposing real factor price effect, while in N and B just the opposite holds. After the output jump at time T there is a continuous contractionary process in any regime. Since the long run equilibrium level of q and q^* does not depend on β and β^* the output contraction for $t > T$ is strongest in the case of real wage rigidity.

Next consider the output development in the case of *domestic-currency* denominated oil (cf. figure 12). In this case the initial domestic output jump is still positive in regime

[40] By contrast, the case of an increasing degree of openness is often discussed in economics literature (see, for example, Bhandari and Turnovsky (1984)). See also the footnotes 9 and 14 in this paper.

N of nominal wage rigidity, but is negative in regime R of real wage rigidity:

$$q(0+)|_B > q(0+)|_N > \overline{q}_0 > q(0+)|_R \tag{30}$$

An analogous inequality holds for foreign output where $q^*(0+)$ is smaller than the initial steady state $\overline{q}_0^*$ for any regime of wage indexation. If crude oil imports are priced in Euro the domestic real interest rate rises on impact – and the increase is strongest in the case of real wage rigidity. Regime R also leads to a sharp rise of the foreign real interest rate while it falls on impact in the benchmark scenario and in regime N. At the date of implementation regime R leads again to a strong *rise* of q and q^* (due to a sharp fall of the domestic and foreign real interest rate) while both output variables decrease in T if nominal wage rigidity holds. Note that with domestic-currency denominated oil the positive output jump in the case of real wage rigidity is greater than with foreign-currency denominated oil. The output contraction immediately after the date of implementation is therefore very strong in regime R. On the other hand, it is weak if nominal wage rigidity holds.[41]

If the domestic output development is compared with the corresponding foreign one we always have $(q - q^*)(0+) > 0$ and $(q - q^*)(T+) < 0$, i.e., in the short run the domestic output variable lies above the foreign output, while the opposite holds immediately after the date of implementation. This holds for any regime of wage indexation and does not depend on the currency in which raw materials imports are denominated. In the benchmark scenario as well as in the regime of nominal wage rigidity the output differential $q - q^*$ is negative for all $t > T$ so that in these regimes the foreign output contraction runs always weaker than the corresponding domestic contractionary process. This does not hold in regime R of real wage rigidity. During the phase after the realization of the oil price shock there exists a time interval $[t_1, t_2]$ (with $T < t_1 < t_2 < \infty$) where the output differential $q - q^*$ is positive (cf. figure 13). With real wage rigidity domestic output does not only lie above foreign output immediately after the anticipation of a future oil price rise but also during a finite time span after its implementation. The reason is that both the real interest rate differential and the terms of trade τ start to fall during a short time interval after time T so that the output differential $q - q^*$ begins to rise after its negative jump at time T.[42]

Now we consider the adjustment process of the inflation rates in the case of nominal and real wage rigidity (figure 14). With nominal wage rigidity in both economies the wage inflation rates $\dot{w}$ and $\dot{w}^*$ are independent of the price-index based inflation rates $\dot{p}^c$ and $\dot{p}^{*c}$ respectively. In this case there is no direct impact of the depreciation rate $\dot{e}$ on $\dot{w}$ and $\dot{w}^*$. In the other polar case of real wage rigidity or complete wage indexation there is a strong influence of $\dot{e}$ on $\dot{w}$ and $\dot{w}^*$. During the entire anticipation phase the depreciation rate is positive. This holds for any degree of wage indexation for both foreign- and domestic-

[41] In regime N we also have $q|_{(E)} > q|_{(D)}$ and $q^*|_{(E)} > q^*|_{(D)}$ for any $t \lesseqgtr T$ where the subscripts E and D denote Euro- and Dollar-denominated oil imports respectively.

[42] In the benchmark scenario as well as in regime N there is a process of real appreciation after the date of implementation.

currency denominated oil. The growth rate of nominal wages also depends on the output gap $q - \overline{q}$ and $q^* - \overline{q}^*$ respectively. If raw materials imports are priced in US dollars the domestic output gap is positive on impact where it is greatest in regime R of real wage rigidity (cf. equation (29)). Since $\dot{e}_R > \dot{e}_N$ for $0 < t < T$ the domestic wage and price inflation rates are in the short run greater in regime R of real than in regime N of nominal wage rigidity:

$$\dot{z}(0+)|_R > \dot{z}(0+)|_B > \dot{z}(0+)|_N > 0 \quad \text{for } \dot{z} \in \{\dot{w}, \dot{p}, \dot{p}^c\} \tag{31}$$

For the corresponding foreign inflation rates an analogous rank order holds, where $\dot{z}^*(0+)$ is negative in the benchmark case B and in regime N, while it is in general positive in regime R.[43] At the date T of the oil price increase there is a sharp rise in any domestic and foreign inflation rate. Since there is a positive output jump in regime R, while it is negative in B and N, inequality (31) also holds immediately after the date of implementation (i.e., for $t = T+$). This implies that the positive jump in the domestic and foreign inflation rate at the date of implementation is much stronger in R than in N.[44] The deflationary process thereafter is then stronger in R than in N or B. Note that the sharp rise of the inflation rates at time T in the regime of real wage rigidity is increased if imported raw materials are priced in Euro (cf. figure 15).[45] The reason is that with domestic-currency imported oil the positive output jump in T is reinforced. On the other hand, in the benchmark scenario or in the regime of nominal wage rigidity the changeover from foreign to domestic-currency denominated raw materials imports leads to slightly reduced inflation rates. After the jump in T a deflationary process takes place which is weak in B and N. In the regime of real wage rigidity the fall of the inflation rates immediately after the jump in T is very sharp and strongest in case of domestic-currency denominated oil. Since the same holds for the output variables it is obvious that the volatility of the nominal and real variables is strong if real wage rigidity instead of nominal wage rigidity holds, and that it is not reduced in regime R if raw materials imports are priced in Euro.

[43] Note that $q^*(0+)|_R > \overline{q}_0^*$ holds in general. If the corresponding parameter δ^* is sufficiently large, $\dot{z}^*(0+)|_R$ is positive although the positive value of the rate of change $\dot{e}$ leads – in isolation – to a negative impact on $\dot{z}^*(0+)$ in regime R.

[44] Since the foreign is greater than the domestic output gap at time T and $\dot{e}_R(T+) < 0$, the foreign inflation rates $\dot{z}^*(T+)|_R$ are in general greater than the corresponding domestic ones.

[45] On the other hand, the initial jump of $\dot{z}|_R$ and $\dot{z}^*|_R$ is now negative, since q and q^* fall on impact and the positive value of $\dot{e}(0+)$ has no effect on $\dot{z}|_R$ if raw materials imports are priced in Euro.

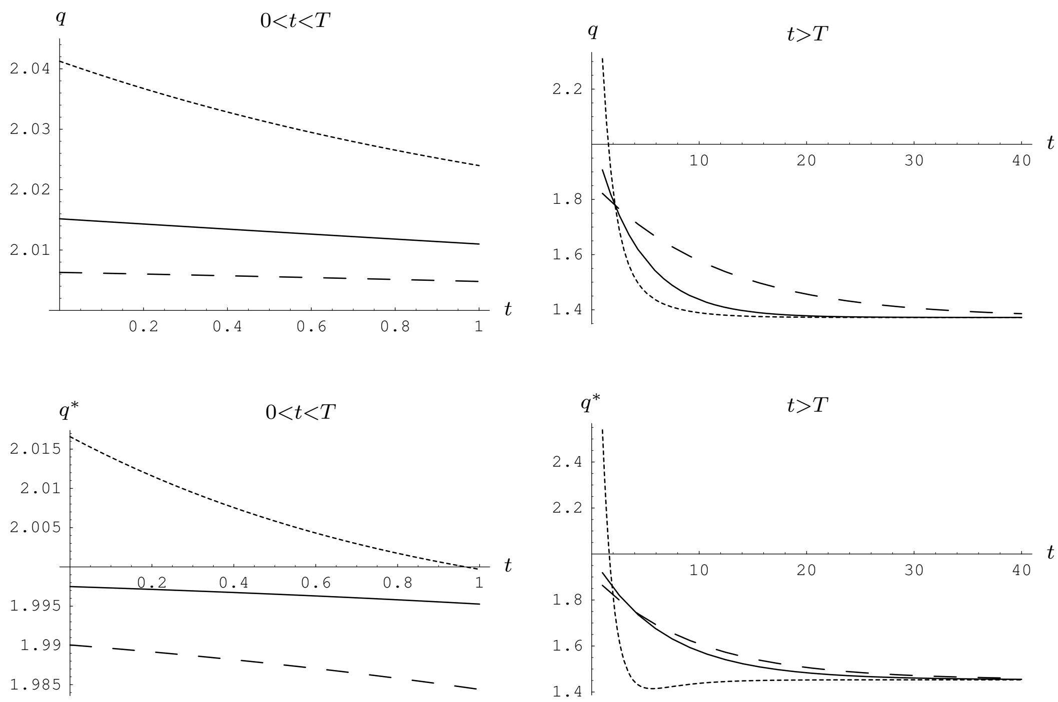

Figure 11: Response of domestic output q (top) and foreign output q^* (bottom) to an anticipated oil price shock for foreign-currency denominated oil in regime B (**solid lines**), R (**dotted lines**) and N (**dashed lines**)

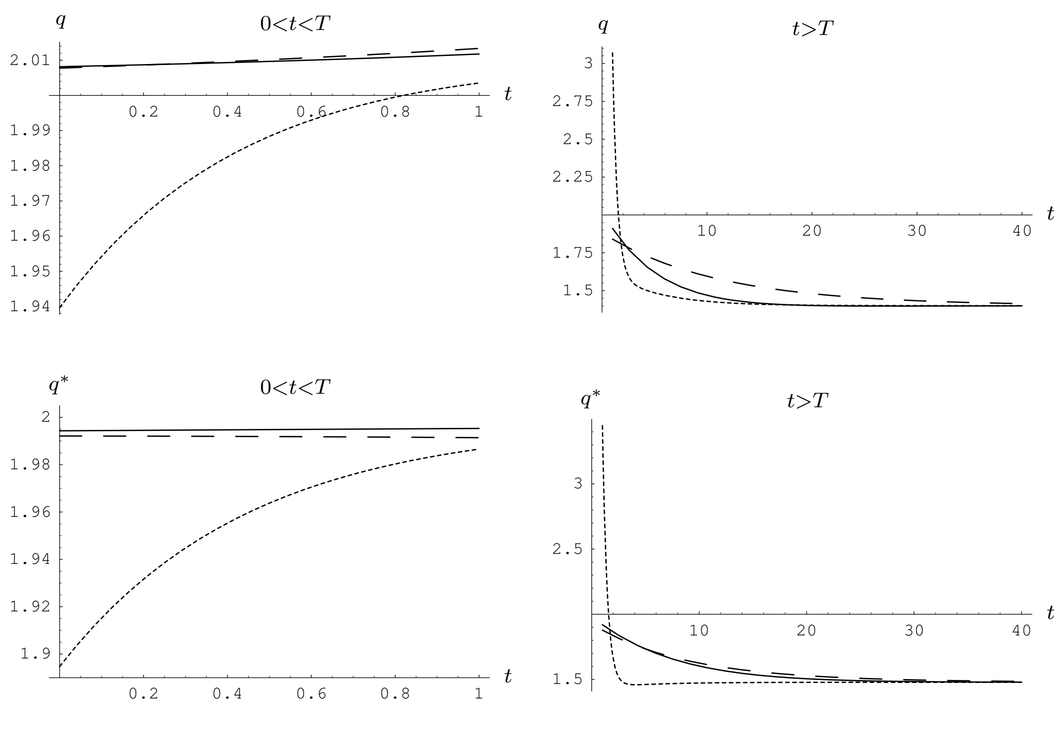

Figure 12: Response of domestic output q (top) and foreign output q^* (bottom) to an anticipated oil price shock for domestic-currency denominated oil in regime B (**solid lines**), R (**dotted lines**) and N (**dashed lines**)

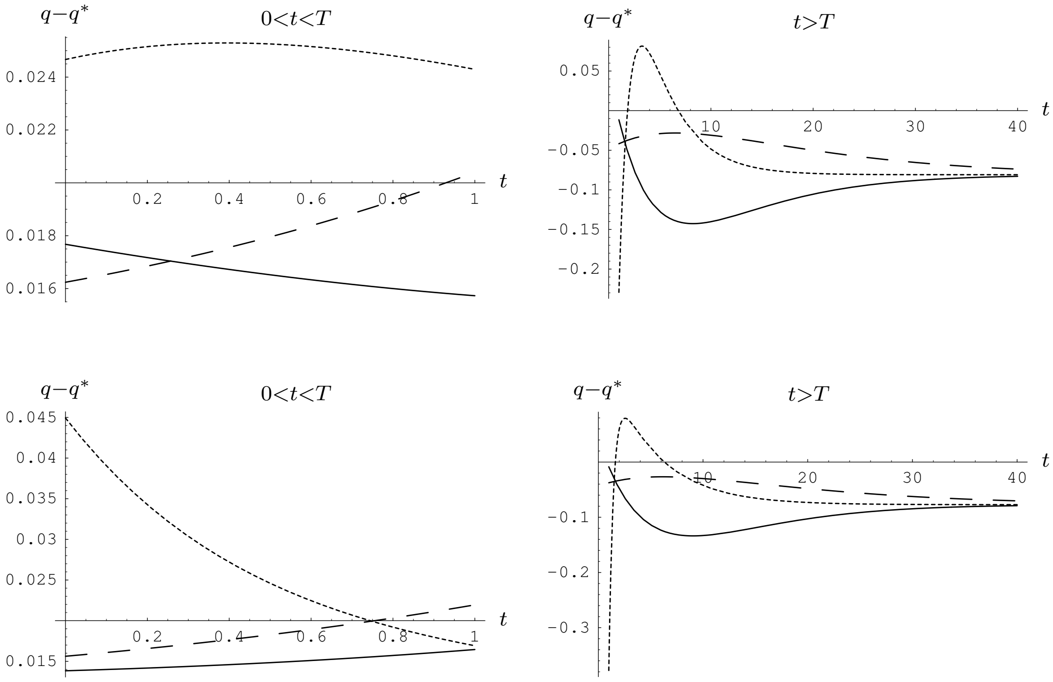

Figure 13: Response of output differential $q - q^*$ to an anticipated oil price shock for foreign-currency denominated oil (top) and domestic-currency denominated oil (bottom) in regime B (**solid lines**), R (**dotted lines**) and N (**dashed lines**)

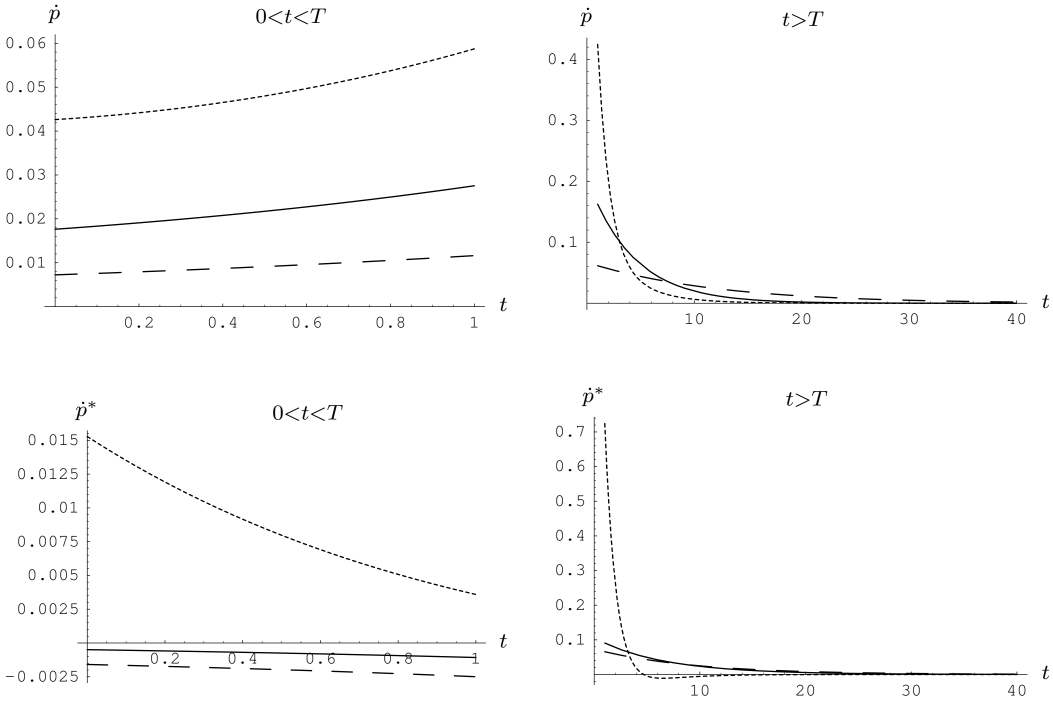

Figure 14: Response of domestic inflation rate $\dot{p}$ (top) and foreign inflation rate $\dot{p}^*$ (bottom) to an anticipated oil price shock for foreign-currency denominated oil in regime B (**solid lines**), R (**dotted lines**) and N (**dashed lines**)

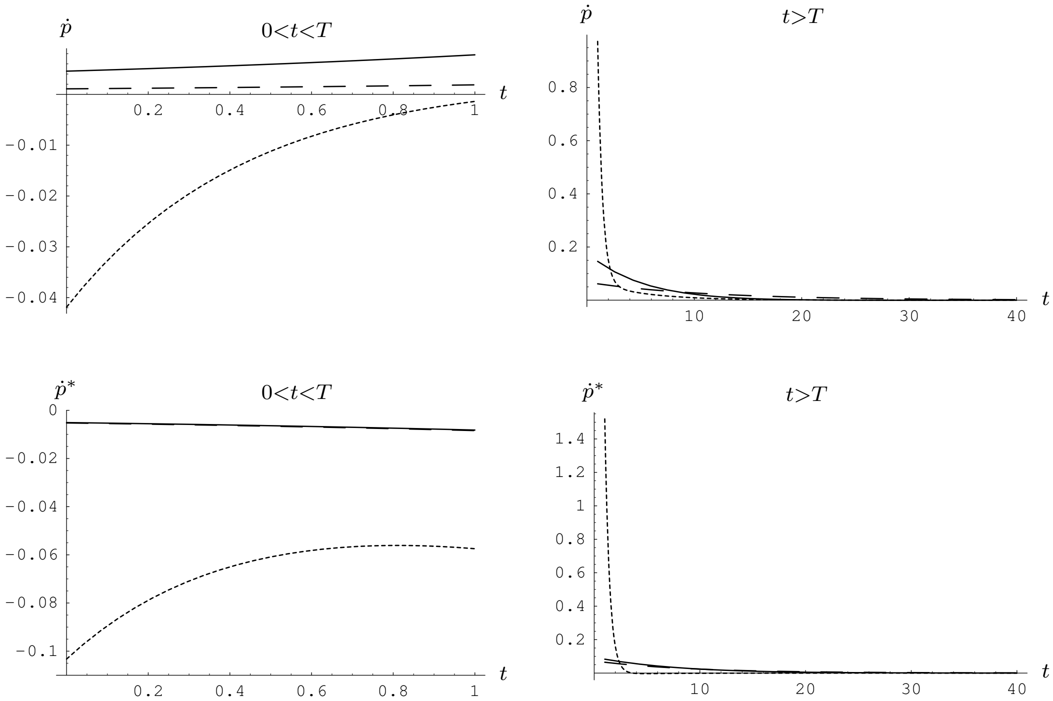

Figure 15: Response of domestic inflation rate $\dot{p}$ (top) and foreign inflation rate $\dot{p}^*$ (bottom) to an anticipated oil price shock for domestic-currency denominated oil in regime B (**solid lines**), R (**dotted lines**) and N (**dashed lines**)

6 Monetary Stabilization Policies

We have shown that an increase in the price of oil leads to stagflation as well as temporary balance of trade problems for oil-dependent economies, while the precise degree of severity of these effects depends upon the degree of oil-dependency and the currency in which OPEC oil is denominated. This section analyzes the consequences of various monetary policy reactions that could be employed by the domestic and foreign economy in an effort to reduce the potentially disruptive effects of oil price shocks. The section is organized as follows: We first consider monetary policy rules that are calculated to fix the growth rate of the consumer price index at its initial equilibrium level at all times. In a first step we discuss the problem of complete stabilization of the inflation rate based on the consumer price index over the time interval $T < t < \infty$. Since the anticipation of a future increase in the price of oil not only results in inflation *after* the realization of the materials price increase but also *during* the time span between the anticipation and the implementation of the oil price shock, we also analyze the problem of fixing the consumer price inflation $\dot{p}^c$ at its initial steady state level for all $t > 0$. In the second part of this section we analyze the problem of *complete* system stabilization: Is monetary policy able to neutralize all adjustment dynamics that result from an anticipated increase in the price of raw materials imports? The absorption of the dynamic effects of anticipated oil price shocks means fixing the endogenous variables of the world system at their respective initial steady state level during the whole anticipation phase and after the implementation of the oil price increase fixing them at their respective new steady state level for all $t > T$. We will show that this is possible by a suitable combination of contractionary domestic and foreign monetary policy but that there may occur time inconsistency problems.

6.1 Stabilization of the Consumer Inflation Rate

We first consider the problem of fixing the domestic consumer inflation rate $\dot{p}^c$ at its initial steady state level $\overline{\dot{p}^c} = 0$ for all $t > T$.[46] Such an effect may be achieved by adjusting the growth rate of domestic money supply according to the policy rule

$$\dot{m} = (1-\alpha)\dot{\tau} + \frac{1}{2}\dot{l}^s + \frac{1}{2}\dot{l}^d \tag{32}$$

This rule must be credibly announced at time $t = 0$ to be implemented at the date of the oil price increase T. Since the rise of p_R^* leads to temporary inflation (cf. figure 4) it is obvious that $\dot{m}$ must be negative for $T < t < \infty$ (figure 16). The policy rule (32) not only prevents consumer price inflation for all $t > T$ but also leads to a dampening of the price and wage inflation rates $\dot{p}$ and $\dot{w}$ (figure 17). Since the policy rule is anticipated by the public it leads to adjustment dynamics during the time span $0 < t < T$ (figure 18). The contractionary monetary policy rule causes on impact a rise of the terms of trade τ, a decline in domestic output and deflation, i.e. a fall of the inflation rates $\dot{p}$ and $\dot{p}^c$ during

[46] We assume that initially $\dot{m}_0 = 0$ holds.

the whole anticipation phase $0 < t < T$.[47] On the other hand, it leads to an increase of foreign output and to foreign inflation during the time span $0 < t < T$.

To avoid domestic deflation during the anticipation period the monetary policy rule (32) must already be implemented at the time of anticipation of the oil price shock, i.e. at $t = 0$. It then guarantees $\dot{p}^c = 0$ at any time $t > 0$. Note that the growth rate of money supply that is induced by the policy rule (32) must be *positive* for $0 < t < T$ (figure 19). This is not surprising since the anticipation of a future contraction in monetary growth rate as a response to the realization of the oil price increase causes on impact domestic *disinflation* which can only be removed by an *expansionary* monetary policy over the time interval $0 < t < T$.

A unilateral fixing of the rate of change of the domestic price index with the help of the domestic policy rule (32) has the drawback that it causes *foreign inflation* during the anticipation phase and is unable to reduce the inflationary effects for the *foreign* economy which occur after the implementation of the oil price increase (figure 20).

A simultaneous stabilization of the domestic and foreign consumer inflation rate at their respective initial steady state level is only possible if in addition to the domestic monetary policy rule an analogous foreign policy rule is implemented at the time of anticipation of the oil price shock:

$$\dot{m}^* = -(1 - \alpha^*)\dot{\tau} + \frac{1}{2}\dot{l}^s - \frac{1}{2}\dot{l}^d \qquad (33)$$

Figure 21 shows that the growth rate of foreign money supply that results from (33) is negative for both $t < T$ and $t > T$. It must be negative for $T < t < \infty$ in order to eliminate foreign inflation for $t > T$. In contrast to domestic monetary policy it must also be negative during the anticipation phase $0 < t < T$ since the implementation of the domestic monetary policy rule leads to relatively strong foreign inflationary effects over the time interval $0 < t < T$. These effects can not be neutralized by the anticipation effects of the contractionary foreign monetary policy rule (33) if it is implemented at time T.

[47] The fact that a credible announcement of a contractionary monetary policy leads to disinflation even before the contraction actually occurs is a well known result, see Ball (1994). Due to the contractionary effect of the real appreciation we do not find – in contrast to Ball (1994) in an closed economy model – a disinflationary boom in our open economy framework.

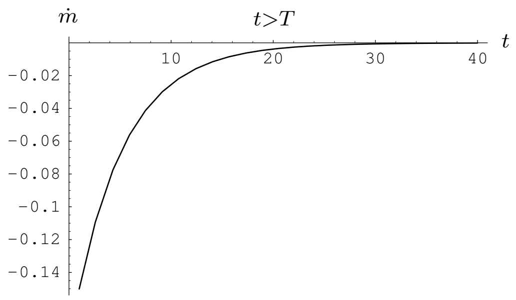

Figure 16: Development of domestic monetary growth rate $\dot{m}$ according to the policy rule (32)

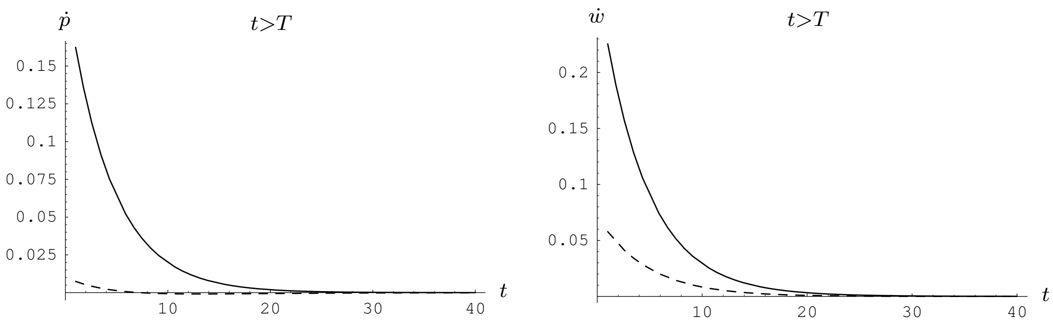

Figure 17: Response of domestic price and wage inflation rate $\dot{p}$ and $\dot{w}$ respectively to an unstabilized (**solid lines**) and a stabilized oil price shock (**dashed lines**)

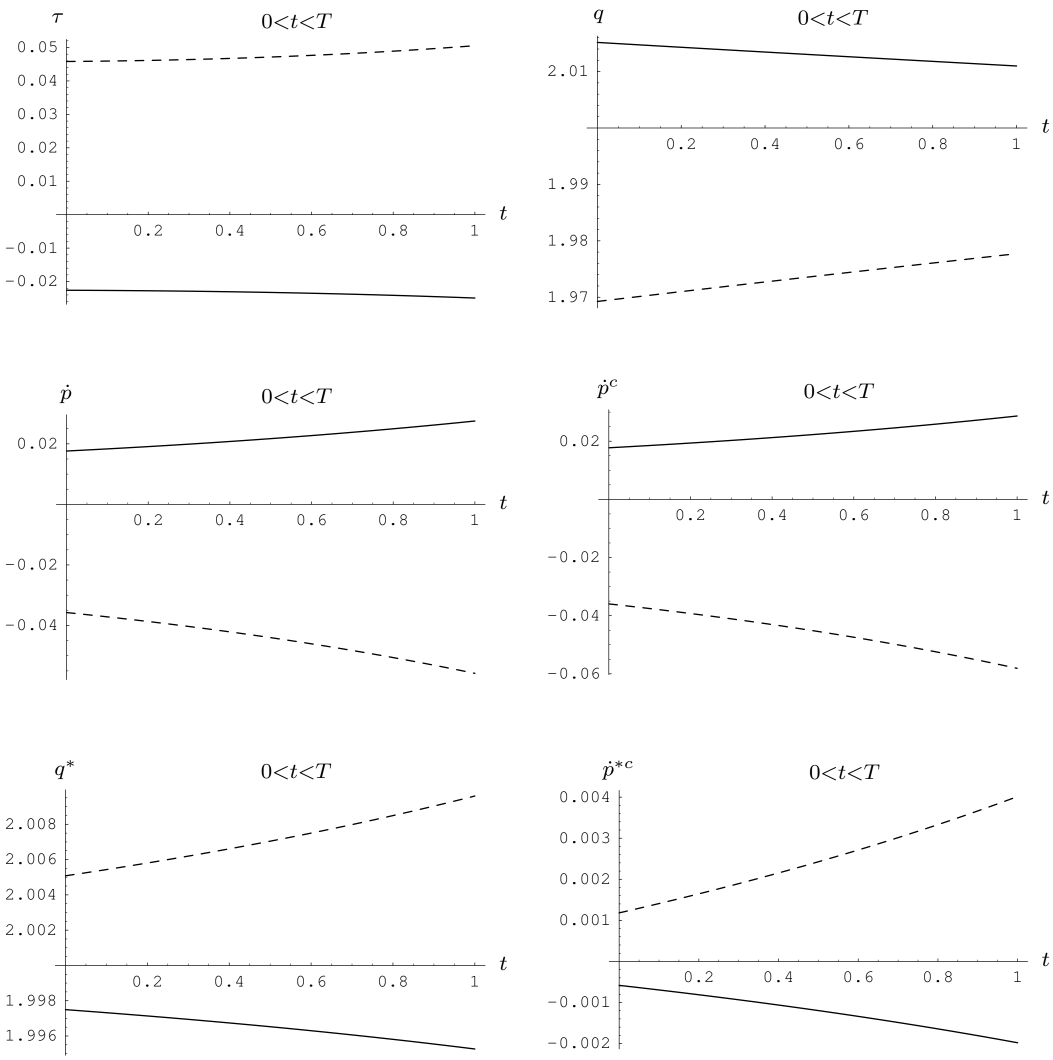

Figure 18: Response of terms of trade τ, domestic output q, domestic price inflation rate $\dot{p}$, domestic consumer price inflation rate $\dot{p}^c$, foreign output q and foreign consumer inflation rate $\dot{p}^{*c}$ to an isolated oil price shock (**solid lines**) and to a stabilized oil price shock (**dashed lines**) during the anticipation period

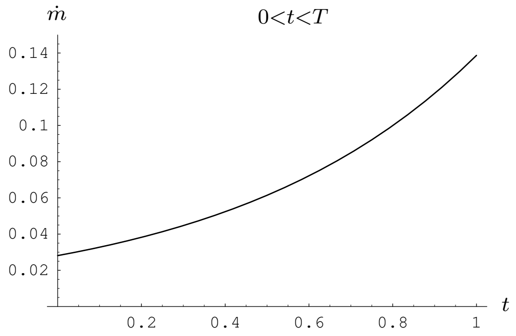

Figure 19: Development of domestic monetary growth rate $\dot{m}$ during the anticipation period according to the policy rule (32)

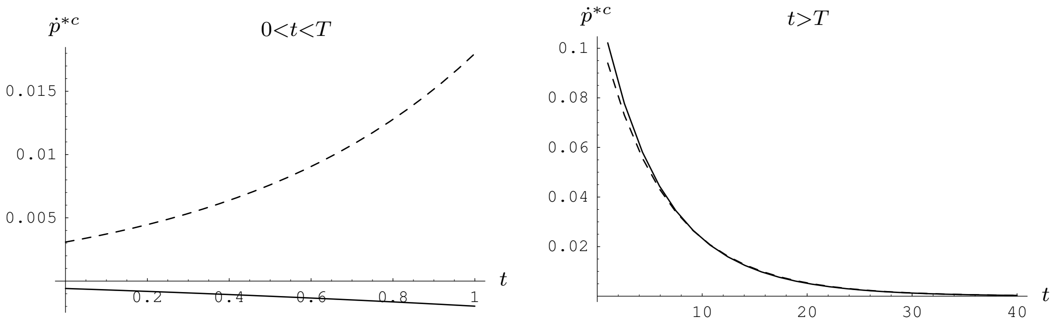

Figure 20: Response of foreign consumer inflation rate $\dot{p}^{*c}$ to an unstabilized (**solid lines**) and a stabilized (**dashed lines**) oil price shock

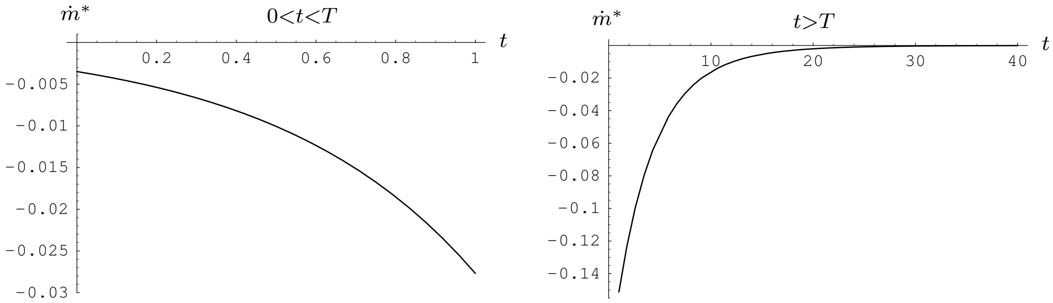

Figure 21: Development of foreign monetary growth rate $\dot{m}^{*}$ according to the policy rule (33)

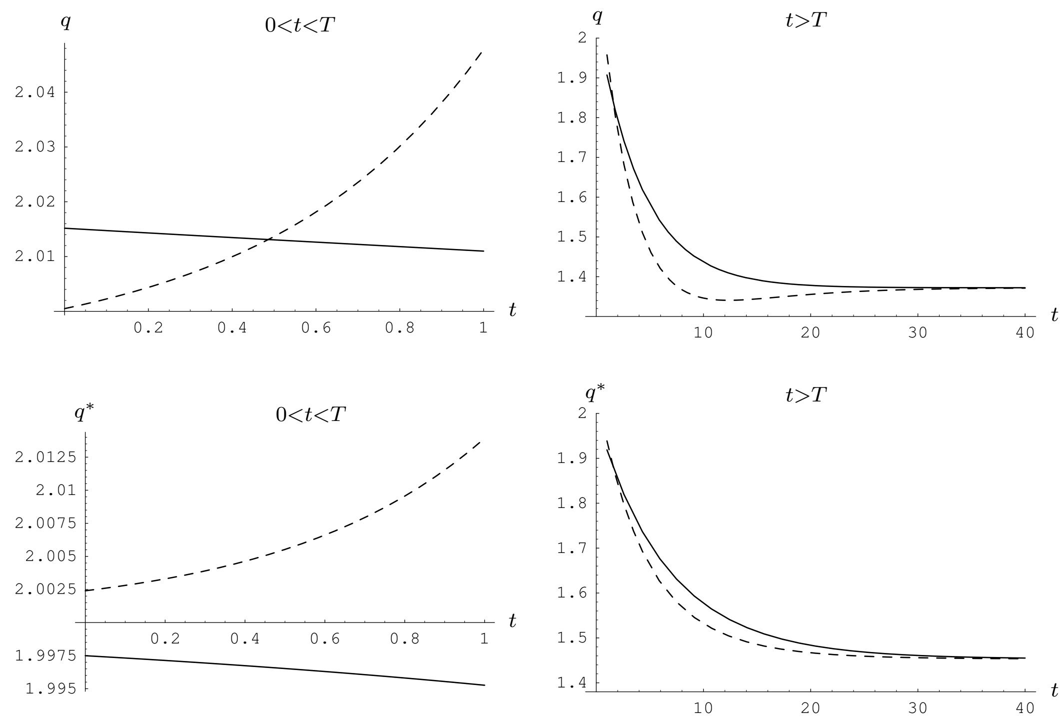

Figure 22: Response of domestic and foreign output q and q^* respectively to an isolated oil price shock (**solid lines**) and to a stabilized oil price shock (**dashed lines**)

6.2 Complete System Stabilization

The implementation of the policy rules (32) and (33) has the disadvantage that during the time interval $0 < t < \infty$ it leads to a *permanent* change of the growth rate of domestic and foreign money supply. A further disadvantage is that, with the exception of the inflation rates $\dot{p}^c$ and $\dot{p}^{*c}$, they cannot prevent adjustment dynamics of the endogenous variables induced by the oil price shock. In particular, the contractionary output effects after the realization of the oil price shock are temporarily increased (figure 22). The question therefore arises whether monetary policy is able to eliminate all *dynamic* effects of an anticipated increase of the price of raw materials imports. On the one hand, that means the neutralization of the anticipation effects of a future rise of p_R^*, i.e. the fixing of all endogenous variables of the system at their respective initial steady state level for $0 < t < T$. On the other hand, complete system stabilization requires an instantaneous jump into the new steady state of the whole system after the implementation of the materials price increase. In this case there are also no adjustment processes in the period after the exogenous price shock. If this is possible by a suitable monetary policy, adjustment dynamics (for example business cycles or divergent economic developments across the large open economies) can be avoided both for $t < T$ and $t > T$. In the mathematical appendix it is shown that the economic policy goal of complete system stabilization is attainable by an international coordination of monetary policy which requires a once-and-for-all reduction of both the domestic and foreign growth rate of money supply.

Dynamic Effects of an Oil Price Increase under Endogenous Oil Pricing Rules

A permanent decline of the growth rate of *foreign* money supply ($d\dot{m}^* < 0$) has the effect that – given a constant US dollar price of imported raw materials for $t > T$ – *no* steady state of the foreign real factor price $p_R^* - p^*$ exists. Without a permanent adjustment of the price of oil there would be a long run positive or negative growth of the real factor price $p_R^* - p^*$ with the rate $\dot{p}_R^* - \overline{\dot{p}_1^*} = -\dot{m}_1^* = -(\dot{m}_0^* + d\dot{m}^*)$.[48] It seems therefore natural to endogenize the foreign-currency price of oil according to the pricing rule[49]

$$\dot{p}_R^* = \dot{m}^* \tag{34}$$

or

$$\dot{p}_R^* = \dot{p}^* \tag{35}$$

The pricing rule can be rationalized if the initial steady state is characterized by a *positive* growth rate of foreign money supply (i.e., $\dot{m}_0^* > 0$) so that the foreign inflation rate is initially positive ($\overline{\dot{p}_0^*} = \dot{m}_0^* > 0$). Given a fixed level of the US dollar price of oil the foreign real factor price $p_R^* - p^*$ would then fall continuously throughout the anticipation phase leading to a *continuous deterioration* of the terms of trade of the oil-exporting nation with

[48] Note that in the long run the inflation rate is determined by the growth rate of money supply. $\dot{m}_0^*$ denotes the initial, $\dot{m}_1^*$ the new monetary growth rate. If $\dot{m}_0^* > 0$ then $\dot{m}_1^*$ may also be positive although $d\dot{m}^* < 0$.

[49] It is also possible to couple $\dot{p}_R^*$ with $-\dot{e}$ if oil imports are priced in dollars. Cf. Yousefi and Wirjanto (2004).

respect to the large foreign economy. To prevent such a process of real depreciation from the perspective of the oil-exporting economy the rate of change of the oil price must be coupled with the monetary growth rate $\dot{m}^*$ or the foreign inflation rate $\dot{p}^*$. In the first case both the adjustment dynamics and steady state effects of a once-and-for-all increase of the factor price p_R^* remain unchanged while under the second materials pricing rule the dynamics and long run effects change considerably compared with the benchmark scenario $\dot{p}_R^* = \dot{m}^* = 0$.[50] If the rate of change of the foreign-currency price of oil is coupled with the foreign inflation rate $\dot{p}^*$ then the real factor price $p_R^* - p^*$ does not rise for $0 < t < T$ (as in the benchmark case) but persists at its initial steady state level during the whole anticipation phase. At the date of implementation of the oil price increase the real factor price $p_R^* - p^*$ rises by the same amount as p_R^* and remains at its new steady state level thereafter (figure 23). A further striking result that differs considerably from the benchmark scenario is the real appreciation of the domestic currency over the interval $0 < t < T$ causing a domestic output contraction on impact and a foreign output expansion (figure 25).

At the date of implementation of the oil price rise there is now a discontinuous *increase* of q and q^* – although the real factor prices $p_R^* + e - p$ and $p_R^* - p^*$ rise sharply at time T (figure 23). The reason is that at time T a strong increase of the consumer inflation rates $\dot{p}^c$ and $\dot{p}^{*c}$ takes place (figure 24) leading to a strong fall of the domestic and foreign real interest rate. After the output jump in T a sharp output contraction in both economies occurs (figure 25). Since the long run rise of the real factor prices is reinforced if $\dot{p}_R^*$ is coupled with the inflation rate $\dot{p}^*$, the steady state output contraction in both economies is *stronger* than in the benchmark scenario. From the perspective of the oil-exporting nation the steady state improvement of its terms of trade (i.e., the real factor prices) with respect to the oil-importing economies is reinforced (figure 23). According to equations (24) and (25) this does not imply that the real oil imports of the large open economies increase in the long run. On the contrary, the steady state rise of the domestic and foreign trade balance with respect to OPEC is generally increased under the pricing rule $\dot{p}_R^* = \dot{p}^*$.

[50] Note that if $\dot{m}^* > 0$ initially and $\dot{p}_R^* = \dot{m}^*$ holds, the input price p_R^* already increases continuously during the time interval $0 < t < T$, i.e., before the discontinuous price shock $dp_R^* > 0$ occurs. The same holds under the pricing rule $\dot{p}_R^* = \dot{p}^*$, since $\dot{p}^* > 0$ for $0 < t < T$ if $\dot{p}_R^*$ is coupled with $\dot{p}^*$. Note that in the benchmark scenario, i.e. in case $\dot{p}_R^* = \dot{m}^* = 0$, the foreign inflation rate is negative for $0 < t < T$ (cf. figure 4). Under the pricing rule $\dot{p}_R^* = \dot{p}^*$ the development of the foreign inflation rate $\dot{p}^*$ is identical with the adjustment of the wage rate $\dot{w}^*$, since in this case equation (14) is equivalent to $\dot{p}^* = \dot{w}^*$.

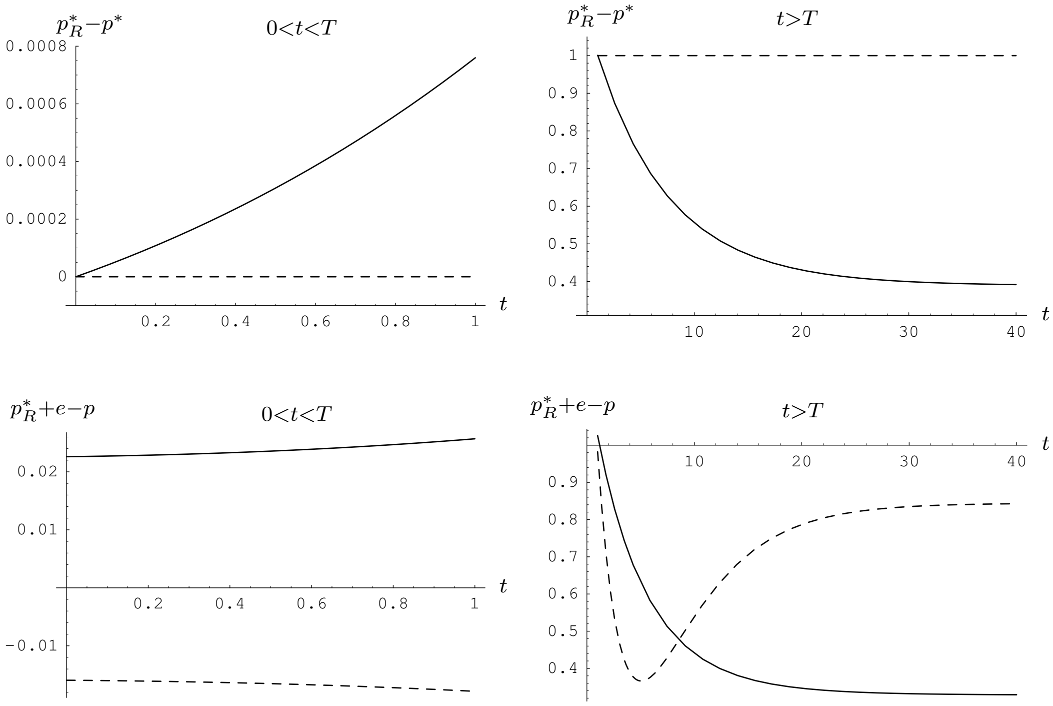

Figure 23: Response of foreign and domestic real factor price $p^*_R - p^*$ and $p^*_R + e - p$ respectively to an anticipated oil price increase in the benchmark case (**solid lines**) and in the case $\dot{p}^*_R = \dot{p}^*$ (**dashed lines**)

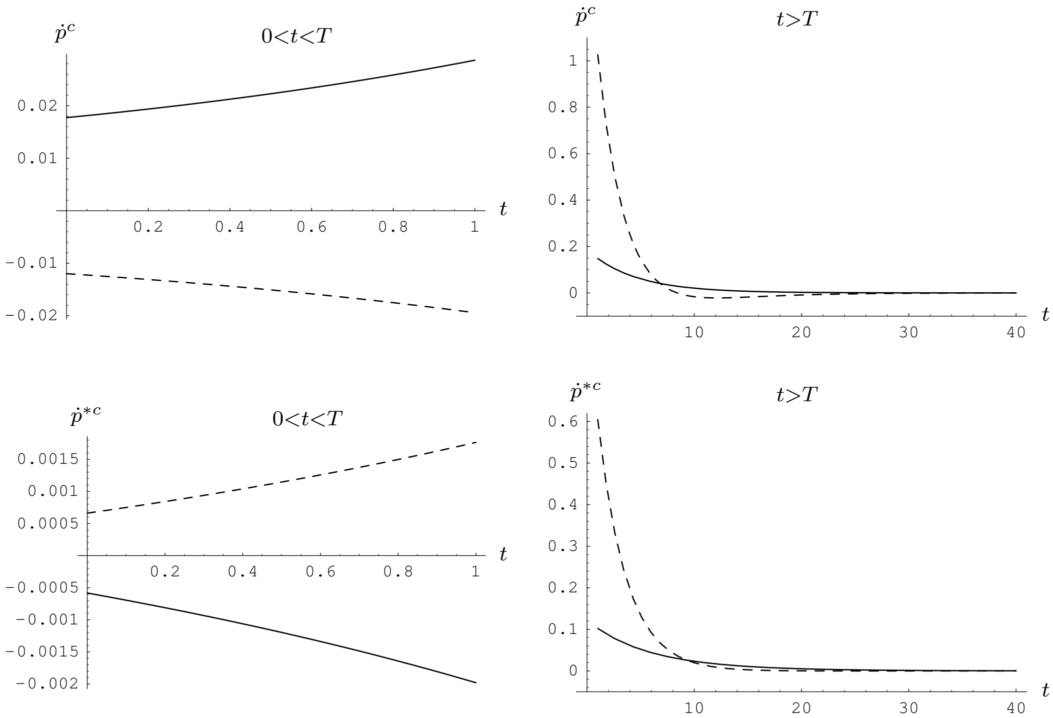

Figure 24: Response of domestic and foreign consumer price inflation rate $\dot{p}^c$ and $\dot{p}^{*c}$ respectively to an anticipated oil price increase in the benchmark case (**solid lines**) and in the case $\dot{p}^*_R = \dot{p}^*$ (**dashed lines**)

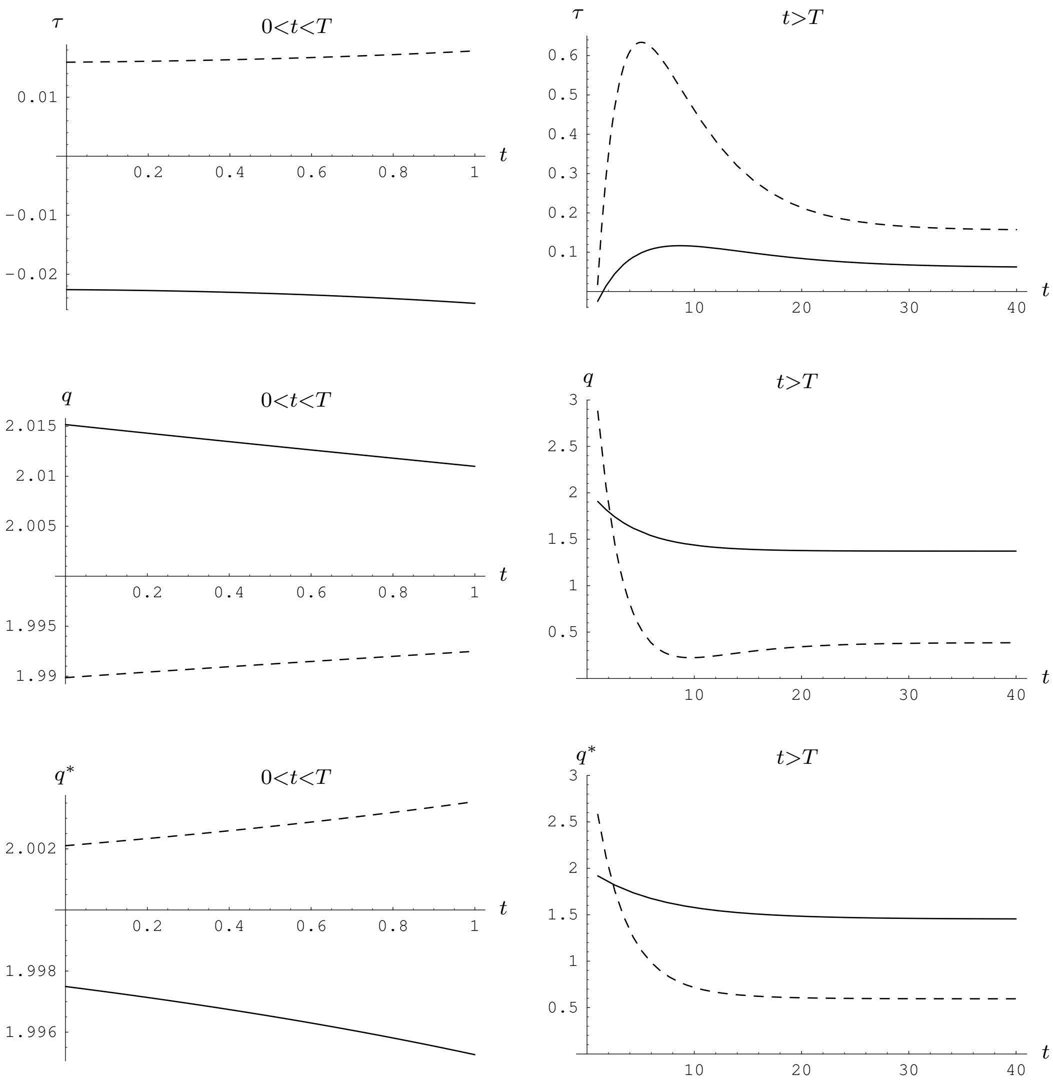

Figure 25: Response of terms of trade τ, domestic and foreign output q and q^* respectively to an anticipated oil price increase in the benchmark case (**solid lines**) and in the case $\dot{p}_R^* = \dot{p}^*$ (**dashed lines**)

The System-Stabilizing Monetary Policy

Consider now the international coordination of monetary policy to attain complete system stabilization if either the materials pricing rule (34) or (35) holds. We first discuss full system stabilization in the period $0 < t < T$ prior to the implementation of the rise of the US dollar price of oil. In the mathematical appendix it is shown that the removal of any anticipation effects of a future oil price shock is achievable by the credible announcement of a *unilateral* monetary policy action at time $t = 0$ to take effect at the time of implementation of the factor price increase. If the materials pricing rule $\dot{p}_R^* = \dot{m}^*$ holds, the exogenous price shock $dp_R^* > 0$ leads on impact to a fall of the domestic terms of trade τ ($\tau(0+) < \overline{\tau}_0$, cf. figure 2). Fixing τ at its initial steady state level $\overline{\tau}_0$ requires the credible announcement of a contractionary domestic monetary policy, i.e. $d\dot{m}^{ann.} < 0$.[51] In case of the pricing rule $\dot{p}_R^* = \dot{p}^*$ the terms of trade τ *rise* on impact (cf. figure 25) so that the credible announcement of a contractionary *foreign* monetary policy (i.e., $d\dot{m}^{*\,ann.} < 0$) stabilizes τ and the other endogenous variables at their respective initial steady state level during the whole anticipation phase.[52]. In particular, the inflation rates remain constant in this period and no output contraction can occur prior to the implementation of the oil price increase.

If the domestic and foreign central bank in the case of the pricing rule $\dot{p}_R^* = \dot{m}^*$ and $\dot{p}_R^* = \dot{p}^*$ respectively implement the announced reduction in monetary growth and given the discretionary increase of the oil price in T, the state vector $(l^s, \tau, l^d)'$ continuously moves in period $t > T$ to a new steady state that differs from that one in the case of a passive monetary policy. In a phase diagram the state vector $(l^s, \tau, l^d)'$ without jump converges across a stable trajectory from its initial steady state towards its new steady state (figure 26).[53] In comparison with the new steady state in case of a passive monetary policy we get the same rise of the equilibrium value of the terms of trade τ (cf. figure 27). On the other hand, the long run fall of the aggregate monetary state variable l^s induced by the oil price increase $dp_R^* > 0$ is now weaker, since the monetary policy $d\dot{m} < 0$ ($d\dot{m}^* < 0$ in case $\dot{p}_R^* = \dot{p}^*$ respectively) in isolation leads to a rise of the steady state variable $\overline{l}^s$. The same holds for the difference variable $\overline{l}^d$ in case $d\dot{m} < 0$ (cf. figure 27, left), while the fall of $\overline{l}^d$ is reinforced if $d\dot{m}^* < 0$ holds (cf. figure 27, right).[54] Adjustment dynamics throughout the

[51] The precise formula for $d\dot{m}^{ann.}$ is given in the mathematical appendix, Section D. Note that the policy is consistent with the goal of price stability since it does not lead to a long run rise of the domestic inflation rates $\dot{p}$ and $\dot{p}^c$.

[52] It is a well known result that the anticipation of a future once-and-for-all fall of the growth rate of money supply leads on impact to a real appreciation. See, for example, Clausen and Wohltmann (2005).

[53] The trajectory lies on the stable saddle path belonging to the initial steady state. The formula for the stable saddle path, which is a hyperplane in the case of a three-dimensional state vector, is presented in the mathematical appendix.

[54] The corresponding multipliers are given by

$$\frac{\partial \overline{l}^s}{\partial \dot{m}} = \frac{\partial \overline{l}^d}{\partial \dot{m}} = -l_2$$

$$\left.\frac{\partial \overline{l}^s}{\partial \dot{m}^*}\right|_{\dot{p}_R^*=\dot{p}^*} = -\left.\frac{\partial \overline{l}^d}{\partial \dot{m}^*}\right|_{\dot{p}_R^*=\dot{p}^*} = -l_2$$

period after the oil price shock also occur for the other endogenous variables of the system (cf. figure 28), i.e. cannot be avoided by the implementation of the announced restrictive monetary policy. Since the stabilization of the system prior to the implementation of the oil price shock requires a *weak* contractionary monetary policy the output development for $t > T$ in the case of an active monetary policy differs only *slightly* from the corresponding output adjustment in case of a passive monetary policy (cf. figure 28). Compared with the case of a passive monetary policy ($d\dot{m} = 0$) the jumps of the inflation rates at time T are now slightly smaller (figure 29). Moreover, a long run fall of the domestic inflation rates takes place if $d\dot{m}^{ann.} < 0$ is actually implemented.[55]

The removal of any adjustment dynamics throughout the period $t > T$ will only be achieved if the central bank deviates from the previously announced and therefore anticipated contractionary monetary policy by implementing a reduction of the growth rate of money supply which is *stronger* than the announced one (i.e., $d\dot{m}^{impl.} < d\dot{m}^{ann.}$). Moreover, full system stabilization for $t > T$ is *not* attainable by a *unilateral* monetary policy response but requires a *simultaneous* coordinated action of the domestic and foreign central bank in the sense that both the domestic and foreign monetary growth rate must be reduced at time T in a *non-anticipated manner* (i.e., $d\dot{m}^{impl.} < 0$ *and* $d\dot{m}^{*\,impl.} < 0$, cf. figure 30).[56] An analogous result holds in case $d\dot{m}^{*\,ann.} < 0$, i.e. if the pricing rule $\dot{p}_R^* = \dot{p}^*$ holds.

In the mathematical appendix it is shown that the realized domestic and foreign monetary policy does not depend upon the underlying materials pricing rule. It can also be shown that the long run *total* change of any endogenous variable remains unchanged if the pricing rule $\dot{p}_R^* = \dot{m}^*$ is replaced by $\dot{p}_R^* = \dot{p}^*$. In particular,

$$d\overline{x}|_{\dot{p}_R^*=\dot{m}^*} = d\overline{x}|_{\dot{p}_R^*=\dot{p}^*} \qquad \text{for } \overline{x} \in \{\overline{q}, \overline{q}^*\} \tag{36}$$

holds. Since *foreign* monetary policy has long run output effects, if $\dot{p}_R^* = \dot{m}^*$, while it is neutral under the pricing rule $\dot{p}_R^* = \dot{p}^*$[57], equation (36) implies that the decrease of $\dot{m}^*$ *reinforces* the long run output contraction of oil price shocks, provided $\dot{p}_R^* = \dot{m}^*$ holds. The total output contraction induced by the oil price shock and the monetary policy response coincides with the long run output decrease of the price shock in case $p_R^* = \dot{p}^*$.[58] The required reduction of $\dot{m}$ and $\dot{m}^*$ to achieve full system stabilization is determined by the condition that all impulses taken together – the oil price shock and the domestic and foreign policy response – do *not* change the initial steady state values of the monetary

[55] The same holds for the foreign inflation rates $\dot{p}^*$ and $\dot{p}^{*c}$ in case that $d\dot{m}^{*\,ann.} < 0$ is realized at time T.

[56] Note that if the removal of adjustment dynamics is required only for the period *after* the implementation of the oil price shock, the domestic and foreign growth rate of money supply must be reduced at time T in an *anticipated* manner (cf. the mathematical appendix, Section D.4). In this case there exist anticipation effects which lead on impact to a reduction in domestic and an increase in foreign output. Moreover, a disinflationary process in the domestic and an inflationary process in the foreign economy occur during the anticipation phase $0 < t < T$.

[57] See the mathematical appendix, Section D.

[58] Note that the price shock $dp_R^* > 0$ has *stronger* steady state output effects under the pricing rule $\dot{p}_R^* = \dot{p}^*$ than in case $\dot{p}_R^* = \dot{m}^*$ (cf. figure 23).

state variables l^s and l^d:

$$d\bar{l}^s \;=\; \sum_{i=1}^{3} \frac{\partial \bar{l}^s}{\partial x_i} dx_i \;=\; d\bar{l}^d \;=\; \sum_{i=1}^{3} \frac{\partial \bar{l}^d}{\partial x_i} dx_i \;=\; 0 \qquad x_i \in \{p_R^*, \dot{m}^*, \dot{m}\} \tag{37}$$

Saddle path stability and the sluggishness of the state variables l^s and l^d then imply that in a three-dimensional phase diagram the state vector in T jumps in response to the oil price increase and the correction of expectations with respect to the actual growth rate of money supply vertically along the τ axis into its new steady state and remains there thereafter. The same holds for the other jump variables of the system (q and q^* in particular) where the jump in T coincides with the steady state change of the corresponding variable, which is independent from T and the assumed materials pricing rule. Since the price shock $dp_R^* > 0$ leads to a stronger fall of $\bar{l}^s$ than $\bar{l}^d$, and the steady state effects of $d\dot{m} < 0$ with respect to the state variables l^s and l^d are completely symmetric, foreign monetary policy must close the gap between $d\bar{l}^s$ and $d\bar{l}^d$ induced by the shock $dp_R^* > 0$. Such a monetary policy then leads to a fixing of the foreign real money stock $(m^* - p^*)$ at its initial steady state level:

$$\begin{aligned} &\frac{\partial \bar{l}^s}{\partial p_R^*} dp_R^* + \frac{\partial \bar{l}^s}{\partial \dot{m}^*} d\dot{m}^* - \left(\frac{\partial \bar{l}^d}{\partial p_R^*} dp_R^* + \frac{\partial \bar{l}^d}{\partial \dot{m}^*} d\dot{m}^* \right) = \\ &\frac{1}{2} \left(\frac{\partial(\overline{m^* - p^*})}{\partial p_R^*} dp_R^* + \frac{\partial(\overline{m^* - p^*})}{\partial \dot{m}^*} d\dot{m}^* \right) \;=\; \frac{1}{2} \cdot d(\overline{m^* - p^*}) \;=\; 0 \end{aligned} \tag{38}$$

Solving this equation for $\dot{m}^*$ leads to the decision rule for foreign monetary policy. Since both multipliers $\partial(\overline{m^* - p^*})/\partial p_R^*$ and $\partial(\overline{m^* - p^*})/\partial \dot{m}^*$ are negative it follows that a reduction of the growth rate of foreign money supply is required to stabilize the foreign real money stock at its initial equilibrium level.

Complete system stabilization for $t > T$ is achievable if the foreign monetary policy is combined with a domestic monetary policy that leads to a rise of the state variables $\bar{l}^s$ and $\bar{l}^d$ of equal size such that their initial steady state levels are attained. Obviously, domestic monetary policy then fixes domestic real money supply at its initial equilibrium level (i.e., $d(\overline{m - p}) = 0$) which requires a fall of the growth rate of domestic money supply by the amount

$$d\dot{m} \;=\; \frac{-1}{\partial(\overline{m - p})/\partial \dot{m}} \left(\frac{\partial(\overline{m - p})}{\partial p_R^*} dp_R^* + \frac{\partial(\overline{m - p})}{\partial \dot{m}^*} d\dot{m}^* \right) < 0 \tag{39}$$

where $\partial(\overline{m - p})/\partial \dot{m} = -l_2$ and $\partial(\overline{m - p})/\partial \dot{m}^* = 0$ in case $\dot{p}_R^* = \dot{p}^*$. The realized domestic monetary policy (39) is stronger contractionary than the one previously announced.[59] The reason is that the implementation of the pre-announced contractionary monetary policy is insufficient to stabilize the domestic real money supply at its initial steady state level. The actual reduction of the growth rate of domestic money supply must therefore be stronger than the announced one.

[59] The same holds in case of an announced foreign monetary policy ($d\dot{m}^{*\,implemented} < d\dot{m}^{*\,announced} < 0$).

The announcement or anticipation of a contractionary monetary policy and the actual implementation of a policy which is *more* restrictive, means that in *quantitative* terms the behavior of the central bank is *time-inconsistent*.[60] In contrast, monetary policy remains *time-consistent* in *qualitative* terms because the previously announced and the actual course of monetary policy still move in the same direction.[61] The quantitative deviation of the actual policy from the announced policy response does not seriously undermine the *reputation* of monetary policy.[62] This holds the more as the long run inflation rate decreases in both cases so that the goal of price stability is not violated. Finally, the changeover from the previously announced monetary policy to the actual response (39) in combination with an unexpected international monetary policy coordination leads to a complete system stabilization. Adjustment dynamics of the domestic and foreign real variables as well as temporary inflation resulting from an anticipated increase in the US dollar price of oil can be *completely* avoided.

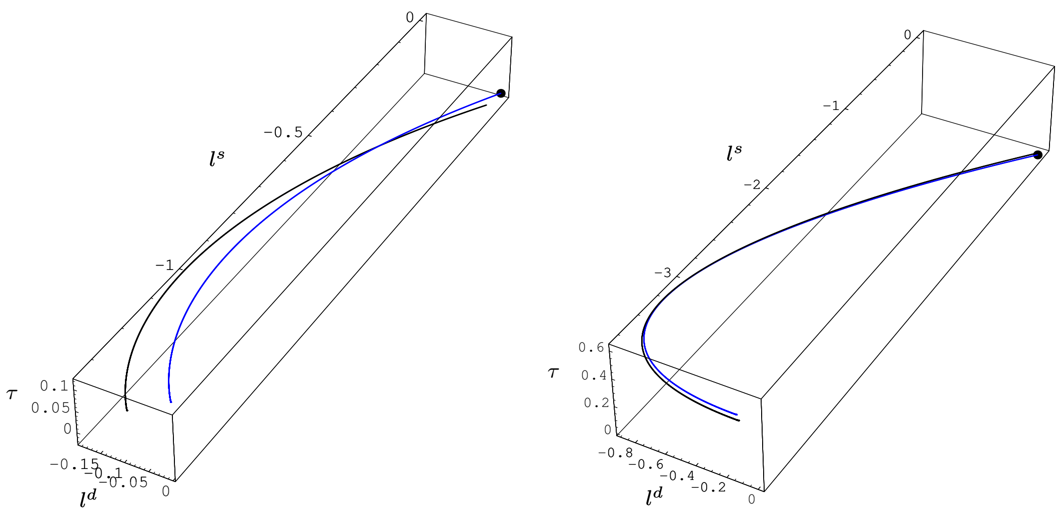

Figure 26: Response of state vector $(l^s, \tau, l^d)'$ for $t > T$ to an active monetary policy (**pale line**) and to a passive monetary policy (**solid line**) for both the pricing rule $\dot{p}^*_R = \dot{m}^*$ (left) and the pricing rule $\dot{p}^*_R = \dot{p}^*$ (right) in a phase diagram; initial steady state (**bold dot**)

[60] Note that time-inconsistency problems can only occur in case $T > 0$, i.e., if exogenous price shocks are anticipated and if – in addition – full system stabilization shall be achieved both prior to and after the implementation of the oil price shock. If the anticipation effects are not neutralized no time-inconsistency problems occur.

[61] Cf. Wohltmann und Clausen (2003).

[62] Several numerical simulations illustrate that if p^*_R increases by one unit ($dp^*_R = 1$) the difference between $d\dot{m}^{ann.}$ and $d\dot{m}^{impl.}$ may be greater than 1 (cf. figure 30). The removal of the anticipation effects of the price shock $dp^*_R = 1$ only requires a *small* reduction of the growth rate of domestic money supply, while for the neutralization of the dynamic effects after the implementation of the oil price increase a *strong* decrease of $\dot{m}$ is necessary (cf. figure 30).

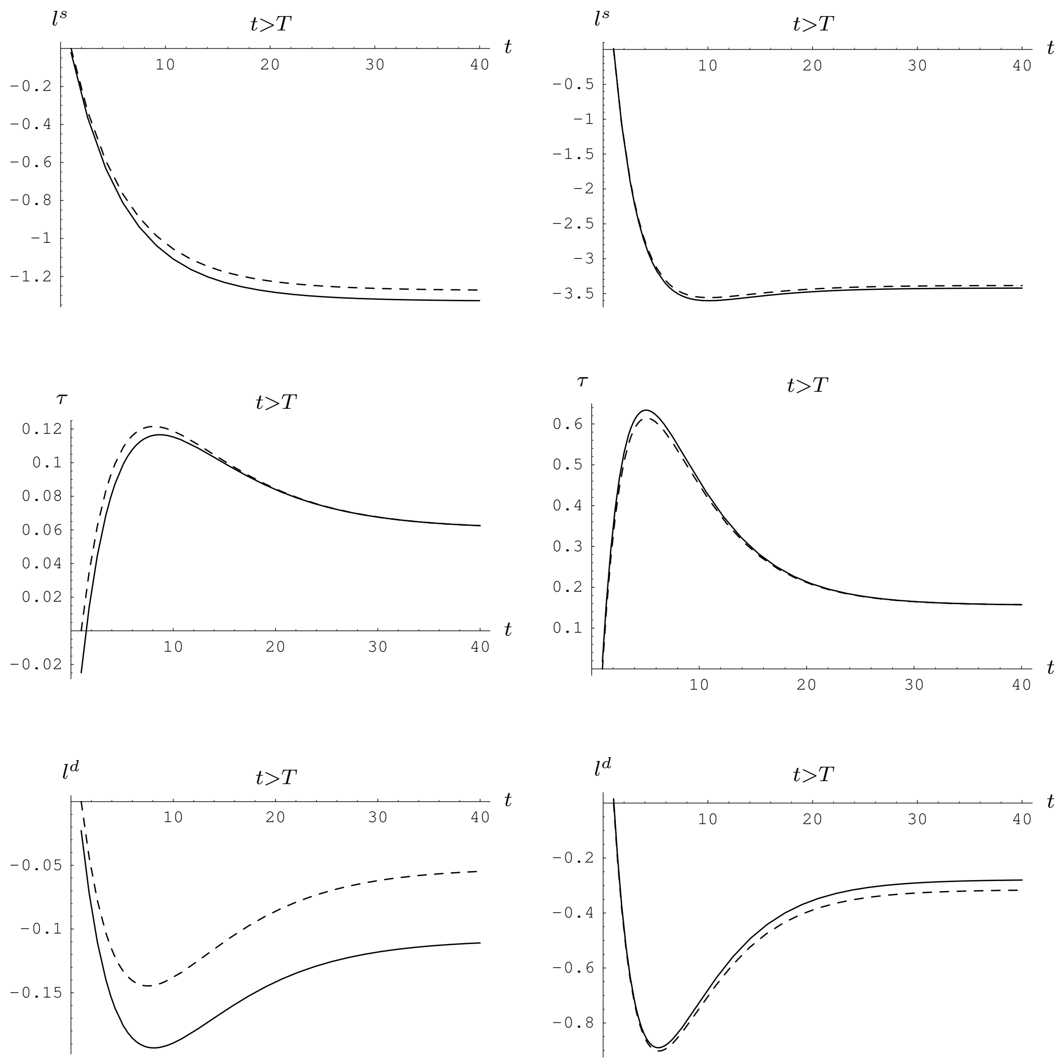

Figure 27: Response of state vector $(l^s, \tau, l^d)'$ to an active monetary policy (**dashed lines**) and to a passive monetary policy (**solid lines**) for both the pricing rule $\dot{p}_R^* = \dot{m}^*$ (left) and the pricing rule $\dot{p}_R^* = \dot{p}^*$ (right)

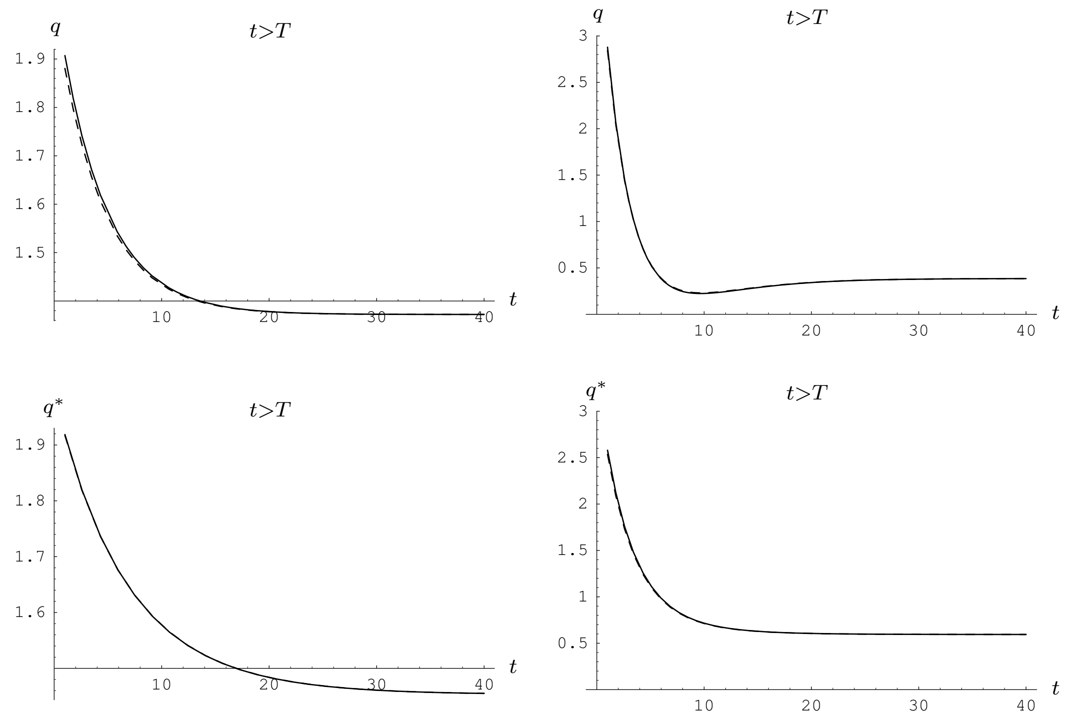

Figure 28: Response of domestic and foreign output q and q^* respectively to an active monetary policy (**dashed lines**) and to a passive monetary policy (**solid lines**) for both the pricing rule $\dot{p}_R^* = \dot{m}^*$ (left) and the pricing rule $\dot{p}_R^* = \dot{p}^*$ (right)

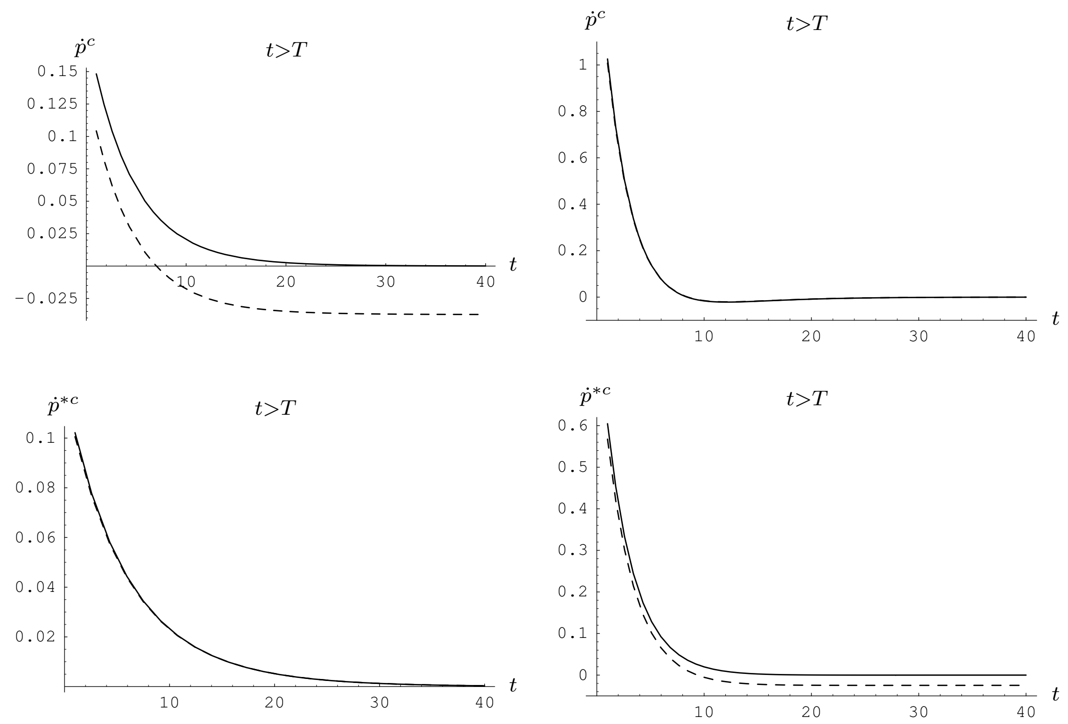

Figure 29: Response of domestic and foreign consumer price inflation rate $\dot{p}^c$ and $\dot{p}^{*c}$ respectively to an active monetary policy (**dashed lines**) and to a passive monetary policy (**solid lines**) for both the pricing rule $\dot{p}_R^* = \dot{m}^*$ (left) and the pricing rule $\dot{p}_R^* = \dot{p}^*$ (right)

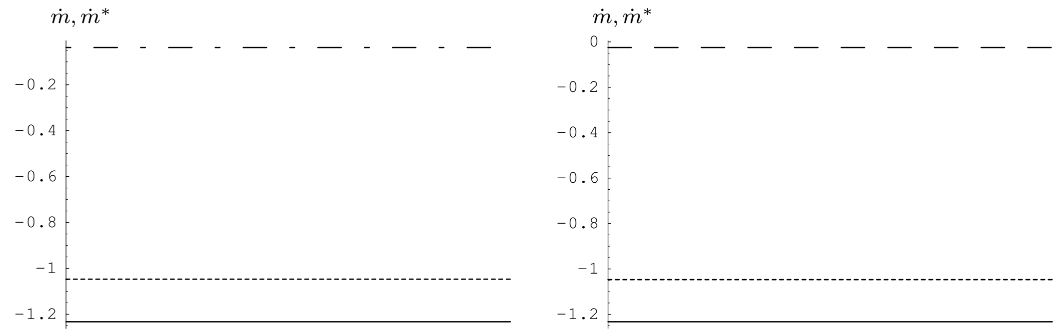

Figure 30: *Left*: Announced growth rate of domestic money supply (**dot-dashed line**) and realized growth rate of domestic (**solid line**) and foreign money supply (**dotted line**) in case $\dot{p}_R^* = \dot{m}^*$. *Right*: Announced growth rate of foreign money supply (**dashed line**) and realized growth rate of domestic (**solid line**) and foreign money supply (**dashed line**) in case $\dot{p}_R^* = \dot{p}^*$

7 Summary of the Main Results

This paper has analyzed a macrodynamic model of two large open economies which are completely dependent upon oil imports from a small third country. It is assumed that the domestic economy (like the European Monetary Union) is stronger oil-dependent than the foreign economy (the USA) and that the degree of wage indexation is greater in Europe than in the US economy. The main results of the analysis may be summarized as follows:

(a) An anticipated permanent increase in the dollar price of oil will involve both economies in a stagflationary situation over the long run. Both economies suffer from temporary inflation, long run price and real factor price increases and a permanent output contraction. The stagflationary effects are stronger for the domestic economy because of its higher degree of oil-dependency. The domestic terms of trade with respect to the large foreign economy improve permanently while for both large open economies the intermediate goods terms of trade with respect to the oil-exporter deteriorate in the long run. Since domestic output falls the trade balances with respect to the oil-exporting nation generally do not deteriorate in the long run.

(b) The impact effects of anticipated oil price shocks are in sharp contrast to the steady state effects. The domestic terms of trade fall instantaneously causing a stimulation of domestic real output above its pre-disturbance level. On the other hand, real output of the large foreign economy on impact decreases while the decline is smaller than the long run contraction. The same holds at the date of implementation of the oil price increase. The rise of the real factor price of oil induces both in the domestic and foreign economy a decline of real output which is smaller than the long run output reduction. This leads to a temporary deterioration of the trade balance against the oil-exporting nation.

(c) The paper also discusses the dynamic effects of an oil price increase if oil is denominated in terms of domestic currency (Euro) rather than US dollars. It is demonstrated that under such pricing the stagflationary effects of oil price shocks are reduced. This holds for both the domestic and the foreign economy. With domestic-currency denominated oil both large open economies are better insulated against oil price increases, except for the fact that the long run improvement of the bilateral real trade balance with respect to the oil-exporting nation is weakened. On impact, the jumps of the output variables are weakened as well.

(d) In addition to the polar cases that oil imports are either completely priced in US dollars or in terms of the domestic currency (Euro), we have also discussed a combination of these cases, i.e. that a fixed share of imported raw materials imports is denominated in dollars while the other share is priced in Euro. It is shown that any mixed case of currency denomination generates long run stagflationary results for both economies which are stronger than in the polar case that all oil imports are priced in Euro. For both large open economies the long run stagflationary effects of materials price increases are minimized if all imports of raw materials or other intermediate goods are completely denominated in terms of Euro. On the other hand, in the case of domestic-currency denominated oil the steady state improvement of the domestic and foreign trade balance with respect to the oil-exporting nation is smallest.

(e) The paper also discusses the adjustment dynamics of anticipated oil price shocks under alternative degrees of wage indexation in the wage adjustment equations of the Phillips' curve type. While the steady state effects of an increase of raw materials imports do not depend on the degree of domestic and foreign wage indexation, this does not hold for the anticipation effects and the dynamic effects resulting from the implementation of the oil price rise. Under real wage rigidity in both economies and with foreign-currency denominated oil, domestic and foreign output on impact rise simultaneously and – due to a strong fall of real interest rates – also at the date of implementation of the oil price shock. The initial increase of domestic output is stronger than in the benchmark scenario (where incomplete and asymmetric wage indexation is assumed). In case of domestic-currency denominated oil the initial jumps of domestic and foreign output are both negative under the regime of real wage rigidity. At the date of implementation of the oil price shock the output jumps are again positive and stronger than in the case of foreign-currency denominated oil imports. The regime of real wage rigidity also leads to higher inflation rates (compared with the benchmark scenario) during the course of adjustment. In this regime the changeover from foreign to domestic-currency denominated oil has the effect that the positive jumps of the inflation rates at the date of implementation are not weakened but reinforced.

(f) The paper also analyzes two types of monetary stabilization policies. It is shown that an international monetary policy coordination is able to fix the domestic and foreign consumer inflation rate at its initial pre-disturbance steady state level at all times. The policy rules for the domestic and foreign growth rate of money supply do not lead to saddle point instability problems, but cause a rise of the positive eigenvalue of the system dynamics. Stabilization of the consumer inflation rates requires a contractionary monetary policy after the realization of the oil price shock. Since the anticipation of these policies leads to a deflation in the domestic economy, domestic monetary policy must be expansionary prior to the implementation of the factor price increase.

In a second step the problem of complete system stabilization, i.e. the removal of any adjustment dynamics caused by an anticipated materials price shock, is discussed. Fixing all endogenous variables throughout the anticipation phase at their respective initial steady state level requires a credible and unilateral announcement of a future once-and-for-all decrease of the growth rate of money supply. Since the realization of such a contractionary monetary policy is not sufficient to neutralize all adjustment dynamics after the implementation of the oil price increase, the realized monetary policy must be stronger contractionary than the announced one. In addition, full system stabilization after the implementation of the oil price shock requires an international monetary policy coordination in the sense of a simultaneous unanticipated reduction of the growth rate of domestic and foreign money supply. In this case all endogenous variables after the occurrence of the price shock immediately jump into their new steady state levels. The new steady state of the complete stabilized system is characterized by a permanent reduction of the domestic and foreign inflation rate. On the other hand, the output contraction induced by the rise of the US dollar price of oil is reinforced. This result holds, since foreign monetary policy has – in contrast to domestic monetary policy – long run output effects if the US dollar price of oil is not coupled with the foreign price level. Moreover, the announcement of a weak and the actual implementation of an unexpected stronger contractionary monetary policy may lead to time-inconsistency problems in quantitative, but not in qualitative terms.

Mathematical Appendix

A Foreign-Currency Denominated Oil Imports

We use the method by Aoki (1981) and transform the whole system (1)–(18) into two subsystems, a difference system and an aggregate system. The difference and the aggregate system consist of the difference and aggregation respectively of corresponding equations of the domestic and foreign economy (like the difference (aggregation) of the *IS* equations). It contains difference and aggregate variables, like $q - q^*$ and $q + q^*$ respectively. The original variables can be obtained using the arithmetic mean of corresponding difference and aggregate variables. Since the supply side of the world system is asymmetric it is not possible to solve the difference system independently of the aggregate system.

The *difference* system consists of the following equations:

$$\begin{aligned}(1 - a_1 + 2c_1)(q - q^*) &= 2c_0 + g - g^* - a_2 i_r^d - (2c_3 - (a_1 - 2c_1)\psi)\tau \\ &\quad + (a_1 - 2c_1)(\psi - \psi^*)(p^* - p_R^*)\end{aligned} \tag{A1}$$

$$y - y^* = q - q^* + \psi\tau + (\psi - \psi^*)(p^* - p_R^*) \tag{A2}$$

$$\begin{aligned}l^d &= (\alpha + \alpha^* - 2)\tau + l_1(q - q^*) \\ &\quad + l_2\dot{\tau} + l_2\dot{l}^d - l_2(\dot{m} - \dot{m}^*)\end{aligned} \tag{A3}$$

$$\begin{aligned}q - q^* &= \overline{q} - \overline{q}^* + \left\{\frac{1}{\delta}\left((1-\beta)(1-\alpha) + \frac{1-\mu}{\mu}\right)\right. \\ &\quad \left. + \frac{1}{\delta^*}(1-\beta^*)(1-\alpha^*)\right\}\dot{\tau} - \frac{\beta}{\delta}(\dot{m} - \dot{p}) \\ &\quad + \frac{\beta^*}{\delta^*}(\dot{m}^* - \dot{p}^*) + \left(\frac{1-\mu}{\delta\mu} - \frac{1-\mu^*}{\delta^*\mu^*}\right)(\dot{p}^* - \dot{p}_R^*)\end{aligned} \tag{A4}$$

$$\overline{q} - \overline{q}^* = f_0 - f_0^* + (f_1 + f_1^* + f_2)\overline{\tau} + (f_2 - f_2^*)(\overline{p^* - p_R^*}) \tag{A5}$$

where

$$i_r^d = (i - \dot{p}^c) - (i^* - \dot{p}^{*c}) = (1 - (\alpha + \alpha^*))\dot{\tau} \tag{A6}$$

is the real interest rate differential. (A1) is the difference of the *IS* equations, (A2) the difference of the income equations (9) and (10), (A3) represents the difference of the *LM* equations (where l^d is the difference of domestic and foreign real money supply and $\dot{e} = -\dot{\tau} - \dot{l}^d + \dot{m} - \dot{m}^*$ is substituted for the nominal interest rate differential $i - i^*$). Equation (A4) is a combination of the difference of corresponding domestic and foreign dynamic price and wage equations, while (A5) represents the difference of the long run aggregate supply functions (17) and (18). Substituting equation (A4) for $q - q^*$ in the *IS* and LM equation (A1) and (A3) respectively and using the transformations

$$\dot{m} - \dot{p} = \frac{1}{2}(\dot{l}^s + \dot{l}^d)\,, \qquad \dot{m}^* - \dot{p}^* = \frac{1}{2}(\dot{l}^s - \dot{l}^d) \tag{A7}$$

(where $\dot{l}^s$ is the rate of change of aggregate real money stock) and

$$\dot{p}^* - \dot{p}^*_R = -\frac{1}{2}(\dot{l}^s - \dot{l}^d) + \dot{m}^* - \dot{p}^*_R \tag{A8}$$

equations (A1), (A3) and (A4) can be rewritten in the form

$$\begin{aligned}
&\Big(\lambda\kappa_1 + a_2(1-(\alpha+\alpha^*))\Big)\dot{\tau} + \lambda\left(-\frac{\beta}{2\delta} + \frac{\beta^*}{2\delta^*} - \frac{1}{2}\kappa_2\right)\dot{l}^s \\
&+ \lambda\left(-\frac{\beta}{2\delta} - \frac{\beta^*}{2\delta^*} + \frac{1}{2}\kappa_2\right)\dot{l}^d + \lambda(\overline{q} - \overline{q}^*) + \lambda\kappa_2(\dot{m}^* - \dot{p}^*_R) \;=\; \\
&\qquad 2c_0 + g - g^* - (2c_3 - (a_1 - 2c_1)\psi)\tau - \frac{1}{2}(a_1 - 2c_1)(\psi - \psi^*)l^s \\
&\qquad + \frac{1}{2}(a_1 - 2c_1)(\psi - \psi^*)l^d + (a_1 - 2c_1)(\psi - \psi^*)(m^* - p^*_R)
\end{aligned} \tag{A9}$$

$$\begin{aligned}
&(l_1\kappa_1 + l_2)\dot{\tau} + \left(l_2 + l_1\left(-\frac{\beta}{2\delta} - \frac{\beta^*}{2\delta^*} + \frac{1}{2}\kappa_2\right)\right)\dot{l}^d \\
&+ l_1\left(-\frac{\beta}{2\delta} + \frac{\beta^*}{2\delta^*} - \frac{1}{2}\kappa_2\right)\dot{l}^s - l_2(\dot{m} - \dot{m}^*) + l_1(\overline{q} - \overline{q}^*) \\
&+ l_1\kappa_2(\dot{m}^* - \dot{p}^*_R) \;=\; l^d + (2 - \alpha - \alpha^*)\tau
\end{aligned} \tag{A10}$$

$$\begin{aligned}
q - q^* \;&=\; \overline{q} - \overline{q}^* + \kappa_1\dot{\tau} + \left(-\frac{\beta}{2\delta} + \frac{\beta^*}{2\delta^*} - \frac{1}{2}\kappa_2\right)\dot{l}^s \\
&\quad + \left(-\frac{\beta}{2\delta} - \frac{\beta^*}{2\delta^*} + \frac{1}{2}\kappa_2\right)\dot{l}^d + \kappa_2(\dot{m}^* - \dot{p}^*_R)
\end{aligned} \tag{A11}$$

where we have used the abbreviations

$$\lambda \;=\; 1 - a_1 + 2c_1 \tag{A12}$$

$$\kappa_1 \;=\; \frac{1}{\delta}\left((1-\beta)(1-\alpha) + \frac{1-\mu}{\mu}\right) + \frac{1}{\delta^*}(1-\beta^*)(1-\alpha^*) \tag{A13}$$

$$\kappa_2 \;=\; \frac{1-\mu}{\delta\mu} - \frac{1-\mu^*}{\delta^*\mu^*} \tag{A14}$$

The *aggregate system* consists of the equations

$$(1-a_1)(q+q^*) = 2a_0 - 2d_0a_1 - a_2 i_r^s + g + g^* + a_1\psi\tau + a_1(\psi+\psi^*)(p^*-p_R^*) \tag{A15}$$

$$y + y^* = q + q^* + \psi\tau + (\psi+\psi^*)(p^*-p_R^*) - 2d_0 \tag{A16}$$

$$l^s = (\alpha-\alpha^*)\tau + 2l_0 + l_1(q+q^*) - l_2(2i^* + \dot{e}) \tag{A17}$$

$$\begin{aligned} q+q^* = \; & \overline{q} + \overline{q}^* + \left\{\frac{1}{\delta}\left((1-\beta)(1-\alpha) + \frac{1-\mu}{\mu}\right) - \frac{1}{\delta^*}(1-\beta^*)(1-\alpha^*)\right\}\dot{\tau} - \left(\frac{\beta}{2\delta} + \frac{\beta^*}{2\delta^*}\right)\dot{l}^s \\ & - \left(\frac{\beta}{2\delta} - \frac{\beta^*}{2\delta^*}\right)\dot{l}^d + \left(\frac{1-\mu}{\delta\mu} + \frac{1-\mu^*}{\delta^*\mu^*}\right)(\dot{p}^* - \dot{p}_R^*) \end{aligned} \tag{A18}$$

$$\overline{q} + \overline{q}^* = f_0 + f_0^* + (f_1 + f_2 - f_1^*)\overline{\tau} + (f_2 + f_2^*)(\overline{p^* - p_R^*}) \tag{A19}$$

where

$$i_r^s = (i - \dot{p}^c) + (i^* - \dot{p}^{*c}) = 2i^* + \dot{e} - (\dot{p}^c + \dot{p}^{*c}) \tag{A20}$$

is the sum of the real interest rates $i - \dot{p}^c$ and $i^* - \dot{p}^{*c}$. Combining the aggregate *IS* and *LM* equation (A15) and (A17) and substituting (A8) and (A18) for $\dot{p}^* - \dot{p}_R^*$ and $q + q^*$ respectively leads to the dynamic equation

$$\begin{aligned} & (a_2l_1 + l_2(1-a_1))\kappa_3\dot{\tau} + (a_2l_1 + l_2(1-a_1))\kappa_4\dot{l}^s \\ & + (a_2l_1 + l_2(1-a_1))\kappa_5\dot{l}^d - a_2l_2(\dot{p}^c + \dot{p}^{*c}) \\ & + (a_2l_1 + l_2(1-a_1))\kappa_6(\dot{m}^* - \dot{p}_R^*) + (a_2l_1 + l_2(1-a_1))(\overline{q} + \overline{q}^*) = \\ & \qquad a_2l^s + (l_2a_1\psi - a_2(\alpha-\alpha^*))\tau + l_2(g+g^*) \\ & \qquad + l_2a_1(\psi+\psi^*)(p^* - p_R^*) + 2a_0l_2 - 2l_0a_2 - 2d_0a_1l_2 \end{aligned} \tag{A21}$$

where

$$\kappa_3 = \frac{1}{\delta}\left((1-\beta)(1-\alpha) + \frac{1-\mu}{\mu}\right) - \frac{1}{\delta^*}(1-\beta^*)(1-\alpha^*) \tag{A22}$$

$$\kappa_4 = -\frac{1}{2}\left(\frac{\beta}{\delta} + \frac{\beta^*}{\delta^*} + \frac{1-\mu}{\delta\mu} + \frac{1-\mu^*}{\delta^*\mu^*}\right) \tag{A23}$$

$$\kappa_5 = \frac{1}{2}\left(-\frac{\beta}{\delta} + \frac{\beta^*}{\delta^*} + \frac{1-\mu}{\delta\mu} + \frac{1-\mu^*}{\delta^*\mu^*}\right) \tag{A24}$$

$$\kappa_6 = \frac{1-\mu}{\delta\mu} + \frac{1-\mu^*}{\delta^*\mu^*} \tag{A25}$$

In (A21) the aggregate inflation rate $\dot{p}^c + \dot{p}^{*c}$ can be replaced by the tautological equation

$$\begin{aligned} \dot{p}^c + \dot{p}^{*c} &= \dot{p}^c - \dot{p} + \dot{p}^{*c} - \dot{p}^* + \dot{p} - \dot{m} + \dot{p}^* - \dot{m}^* + \dot{m} + \dot{m}^* \\ &= (\alpha - \alpha^*)\dot{\tau} - \dot{l}^s + \dot{m} + \dot{m}^* \end{aligned} \tag{A26}$$

while the intermediate goods terms of trade $p^* - p_R^*$ can be replaced by $\frac{1}{2}l^d - \frac{1}{2}l^s + m^* - p_R^*$ (cf. (A8)). Equations (A9), (A10) and (A21) then represent the state space form of the whole model. In deviational form it can be written as follows:

$$\mathbf{B}\begin{pmatrix} \dot{l}^s \\ \dot{\tau} \\ \dot{l}^d \end{pmatrix} = \mathbf{C}\begin{pmatrix} l^s - \bar{l}^s \\ \tau - \bar{\tau} \\ l^d - \bar{l}^d \end{pmatrix} \tag{A27}$$

where the matrices $\mathbf{B} = (b_{ij})_{1\le i,j\le 3}$ and $\mathbf{C} = (c_{ij})_{1\le i,j\le 3}$ are defined by

$$b_{11} = (a_2 l_1 + l_2(1-a_1))\kappa_4 + a_2 l_2 \tag{A28}$$

$$b_{12} = (a_2 l_1 + l_2(1-a_1))\kappa_3 - a_2 l_2(\alpha - \alpha^*) \tag{A29}$$

$$b_{13} = (a_2 l_1 + l_2(1-a_1))\kappa_5 \tag{A30}$$

$$b_{21} = \lambda\left(-\frac{\beta}{2\delta} + \frac{\beta^*}{2\delta^*} - \frac{1}{2}\kappa_2\right) \tag{A31}$$

$$b_{22} = \lambda\kappa_1 + a_2(1 - (\alpha + \alpha^*)) \tag{A32}$$

$$b_{23} = \lambda\left(-\frac{\beta}{2\delta} - \frac{\beta^*}{2\delta^*} + \frac{1}{2}\kappa_2\right) \tag{A33}$$

$$b_{31} = l_1\left(-\frac{\beta}{2\delta} + \frac{\beta^*}{2\delta^*} - \frac{1}{2}\kappa_2\right) \tag{A34}$$

$$b_{32} = l_1\kappa_1 + l_2 \tag{A35}$$

$$b_{33} = l_2 + l_1\left(-\frac{\beta}{2\delta} - \frac{\beta^*}{2\delta^*} + \frac{1}{2}\kappa_2\right) \tag{A36}$$

$$c_{11} = a_2 - \frac{1}{2}l_2 a_1(\psi + \psi^*) \tag{A37}$$

$$c_{12} = l_2 a_1 \psi - a_2(\alpha - \alpha^*) \tag{A38}$$

$$c_{13} = \frac{1}{2}l_2 a_1(\psi + \psi^*) \tag{A39}$$

$$c_{21} = -\frac{1}{2}(a_1 - 2c_1)(\psi - \psi^*) \tag{A40}$$

$$c_{22} = -(2c_3 - (a_1 - 2c_1)\psi) \tag{A41}$$

$$c_{23} = \frac{1}{2}(a_1 - 2c_1)(\psi - \psi^*) \tag{A42}$$

$$c_{31} = 0 \tag{A43}$$

$$c_{32} = 2 - (\alpha + \alpha^*) \tag{A44}$$

$$c_{33} = 1 \tag{A45}$$

The *steady state* of the dynamic system (A27) is obtained if

$$\dot{l}^s = \dot{\tau} = \dot{l}^d = 0 \tag{A46}$$

holds. Equations (A9), (A10) together with (A5) then imply the steady state difference system

$$\begin{aligned}
&\lambda(f_1 + f_1^* + f_2)\overline{\tau} + \frac{1}{2}\lambda(f_2 - f_2^*)\overline{l}^d - \frac{1}{2}\lambda(f_2 - f_2^*)\overline{l}^s = \\
&\quad \lambda(f_2 - f_2^*)(p_R^* - m^*) - \lambda\kappa_2(\dot{m}^* - \dot{p}_R^*) + g - g^* + 2c_0 + \lambda(f_0^* - f_0) \\
&\quad - (2c_3 - (a_1 - 2c_1)\psi)\overline{\tau} - \frac{1}{2}(a_1 - 2c_1)(\psi - \psi^*)\overline{l}^s \\
&\quad + \frac{1}{2}(a_1 - 2c_1)(\psi - \psi^*)\overline{l}^d + (a_1 - 2c_1)(\psi - \psi^*)(m^* - p_R^*)
\end{aligned} \tag{A47}$$

$$\begin{aligned}
\overline{l}^d + (2 - \alpha - \alpha^*)\overline{\tau} \;&=\; -l_2(\dot{m} - \dot{m}^*) + l_1\kappa_2(\dot{m}^* - \dot{p}_R^*) \\
&\quad + l_1(f_1 + f_1^* + f_2)\overline{\tau} + l_1(f_0 - f_0^*) \\
&\quad + l_1(f_2 - f_2^*)\left(\frac{1}{2}\overline{l}^d - \frac{1}{2}\overline{l}^s + m^* - p_R^*\right)
\end{aligned} \tag{A48}$$

where we have used the transformation (cf. (A8))

$$p^* - p_R^* = -\frac{1}{2}(l^s - l^d) + m^* - p_R^* \tag{A49}$$

The steady state equation of the aggregate system follows from (A19), (A21), (A26) and the steady state condition (A46):

$$\begin{aligned}
&(a_2 l_1 + l_2(1 - a_1))\Big\{(f_1 + f_2 - f_1^*)\overline{\tau} + (f_2 + f_2^*)\left(\frac{1}{2}\overline{l}^d - \frac{1}{2}\overline{l}^s + m^* - p_R^*\right) \\
&+ f_0 + f_0^* + \kappa_6(\dot{m}^* - \dot{p}_R^*)\Big\} = 2a_0 l_2 - 2l_0 a_2 - 2d_0 a_1 l_2 + a_2 l_2(\dot{m} + \dot{m}^*) \\
&\qquad + (l_2 a_1 \psi - a_2(\alpha - \alpha^*))\overline{\tau} \\
&\qquad + \left(a_2 - \frac{1}{2}l_2 a_1(\psi + \psi^*)\right)\overline{l}^s \\
&\qquad + \frac{1}{2}l_2 a_1(\psi + \psi^*)\overline{l}^d + l_2(g + g^*) \\
&\qquad + l_2 a_1(\psi + \psi^*)(m^* - p_R^*)
\end{aligned} \tag{A50}$$

Assuming $\dot{m}^* = \dot{p}_R^* = 0$ and constant values of g, g^* and m^* the steady state system (A47), (A48), (A50) has the following matrix representation:

$$\begin{pmatrix} f_{11} & f_{12} & f_{13} \\ f_{21} & f_{22} & f_{23} \\ f_{31} & f_{32} & f_{33} \end{pmatrix} \begin{pmatrix} d\overline{\tau} \\ d\overline{l}^d \\ d\overline{l}^s \end{pmatrix} = \begin{pmatrix} 2f_{12} & 0 \\ -2f_{23} & -l_2 \\ 2f_{32} & -a_2 l_2 \end{pmatrix} \begin{pmatrix} dp_R^* \\ d\dot{m} \end{pmatrix} \tag{A51}$$

where

$$
\begin{aligned}
f_{11} &= \lambda(f_1 + f_1^* + f_2) + 2c_3 - (a_1 - 2c_1)\psi & \text{(A52)}\\
f_{12} &= \frac{1}{2}\Big(\lambda(f_2 - f_2^*) - (a_1 - 2c_1)(\psi - \psi^*)\Big) & \text{(A53)}\\
f_{13} &= -f_{12} & \text{(A54)}\\
f_{21} &= 2 - \alpha - \alpha^* - l_1(f_1 + f_1^* + f_2) & \text{(A55)}\\
f_{22} &= 1 - f_{23} & \text{(A56)}\\
f_{23} &= \frac{1}{2} l_1(f_2 - f_2^*) & \text{(A57)}\\
f_{31} &= l_2 a_1 \psi - a_2(\alpha - \alpha^*) - (a_2 l_1 + l_2(1 - a_1))(f_1 + f_2 - f_1^*) & \text{(A58)}\\
f_{32} &= \frac{1}{2}\Big(l_2 a_1(\psi + \psi^*) - (a_2 l_1 + l_2(1 - a_1))(f_2 + f_2^*)\Big) & \text{(A59)}\\
f_{33} &= a_2 - f_{32} & \text{(A60)}
\end{aligned}
$$

The determinant $|\mathbf{F}|$ of the steady state matrix $\mathbf{F} = (f_{ij})_{1\le i,j\le 3}$ is in general positive and given by

$$|\mathbf{F}| = f_{12}f_{31} - f_{11}f_{32} + a_2(f_{11}f_{22} - f_{12}f_{21}) \qquad \text{(A61)}$$

The steady state system (A51) has the following solution:

$$
\begin{pmatrix} d\overline{\tau} \\ d\overline{l}^d \\ d\overline{l}^s \end{pmatrix} = \frac{1}{|\mathbf{F}|}\begin{pmatrix} f_{22}a_2 - f_{32} & -f_{12}a_2 & f_{12} \\ f_{23}f_{31} - f_{21}f_{33} & f_{11}f_{33} + f_{12}f_{31} & -f_{11}f_{23} - f_{12}f_{21} \\ f_{21}f_{32} - f_{31}f_{22} & f_{12}f_{31} - f_{11}f_{32} & f_{11}f_{22} - f_{12}f_{21} \end{pmatrix} \qquad \text{(A62)}
$$
$$
\cdot \begin{pmatrix} 2f_{12} & 0 \\ -2f_{23} & -l_2 \\ 2f_{32} & -a_2 l_2 \end{pmatrix}\begin{pmatrix} dp_R^* \\ d\dot{m} \end{pmatrix}
$$

The following steady state multipliers can be derived from (A62) in combination with (A49), (A19), (A5):

$$\frac{d\overline{\tau}}{d\dot{m}} = 0 \qquad \text{(A63)}$$

$$\frac{d\overline{l}^d}{d\dot{m}} = \frac{d\overline{l}^s}{d\dot{m}} = -l_2 \qquad \text{(A64)}$$

$$\frac{d(\overline{m-p})}{d\dot{m}} = -l_2\,, \quad \frac{d(\overline{m^*-p^*})}{d\dot{m}} = 0 \qquad \text{(A65)}$$

$$\frac{d(\overline{p^*-p_R^*})}{d\dot{m}} = \frac{d(\overline{p_R^*-e-p})}{d\dot{m}} = 0 \qquad \text{(A66)}$$

$$\frac{d\overline{q}}{d\dot{m}} = \frac{d\overline{q}^*}{d\dot{m}} = 0 \qquad \text{(A67)}$$

$$\frac{d\overline{\tau}}{dp_R^*} = \frac{2f_{12}a_2}{|\mathbf{F}|} > 0 \;\Leftrightarrow \tag{A68}$$

$$\lambda(f_2 - f_2^*) \;>\; (a_1 - 2c_1)(\psi - \psi^*)$$

$$\text{(provided that } |\mathbf{F}| > 0\text{)}$$

$$\frac{d\overline{l}^d}{dp_R^*} = \frac{-2a_2}{|\mathbf{F}|}(f_{12}f_{21} + f_{23}f_{11}) \tag{A69}$$

$$\frac{d\overline{l}^s}{dp_R^*} = \frac{2}{|\mathbf{F}|}(-f_{12}f_{31} + f_{32}f_{11}) \tag{A70}$$

$$\frac{d(\overline{m^* - p^*})}{dp_R^*} = -1 + \frac{f_{11}a_2}{|\mathbf{F}|} \tag{A71}$$

$$\frac{d(\overline{m - p})}{dp_R^*} = \frac{1}{|\mathbf{F}|}(f_{11}f_{32} - f_{12}f_{31} - a_2(f_{12}f_{21} + f_{23}f_{11})) \tag{A72}$$

$$\frac{d(\overline{p_R^* - p^*})}{dp_R^*} = \frac{f_{11}a_2}{|\mathbf{F}|} \tag{A73}$$

$$\frac{d(\overline{p_R^* + e - p})}{dp_R^*} = -\frac{d\overline{\tau}}{dp_R^*} + \frac{d(\overline{p_R^* - p^*})}{dp_R^*} = \frac{a_2}{|\mathbf{F}|}(f_{11} - 2f_{12}) \tag{A74}$$

$$\begin{aligned} \frac{d\overline{q}}{dp_R^*} &= (f_1 + f_2)\frac{d\overline{\tau}}{dp_R^*} - f_2\frac{d(\overline{p_R^* - p^*})}{dp_R^*} \\ &= \frac{a_2}{|\mathbf{F}|}\big((2f_{12} - f_{11})f_2 + 2f_{12}f_1\big) \end{aligned} \tag{A75}$$

$$\begin{aligned} \frac{d\overline{q}^*}{dp_R^*} &= -f_1^*\frac{d\overline{\tau}}{dp_R^*} - f_2^*\frac{d(\overline{p_R^* - p^*})}{dp_R^*} \\ &= -\frac{a_2}{|\mathbf{F}|}(2f_{12}f_1^* + f_{11}f_2^*) < 0 \end{aligned} \tag{A76}$$

Note that

$$\begin{aligned} \frac{d\overline{q}^*}{dp_R^*} > \frac{d\overline{q}}{dp_R^*} &\Leftrightarrow f_{11}(f_2 - f_2^*) \;>\; 2f_{12}(f_1 + f_1^* + f_2) \\ &\Leftrightarrow (f_2 - f_2^*)\big(2c_3 - (a_1 - 2c_1)\psi\big) \\ &\qquad + (a_1 - 2c_1)(\psi - \psi^*)(f_1 + f_1^* + f_2) > 0 \end{aligned} \tag{A77}$$

This inequality is met since we have assumed $\psi > \psi^*$, $f_2 > f_2^*$ and $2c_3 - (a_1 - 2c_1)\psi > 0$.

Equation (23) implies

$$\frac{d\overline{im}_R}{dp_R^*} = \frac{d\overline{q}}{dp_R^*} + (1-\sigma)\frac{d(\overline{p_R^* + e - p})}{dp_R^*} \tag{A78}$$
$$= \frac{a_2}{|\mathbf{F}|}\Big((2f_{12} - f_{11})(f_2 + \sigma - 1) + 2f_{12}f_1\Big)$$

$$\frac{d\overline{im}_R^*}{dp_R^*} = \frac{d\overline{q}^*}{dp_R^*} + (1-\sigma^*)\frac{d(\overline{p_R^* - p^*})}{dp_R^*} \tag{A79}$$
$$= -\frac{a_2}{|\mathbf{F}|}\Big(2f_{12}f_1^* + f_{11}(f_2^* + \sigma^* - 1)\Big)$$

If inequality (A77) holds then $d\overline{im}_R^*/dp_R^* > d\overline{im}_R/dp_R^*$ if $\sigma^* \leq \sigma$ and $f_{12} > 0$.

The *convergent solution time path* of the state vector $(l^s, \tau, l^d)'$ is given by

$$\begin{pmatrix} l^s \\ \tau \\ l^d \end{pmatrix} = \begin{pmatrix} \bar{l}_0^s \\ \bar{\tau}_0 \\ \bar{l}_0^d \end{pmatrix} + A_0 h_0 e^{r_0 t} + A_1 h_1 e^{r_1 t} + A_2 h_2 e^{r_2 t} \quad \text{for } 0 < t \leq T \tag{A80}$$

$$\begin{pmatrix} l^s \\ \tau \\ l^d \end{pmatrix} = \begin{pmatrix} \bar{l}_1^s \\ \bar{\tau}_1 \\ \bar{l}_1^d \end{pmatrix} + \widetilde{A}_0 h_0 e^{r_0 t} + \widetilde{A}_2 h_2 e^{r_2 t} \quad \text{for } t \geq T \tag{A81}$$

(A80) represents the general solution of the dynamic system (A27) during the anticipation phase $0 < t < T$ while (A81) is the *bounded* solution of (A27) after the realization of the shock at time T. r_0, r_1, r_2 are the eigenvalues of the matrix

$$\mathbf{G} = \mathbf{B}^{-1}\mathbf{C} = (g_{ij})_{1 \leq i,j \leq 3} \tag{A82}$$

and h_0, h_1, h_2 the corresponding eigenvectors which have the following structure:

$$h_j = \begin{pmatrix} h_{1j} \\ h_{2j} \\ 1 \end{pmatrix} \quad j = 0, 1, 2 \tag{A83}$$

where

$$h_{1j} = \frac{1}{\Delta_j}(-g_{13}(g_{22} - r_j) + g_{12}g_{23}) \tag{A84}$$

$$h_{2j} = \frac{1}{\Delta_j}(g_{21}g_{13} - g_{23}(g_{11} - r_j)) \tag{A85}$$

and

$$\Delta_j = (g_{11} - r_j)(g_{22} - r_j) - g_{12}g_{21} \tag{A86}$$

The dynamic system (A27) exhibits saddlepoint behavior. It has two stable (r_0, r_2) and one unstable (r_1) eigenvalue. The determination of the constants A_0, A_1, A_2, $\widetilde{A}_0$ and $\widetilde{A}_2$

results from the continuity conditions[63]

$$z(0+) = \bar{z}_0 \qquad \text{for } z \in \{l^s, l^d\} \tag{A87}$$
$$z(T+) = z(T-) \qquad \text{for } z \in \{l^s, \tau, l^d\} \tag{A88}$$

The predetermined variables l^s and l^d behave continuously both at the time of anticipation and implementation, while the jump variable τ jumps at the time of anticipation but behaves sluggishly at time T. From equation (A87) we get the conditions

$$0 = A_0 + A_1 + A_2 \tag{A89}$$
$$0 = A_0 h_{10} + A_1 h_{11} + A_2 h_{12} \tag{A90}$$

and therefore

$$A_0 = \frac{1}{h_{10} - h_{12}}(-h_{11} + h_{12})A_1 \tag{A91}$$
$$A_2 = \frac{1}{h_{10} - h_{12}}(h_{11} - h_{10})A_1 \tag{A92}$$

Equation (A88) implies

$$d\bar{l}^s = (A_0 - \widetilde{A}_0)h_{10}e^{r_0 T} + A_1 h_{11} e^{r_1 T} + (A_2 - \widetilde{A}_2)h_{12}e^{r_2 T} \tag{A93}$$
$$d\bar{\tau} = (A_0 - \widetilde{A}_0)h_{20}e^{r_0 T} + A_1 h_{21} e^{r_1 T} + (A_2 - \widetilde{A}_2)h_{22}e^{r_2 T} \tag{A94}$$
$$d\bar{l}^d = (A_0 - \widetilde{A}_0)e^{r_0 T} + A_1 e^{r_1 T} + (A_2 - \widetilde{A}_2)e^{r_2 T} \tag{A95}$$

The solution is given by

$$A_1 = \frac{1}{d}e^{-r_1 T}\Big((h_{22} - h_{20})d\bar{l}^s + (h_{10} - h_{12})d\bar{\tau} + (h_{12}h_{20} - h_{10}h_{22})d\bar{l}^d\Big) \tag{A96}$$

$$\widetilde{A}_0 = A_0 - \frac{1}{d}e^{-r_0 T}\Big((h_{21} - h_{22})d\bar{l}^s + (h_{12} - h_{11})d\bar{\tau} + (h_{11}h_{22} - h_{21}h_{12})d\bar{l}^d\Big) \tag{A97}$$

$$\widetilde{A}_2 = A_2 - \frac{1}{d}e^{-r_2 T}\Big((h_{20} - h_{21})d\bar{l}^s + (h_{11} - h_{10})d\bar{\tau} + (h_{10}h_{21} - h_{11}h_{20})d\bar{l}^d\Big) \tag{A98}$$

where

$$d = h_{10}(h_{21} - h_{22}) + h_{11}(h_{22} - h_{20}) + h_{12}(h_{20} - h_{21}) \tag{A99}$$

From the bounded solution (A81) of the state vector $(l^s, \tau, l^d)'$ the equation for the stable saddlepath can be obtained by eliminating $\widetilde{A}_0 e^{r_0 t}$ and $\widetilde{A}_2 e^{r_2 t}$. The equation for the

[63] Cf. Turnovsky (2000) and Clausen and Wohltmann (2005).

convergent saddlepath is then given by the hyperplane

$$(h_{12}h_{20} - h_{10}h_{22})(l^d - \bar{l}^d) + (h_{22} - h_{20})(l^s - \bar{l}^s) + (h_{10} - h_{12})(\tau - \bar{\tau}) = 0 \qquad \text{(A100)}$$

The unstable arm of the saddlepoint $(\bar{l}^s, \bar{\tau}, \bar{l}^d)'$ can be obtained from equation (A79) by first eliminating $A_1 e^{r_1 t}$ and $A_2 e^{r_2 t}$ and then setting the term belonging to $A_0 e^{r_0 t}$ equal to zero (since this term vanishes if t approaches infinity). The unstable saddlepath is then given by the hyperplane

$$\big(h_{21}(h_{12}-h_{11})-h_{11}(h_{22}-h_{21})\big)(l^d-\bar{l}^d)+(h_{22}-h_{21})(l^s-\bar{l}^s)+(h_{11}-h_{12})(\tau-\bar{\tau}) = 0 \quad \text{(A101)}$$

In a phase diagram the stable and unstable hyperplane ((A100) and (A101)) have the following graphical representation:

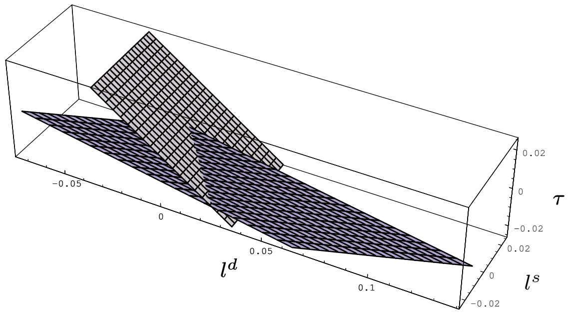

Figure 31: The stable (**pale**) and unstable (**dark**) hyperplane of the initial steady state $(\bar{l}^s_0, \bar{\tau}_0, \bar{l}^d_0)'$ in a phase diagram

For $t > T$ the development of the state vector $(l^s - \bar{l}^s_1, \tau - \bar{\tau}_1, l^d - \bar{l}^d_1)'$ can be represented by a trajectory (solid line) on the stable hyperplane:

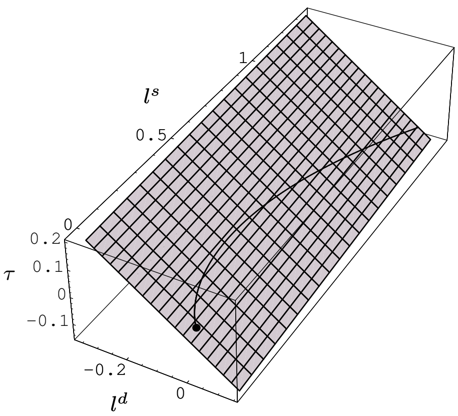

Figure 32: Development of the state vector in deviational form $(l^s - \bar{l}^s_1, \tau - \bar{\tau}_1, l^d - \bar{l}^d_1)'$ for $t > T$ towards its steady state $(0, 0, 0)$ (**bold dot**) represented by a trajectory (**solid line**) on the stable hyperplane

B Domestic-Currency Denominated Oil Imports

Next consider the state space and steady state representation of the world system if raw materials imports are denominated in terms of domestic rather than foreign currency. The difference system is now given by the equations

$$\begin{aligned}\lambda(q-q^*) &= 2c_0+g-g^*-a_2i_r^d-(2c_3-(a_1-2c_1)\psi^*)\tau \\ &\quad +(a_1-2c_1)(\psi-\psi^*)(p-p_R)\end{aligned} \tag{B1}$$

$$y-y^* = q-q^*+\psi^*\tau+(\psi-\psi^*)(p-p_R) \tag{B2}$$

$$\begin{aligned}l^d &= (\alpha+\alpha^*-2)\tau+l_1(q-q^*) \\ &\quad +l_2\dot{\tau}+l_2\dot{l}^d-l_2(\dot{m}-\dot{m}^*)\end{aligned} \tag{B3}$$

$$\begin{aligned}q-q^* &= \overline{q}-\overline{q}^*+\left\{\frac{1}{\delta^*}\left((1-\beta^*)(1-\alpha^*)+\frac{1-\mu^*}{\mu^*}\right)\right. \\ &\quad \left.+\frac{1}{\delta}(1-\beta)(1-\alpha)\right\}\dot{\tau}-\frac{\beta}{\delta}(\dot{m}-\dot{p}) \\ &\quad +\frac{\beta^*}{\delta^*}(\dot{m}^*-\dot{p}^*)+\left(\frac{1-\mu}{\delta\mu}-\frac{1-\mu^*}{\delta^*\mu^*}\right)(\dot{p}-\dot{p}_R)\end{aligned} \tag{B4}$$

$$\dot{p}-\dot{p}_R = -\frac{1}{2}\left(\dot{l}^s+\dot{l}^d\right)+\dot{m}-\dot{p}_R \tag{B5}$$

$$\begin{aligned}\overline{q}-\overline{q}^* &= f_0-f_0^*+(f_1+f_1^*+f_2^*)\overline{\tau} \\ &\quad +(f_2-f_2^*)(\overline{p-p_R})\end{aligned} \tag{B6}$$

$$\overline{p-p_R} = -\frac{1}{2}\left(\overline{l}^s+\overline{l}^d\right)+m-p_R \tag{B7}$$

The corresponding aggregate system is given by the following set of equations:

$$\begin{aligned}(1-a_1)(q+q^*) &= 2a_0-a_2i_r^s+g+g^*-2d_0a_1-a_1\psi^*\tau \\ &\quad +a_1(\psi+\psi^*)(p-p_R)\end{aligned} \tag{B8}$$

$$y+y^* = q+q^*-\psi^*\tau+(\psi+\psi^*)(p-p_R)-2d_0 \tag{B9}$$

$$l^s = (\alpha-\alpha^*)\tau+2l_0+l_1(q+q^*)-l_2(2i^*+\dot{e}) \tag{B10}$$

$$
\begin{aligned}
q + q^* \;\; = \;\; & \overline{q} + \overline{q}^* - \left\{ \frac{1}{\delta^*}\left((1-\beta^*)(1-\alpha^*) + \frac{1-\mu^*}{\mu^*} \right) \right. \\
& \left. - \frac{1}{\delta}(1-\beta)(1-\alpha) \right\} \dot{\tau} - \left(\frac{\beta}{2\delta} + \frac{\beta^*}{2\delta^*} \right) \dot{l}^s \\
& - \left(\frac{\beta}{2\delta} - \frac{\beta^*}{2\delta^*} \right) \dot{l}^d + \left(\frac{1-\mu}{\delta\mu} + \frac{1-\mu^*}{\delta^*\mu^*} \right) (\dot{p} - \dot{p}_R)
\end{aligned} \tag{B11}
$$

$$
\overline{q} + \overline{q}^* \;\; = \;\; f_0 + f_0^* + (f_1 - f_1^* - f_2^*)\overline{\tau} + (f_2 + f_2^*)(\overline{p - p_R}) \tag{B12}
$$

The dynamics of the difference system and the aggregate system can be represented by the equations (cf. (A9), (A10), (A21))

$$
\begin{aligned}
& \Big(\lambda \hat{\kappa}_1 + a_2(1 - (\alpha + \alpha^*)) \Big) \dot{\tau} + \lambda \left(-\frac{\beta}{2\delta} + \frac{\beta^*}{2\delta^*} - \frac{1}{2}\kappa_2 \right) \dot{l}^s \\
& + \lambda \left(-\frac{\beta}{2\delta} - \frac{\beta^*}{2\delta^*} - \frac{1}{2}\kappa_2 \right) \dot{l}^d + \lambda(\overline{q} - \overline{q}^*) + \lambda\kappa_2(\dot{m} - \dot{p}_R) \;\; = \\
& \qquad 2c_0 + g - g^* - (2c_3 - (a_1 - 2c_1)\psi^*)\tau - \frac{1}{2}(a_1 - 2c_1)(\psi - \psi^*) l^s \\
& \qquad - \frac{1}{2}(a_1 - 2c_1)(\psi - \psi^*) l^d + (a_1 - 2c_1)(\psi - \psi^*)(m - p_R)
\end{aligned} \tag{B13}
$$

$$
\begin{aligned}
& (l_1\hat{\kappa}_1 + l_2)\dot{\tau} + \left(l_2 + l_1 \left(-\frac{\beta}{2\delta} - \frac{\beta^*}{2\delta^*} - \frac{1}{2}\kappa_2 \right) \right) \dot{l}^d \\
& + l_1 \left(-\frac{\beta}{2\delta} + \frac{\beta^*}{2\delta^*} - \frac{1}{2}\kappa_2 \right) \dot{l}^s - l_2(\dot{m} - \dot{m}^*) + l_1(\overline{q} - \overline{q}^*) \\
& + l_1\kappa_2(\dot{m} - \dot{p}_R) \;\; = \;\; l^d + (2 - \alpha - \alpha^*)\tau
\end{aligned} \tag{B14}
$$

$$
\begin{aligned}
& \Big((a_2 l_1 + l_2(1 - a_1))\hat{\kappa}_3 - a_2 l_2(\alpha - \alpha^*) \Big) \dot{\tau} \\
& + \Big((a_2 l_1 + l_2(1 - a_1))\kappa_4 + a_2 l_2 \Big) \dot{l}^s + \Big(a_2 l_1 + l_2(1 - a_1) \Big) \hat{\kappa}_5 \dot{l}^d \\
& + (a_2 l_1 + l_2(1 - a_1))\kappa_6(\dot{m} - \dot{p}_R) + (a_2 l_1 + l_2(1 - a_1))(\overline{q} + \overline{q}^*) \\
& - a_2 l_2(\dot{m} + \dot{m}^*) \;\; = \\
& \qquad \left(a_2 - \frac{1}{2} l_2 a_1(\psi + \psi^*) \right) l^s - \Big(a_2(\alpha - \alpha^*) + l_2 a_1 \psi^* \Big) \tau \\
& \qquad - \frac{1}{2}\big(l_2 a_1(\psi + \psi^*) \big) l^d + l_2(g + g^*) \\
& \qquad + l_2 a_1(\psi + \psi^*)(m - p_R) + 2a_0 l_2 - 2l_0 a_2 - 2d_0 a_1 l_2
\end{aligned} \tag{B15}
$$

where

$$\hat{\kappa}_1 = \frac{1}{\delta}(1-\beta)(1-\alpha) + \frac{1}{\delta^*}\left((1-\beta^*)(1-\alpha^*) + \frac{1-\mu^*}{\mu^*}\right) \tag{B16}$$

$$\hat{\kappa}_3 = \frac{1}{\delta}(1-\beta)(1-\alpha) - \frac{1}{\delta^*}\left((1-\beta^*)(1-\alpha^*) + \frac{1-\mu^*}{\mu^*}\right) \tag{B17}$$

$$\hat{\kappa}_5 = -\frac{1}{2}\left(\frac{\beta}{\delta} - \frac{\beta^*}{\delta^*} + \frac{1-\mu}{\delta\mu} + \frac{1-\mu^*}{\delta^*\mu^*}\right) \tag{B18}$$

and κ_2, κ_4 and κ_6 are defined in (A14), (A23) and (A25) respectively. The matrix representation in deviational form of the state equations (B15), (B13), (B14) is given by

$$\hat{\mathbf{B}} \begin{pmatrix} \dot{l}^s \\ \dot{\tau} \\ \dot{l}^d \end{pmatrix} = \hat{\mathbf{C}} \begin{pmatrix} l^s - \bar{l}^s \\ \tau - \bar{\tau} \\ l^d - \bar{l}^d \end{pmatrix} \tag{B19}$$

where

$$\hat{b}_{11} = (a_2 l_1 + l_2(1-a_1))\kappa_4 + a_2 l_2 = b_{11} \tag{B20}$$

$$\hat{b}_{12} = (a_2 l_1 + l_2(1-a_1))\hat{\kappa}_3 - a_2 l_2(\alpha - \alpha^*) \tag{B21}$$

$$\hat{b}_{13} = (a_2 l_1 + l_2(1-a_1))\hat{\kappa}_5 \tag{B22}$$

$$\hat{b}_{21} = \lambda\left(-\frac{\beta}{2\delta} + \frac{\beta^*}{2\delta^*} - \frac{1}{2}\kappa_2\right) = b_{21} \tag{B23}$$

$$\hat{b}_{22} = \lambda\hat{\kappa}_1 + a_2(1-(\alpha+\alpha^*)) \tag{B24}$$

$$\hat{b}_{23} = \lambda\left(-\frac{\beta}{2\delta} - \frac{\beta^*}{2\delta^*} - \frac{1}{2}\kappa_2\right) \tag{B25}$$

$$\hat{b}_{31} = l_1\left(-\frac{\beta}{2\delta} + \frac{\beta^*}{2\delta^*} - \frac{1}{2}\kappa_2\right) = b_{31} \tag{B26}$$

$$\hat{b}_{32} = l_1\hat{\kappa}_1 + l_2 \tag{B27}$$

$$\hat{b}_{33} = l_2 + l_1\left(-\frac{\beta}{2\delta} - \frac{\beta^*}{2\delta^*} - \frac{1}{2}\kappa_2\right) \tag{B28}$$

$$\hat{c}_{11} = a_2 - \frac{1}{2}l_2 a_1(\psi + \psi^*) = c_{11} \tag{B29}$$

$$\hat{c}_{12} = -l_2 a_1 \psi^* - a_2(\alpha - \alpha^*) \tag{B30}$$

$$\hat{c}_{13} = -\frac{1}{2}l_2 a_1(\psi + \psi^*) \tag{B31}$$

$$\hat{c}_{21} = -\frac{1}{2}(a_1 - 2c_1)(\psi - \psi^*) = c_{21} \tag{B32}$$

$$\hat{c}_{22} = -(2c_3 - (a_1 - 2c_1)\psi^*) \tag{B33}$$

$$\hat{c}_{23} = -\frac{1}{2}(a_1 - 2c_1)(\psi - \psi^*) \tag{B34}$$

$$\hat{c}_{31} = 0 = c_{31} \tag{B35}$$

$$\hat{c}_{32} = 2 - (\alpha + \alpha^*) = c_{32} \tag{B36}$$

$$\hat{c}_{33} = 1 = c_{33} \tag{B37}$$

The steady state system that results from (B13), (B14) and (B15) by inserting the steady state condition (A46) and the long run supply functions (B6) and (B12) is given by the following equations:

$$\begin{aligned}
&\lambda(f_1+f_1^*+f_2^*)\overline{\tau}-\frac{1}{2}\lambda(f_2-f_2^*)\overline{l}^d-\frac{1}{2}\lambda(f_2-f_2^*)\overline{l}^s= \\
&\quad \lambda(f_2-f_2^*)(p_R-m)-\lambda\kappa_2(\dot{m}-\dot{p}_R)+g-g^*+2c_0+\lambda(f_0^*-f_0) \\
&\quad -(2c_3-(a_1-2c_1)\psi^*)\overline{\tau}-\frac{1}{2}(a_1-2c_1)(\psi-\psi^*)\overline{l}^s \\
&\quad -\frac{1}{2}(a_1-2c_1)(\psi-\psi^*)\overline{l}^d+(a_1-2c_1)(\psi-\psi^*)(m-p_R)
\end{aligned} \tag{B38}$$

$$\begin{aligned}
\overline{l}^d+(2-\alpha-\alpha^*)\overline{\tau} \;=\;& -l_2(\dot{m}-\dot{m}^*)+l_1\kappa_2(\dot{m}-\dot{p}_R) \\
& +l_1(f_1+f_1^*+f_2^*)\overline{\tau}+l_1(f_0-f_0^*) \\
& +l_1(f_2-f_2^*)\left(-\frac{1}{2}\overline{l}^d-\frac{1}{2}\overline{l}^s+m-p_R\right)
\end{aligned} \tag{B39}$$

$$\begin{aligned}
&(a_2l_1+l_2(1-a_1))\Big\{(f_1-f_1^*-f_2^*)\overline{\tau}+(f_2+f_2^*)\left(-\frac{1}{2}\overline{l}^d-\frac{1}{2}\overline{l}^s+m-p_R\right) \\
&+f_0+f_0^*+\kappa_6(\dot{m}-\dot{p}_R)\Big\} \;=\; 2a_0l_2-2l_0a_2-2d_0a_1l_2+a_2l_2(\dot{m}+\dot{m}^*) \\
&\qquad -(a_2(\alpha-\alpha^*)+l_2a_1\psi^*)\overline{\tau} \\
&\qquad +\left(a_2-\frac{1}{2}l_2a_1(\psi+\psi^*)\right)\overline{l}^s \\
&\qquad -\frac{1}{2}l_2a_1(\psi+\psi^*)\overline{l}^d+l_2(g+g^*) \\
&\qquad +l_2a_1(\psi+\psi^*)(m-p_R)
\end{aligned} \tag{B40}$$

We only consider the case $dp_R > 0$ and assume $\dot{m}=\dot{m}^*=\dot{p}_R=0$. It then follows from (B38), (B39), (B40)

$$\begin{pmatrix} \hat{f}_{11} & \hat{f}_{12} & \hat{f}_{13} \\ \hat{f}_{21} & \hat{f}_{22} & \hat{f}_{23} \\ \hat{f}_{31} & \hat{f}_{32} & \hat{f}_{33} \end{pmatrix} \begin{pmatrix} d\overline{\tau} \\ d\overline{l}^d \\ d\overline{l}^s \end{pmatrix} = \begin{pmatrix} -2\hat{f}_{12} \\ -2\hat{f}_{23} \\ -2\hat{f}_{32} \end{pmatrix} dp_R \tag{B41}$$

where

$$\hat{f}_{11} = \lambda(f_1 + f_1^* + f_2^*) + 2c_3 - (a_1 - 2c_1)\psi^* \tag{B42}$$

$$\hat{f}_{12} = -\frac{1}{2}\Big(\lambda(f_2 - f_2^*) - (a_1 - 2c_1)(\psi - \psi^*)\Big) = -f_{12} \tag{B43}$$

$$\hat{f}_{13} = \hat{f}_{12} \tag{B44}$$

$$\hat{f}_{21} = 2 - \alpha - \alpha^* - l_1(f_1 + f_1^* + f_2^*) = f_{21} \tag{B45}$$

$$\hat{f}_{22} = 1 + \frac{1}{2}l_1(f_2 - f_2^*) = 1 + \hat{f}_{23} \tag{B46}$$

$$\hat{f}_{23} = \frac{1}{2}l_1(f_2 - f_2^*) = f_{23} \tag{B47}$$

$$\hat{f}_{31} = -l_2 a_1 \psi^* - a_2(\alpha - \alpha^*) - (a_2 l_1 + l_2(1 - a_1))(f_1 - f_1^* - f_2^*) \tag{B48}$$

$$\hat{f}_{32} = \frac{1}{2}\Big(- l_2 a_1(\psi + \psi^*) + (a_2 l_1 + l_2(1 - a_1))(f_2 + f_2^*)\Big) = -f_{32} \tag{B49}$$

$$\hat{f}_{33} = a_2 + \hat{f}_{32} \tag{B50}$$

The determinant $|\hat{\mathbf{F}}|$ of the matrix $\hat{\mathbf{F}} = (\hat{f}_{ij})_{1\leq i,j\leq 3}$ is given by

$$|\hat{\mathbf{F}}| = \hat{f}_{11}\hat{f}_{32} - \hat{f}_{12}\hat{f}_{31} + a_2(\hat{f}_{11}\hat{f}_{22} - \hat{f}_{12}\hat{f}_{21}) \tag{B51}$$

System (B41) has the following solution:

$$\begin{pmatrix} d\overline{\tau} \\ d\bar{l}^d \\ d\bar{l}^s \end{pmatrix} = \frac{1}{|\hat{\mathbf{F}}|}\begin{pmatrix} \hat{f}_{22}a_2 + \hat{f}_{32} & -\hat{f}_{12}a_2 & -\hat{f}_{12} \\ \hat{f}_{23}\hat{f}_{31} - \hat{f}_{21}\hat{f}_{33} & \hat{f}_{11}\hat{f}_{33} - \hat{f}_{12}\hat{f}_{31} & \hat{f}_{12}\hat{f}_{21} - \hat{f}_{11}\hat{f}_{23} \\ \hat{f}_{21}\hat{f}_{32} - \hat{f}_{31}\hat{f}_{22} & \hat{f}_{12}\hat{f}_{31} - \hat{f}_{11}\hat{f}_{32} & \hat{f}_{11}\hat{f}_{22} - \hat{f}_{12}\hat{f}_{21} \end{pmatrix} \cdot \begin{pmatrix} -2\hat{f}_{12} \\ -2\hat{f}_{23} \\ -2\hat{f}_{32} \end{pmatrix} dp_R \tag{B52}$$

From (B52) we get the following multipliers of a once-and-for-all increase in p_R:

$$\begin{aligned} \frac{d\overline{\tau}}{dp_R} &= -\frac{2\hat{f}_{12}a_2}{|\hat{\mathbf{F}}|} = \frac{2a_2 f_{12}}{|\hat{\mathbf{F}}|} < \frac{d\overline{\tau}}{dp_R^*} \\ &= \frac{2a_2 f_{12}}{|\mathbf{F}|} \Leftrightarrow |\hat{\mathbf{F}}| > |\mathbf{F}| \end{aligned} \tag{B53}$$

$$\frac{d\bar{l}^d}{dp_R} = -\frac{2a_2}{|\hat{\mathbf{F}}|}(\hat{f}_{11}\hat{f}_{23} - \hat{f}_{12}\hat{f}_{21}) = -\frac{2a_2}{|\hat{\mathbf{F}}|}(\hat{f}_{11}f_{23} + f_{12}f_{21}) \tag{B54}$$

$$\frac{d\bar{l}^s}{dp_R} = -\frac{2}{|\hat{\mathbf{F}}|}(\hat{f}_{32}\hat{f}_{11} - \hat{f}_{12}\hat{f}_{31}) = -\frac{2}{|\hat{\mathbf{F}}|}(-f_{32}\hat{f}_{11} + f_{12}\hat{f}_{31}) \tag{B55}$$

$$\frac{d(\overline{m-p})}{dp_R} = -1 + \frac{a_2\hat{f}_{11}}{|\hat{\mathbf{F}}|} \tag{B56}$$

$$\frac{d(\overline{m^*-p^*})}{dp_R} = -\frac{1}{|\hat{\mathbf{F}}|}\Big(-\hat{f}_{12}\hat{f}_{31} + \hat{f}_{32}\hat{f}_{11} + a_2(\hat{f}_{12}\hat{f}_{21} - \hat{f}_{23}\hat{f}_{11})\Big) = -\frac{1}{|\hat{\mathbf{F}}|}\Big(f_{12}\hat{f}_{31} - f_{32}\hat{f}_{11} + a_2(-f_{12}f_{21} - f_{23}\hat{f}_{11})\Big) \tag{B57}$$

$$\frac{d(\overline{p_R-p})}{dp_R} = \frac{a_2\hat{f}_{11}}{|\hat{\mathbf{F}}|} \tag{B58}$$

$$\frac{d(\overline{p_R-e-p^*})}{dp_R} = \frac{d\overline{\tau}}{dp_R} + \frac{d(\overline{p_R-p})}{dp_R} = \frac{a_2}{|\hat{\mathbf{F}}|}(\hat{f}_{11} - 2\hat{f}_{12}) = \frac{a_2}{|\hat{\mathbf{F}}|}(\hat{f}_{11} + 2f_{12}) \tag{B59}$$

$$\frac{d\overline{q}}{dp_R} = f_1\frac{d\overline{\tau}}{dp_R} - f_2\frac{d(\overline{p_R-p})}{dp_R} = -\frac{a_2}{|\hat{\mathbf{F}}|}(2\hat{f}_{12}f_1 + \hat{f}_{11}f_2) = -\frac{a_2}{|\hat{\mathbf{F}}|}(-2f_{12}f_1 + \hat{f}_{11}f_2) \tag{B60}$$

$$\frac{d\overline{q}^*}{dp_R} = -(f_1^* + f_2^*)\frac{d\overline{\tau}}{dp_R} - f_2^*\frac{d(\overline{p_R-p})}{dp_R} = \frac{a_2}{|\hat{\mathbf{F}}|}\Big((2\hat{f}_{12} - \hat{f}_{11})f_2^* + 2\hat{f}_{12}f_1^*\Big) = -\frac{a_2}{|\hat{\mathbf{F}}|}\Big((2f_{12} + \hat{f}_{11})f_2^* + 2f_{12}f_1^*\Big) \tag{B61}$$

Note that

$$\frac{d\overline{q}^*}{dp_R} > \frac{d\overline{q}}{dp_R} \Leftrightarrow \hat{f}_{11}(f_2 - f_2^*) > -2\hat{f}_{12}(f_1 + f_1^* + f_2^*) \Leftrightarrow \hat{f}_{11}(f_2 - f_2^*) > 2f_{12}(f_1 + f_1^* + f_2^*) \Leftrightarrow (f_2 - f_2^*)\big(2c_3 - (a_1 - 2c_1)\psi^*\big) + (a_1 - 2c_1)(\psi - \psi^*)(f_1 + f_1^* + f_2^*) > 0 \tag{B62}$$

Since $f_2 > f_2^*$ and $\psi > \psi^*$ by assumption inequality (B62) is met if inequality (A77) holds.

C Combination of the Two Polar Cases

We have as yet discussed the two polar cases that raw materials imports are either completely denominated in terms of the foreign or the domestic currency. Let us now consider a combination of these two cases. The dynamic price equations are then of the form (26), (27) so that the dynamic supply functions that result from the price-wage equations can be written as follows:

$$\begin{aligned} q-\overline{q} &= \frac{1}{\mu\delta}\Big(\mu(1-\beta)(1-\alpha)+(1-\mu)\gamma\Big)\dot{\tau} \\ &\quad -\frac{1}{2\delta}\left(\beta+\frac{(1-\mu)(1-\gamma)}{\mu}+\frac{(1-\mu)\gamma}{\mu}\right)\dot{l}^s \\ &\quad -\frac{1}{2\delta}\left(\beta+\frac{(1-\mu)(1-\gamma)}{\mu}-\frac{(1-\mu)\gamma}{\mu}\right)\dot{l}^d \\ &\quad +\frac{(1-\mu)(1-\gamma)}{\mu\delta}(\dot{m}-\dot{p}_R)+\frac{(1-\mu)\gamma}{\mu\delta}(\dot{m}^*-\dot{p}_R^*) \end{aligned} \tag{C1}$$

$$\begin{aligned} q^*-\overline{q}^* &= -\frac{1}{\mu^*\delta^*}\Big(\mu^*(1-\beta^*)(1-\alpha^*)+(1-\mu^*)(1-\gamma^*)\Big)\dot{\tau} \\ &\quad -\frac{1}{2\delta^*}\left(\beta^*+\frac{(1-\mu^*)\gamma^*}{\mu^*}+\frac{(1-\mu^*)(1-\gamma^*)}{\mu^*}\right)\dot{l}^s \\ &\quad +\frac{1}{2\delta^*}\left(\beta^*+\frac{(1-\mu^*)\gamma^*}{\mu^*}-\frac{(1-\mu^*)(1-\gamma^*)}{\mu^*}\right)\dot{l}^d \\ &\quad +\frac{(1-\mu^*)\gamma^*}{\mu^*\delta^*}(\dot{m}^*-\dot{p}_R^*)+\frac{(1-\mu^*)(1-\gamma^*)}{\mu^*\delta^*}(\dot{m}-\dot{p}_R) \end{aligned} \tag{C2}$$

The income equations (9), (10) have to be replaced by the equations

$$\begin{aligned} y &= q-\psi\big(\gamma(p_R^*+e-p)+(1-\gamma)(p_R-p)\big)-d_0 \\ &= q+\psi\gamma\tau-\psi\gamma(p_R^*-p^*)-\psi(1-\gamma)(p_R-p)-d_0 \end{aligned} \tag{C3}$$

$$\begin{aligned} y^* &= q^*-\psi^*\big(\gamma^*(p_R^*-p^*)+(1-\gamma^*)(p_R-e-p^*)\big)-d_0 \\ &= q^*-(1-\gamma^*)\psi^*\tau-\psi^*\gamma^*(p_R^*-p^*)-(1-\gamma^*)\psi^*(p_R-p)-d_0 \end{aligned} \tag{C4}$$

The difference system is then given by

$$\begin{aligned} \lambda(q-q^*) &= 2c_0+g-g^*-a_2(1-(\alpha+\alpha^*))\dot{\tau} \\ &\quad +\Big(-2c_3+(a_1-2c_1)(\psi\gamma+\psi^*(1-\gamma^*)\Big)\tau \\ &\quad +\frac{1}{2}(a_1-2c_1)\Big(\psi(2\gamma-1)-\psi^*(2\gamma^*-1)\Big)l^d \\ &\quad -\frac{1}{2}(a_1-2c_1)(\psi-\psi^*)l^s \\ &\quad +(a_1-2c_1)(\psi\gamma-\psi^*\gamma^*)(m^*-p_R^*) \\ &\quad +(a_1-2c_1)\big(\psi(1-\gamma)-\psi^*(1-\gamma^*)\big)(m-p_R) \end{aligned} \tag{C5}$$

$$
\begin{aligned}
y - y^* &= q - q^* + \big(\psi\gamma + \psi^*(1-\gamma^*)\big)\tau \\
&\quad - \big(\psi\gamma - \psi^*\gamma^*\big)(p_R^* - p^*) \\
&\quad - \big(\psi(1-\gamma) - \psi^*(1-\gamma^*)\big)(p_R - p)
\end{aligned} \tag{C6}
$$

$$
l^d + (2 - (\alpha + \alpha^*))\tau = l_1(q - q^*) + l_2\dot{\tau} + l_2\dot{l}^d - l_2(\dot{m} - \dot{m}^*) \tag{C7}
$$

$$
\begin{aligned}
q - q^* &= \overline{q} - \overline{q}^* + \left\{\frac{1}{\delta}\left((1-\beta)(1-\alpha) + \frac{(1-\mu)\gamma}{\mu}\right)\right. \\
&\quad \left. + \frac{1}{\delta^*}\left((1-\beta^*)(1-\alpha^*) + \frac{(1-\mu^*)(1-\gamma^*)}{\mu^*}\right)\right\}\dot{\tau} \\
&\quad - \frac{1}{2}\left\{\frac{1}{\delta}\left(\beta + \frac{1-\mu}{\mu}\right) - \frac{1}{\delta^*}\left(\beta^* + \frac{1-\mu^*}{\mu^*}\right)\right\}\dot{l}^s \\
&\quad - \frac{1}{2}\left\{\frac{1}{\delta}\left(\beta + \frac{(1-\mu)(1-2\gamma)}{\mu}\right)\right. \\
&\quad \left. + \frac{1}{\delta^*}\left(\beta^* - \frac{(1-\mu^*)(1-2\gamma^*)}{\mu^*}\right)\right\}\dot{l}^d \\
&\quad + \left\{\frac{(1-\mu)(1-\gamma)}{\mu\delta} - \frac{(1-\mu^*)(1-\gamma^*)}{\mu^*\delta^*}\right\}(\dot{m} - \dot{p}_R) \\
&\quad + \left\{\frac{(1-\mu)\gamma}{\mu\delta} - \frac{(1-\mu^*)\gamma^*}{\mu^*\delta^*}\right\}(\dot{m}^* - \dot{p}_R^*)
\end{aligned} \tag{C8}
$$

where the long run supply functions are defined by

$$
\begin{aligned}
\overline{q} &= f_0 + f_1\overline{\tau} + f_2\Big(\gamma(\overline{p - (p_R^* + e)}) + (1-\gamma)(\overline{p - p_R})\Big) \\
&= f_0 + (f_1 + f_2\gamma)\overline{\tau} + f_2\Big(\gamma(\overline{p^* - p_R^*}) + (1-\gamma)(\overline{p - p_R})\Big) \\
&= f_0 + (f_1 + f_2\gamma)\overline{\tau} - \frac{1}{2}f_2\overline{l}^s + \frac{1}{2}f_2(2\gamma - 1)\overline{l}^d \\
&\quad + f_2(1-\gamma)(m - p_R) + f_2\gamma(m^* - p_R^*)
\end{aligned} \tag{C9}
$$

$$
\begin{aligned}
\overline{q}^* &= f_0^* - f_1^*\overline{\tau} + f_2^*\Big(\gamma^*(\overline{p^* - p_R^*}) + (1-\gamma^*)(\overline{p^* - (p_R - e)})\Big) \\
&= f_0^* - \Big(f_1^* + (1-\gamma^*)f_2^*\Big)\overline{\tau} + f_2^*\Big(\gamma^*(\overline{p^* - p_R^*}) + (1-\gamma^*)(\overline{p - p_R})\Big) \\
&= f_0^* - \Big(f_1^* + (1-\gamma^*)f_2^*\Big)\overline{\tau} - \frac{1}{2}f_2^*\overline{l}^s + \frac{1}{2}f_2^*(2\gamma^* - 1)\overline{l}^d \\
&\quad + f_2^*\gamma^*(m^* - p_R^*) + f_2^*(1-\gamma^*)(m - p_R)
\end{aligned} \tag{C10}
$$

so that

$$\overline{q}-\overline{q}^* = f_0 - f_0^* + \Big(f_1 + f_2\gamma + f_1^* + (1-\gamma^*)f_2^*\Big)\overline{\tau} - \frac{1}{2}(f_2 - f_2^*)\overline{l}^s + \frac{1}{2}\Big(f_2(2\gamma-1) - f_2^*(2\gamma^*-1)\Big)\overline{l}^d + \Big(f_2(1-\gamma) - f_2^*(1-\gamma^*)\Big)(m - p_R) + \big(f_2\gamma - f_2^*\gamma^*\big)(m^* - p_R^*) \quad \text{(C11)}$$

The corresponding aggregate system is given by the following equations:

$$(1-a_1)(q+q^*) = a_1\big(\psi\gamma - \psi^*(1-\gamma^*)\big)\tau - a_1\big(\psi\gamma + \psi^*\gamma^*\big)(p_R^* - p^*) - a_1\big(\psi(1-\gamma) + \psi^*(1-\gamma^*)\big)(p_R - p) + 2a_0 - 2d_0a_1 + g + g^* - a_2(2i^* + \dot{e}) + a_2\big((\alpha-\alpha^*)\dot{\tau} - \dot{l}^s + \dot{m} + \dot{m}^*\big) \quad \text{(C12)}$$

$$y + y^* = q + q^* + \big(\psi\gamma - (1-\gamma^*)\psi^*\big)\tau - \big(\psi\gamma + \psi^*\gamma^*\big)(p_R^* - p^*) - \big(\psi(1-\gamma) + \psi^*(1-\gamma^*)\big)(p_R - p) - 2d_0 \quad \text{(C13)}$$

$$l^s = (\alpha - \alpha^*)\tau + 2l_0 + l_1(q+q^*) - l_2(2i^* + \dot{e}) \quad \text{(C14)}$$

$$q + q^* = \overline{q} + \overline{q}^* + \left\{\frac{1}{\delta}\left((1-\beta)(1-\alpha) + \frac{(1-\mu)\gamma}{\mu}\right) - \frac{1}{\delta^*}\left((1-\beta^*)(1-\alpha^*) + \frac{(1-\mu^*)(1-\gamma^*)}{\mu^*}\right)\right\}\dot{\tau} - \frac{1}{2}\left\{\frac{1}{\delta}\left(\beta + \frac{1-\mu}{\mu}\right) + \frac{1}{\delta^*}\left(\beta^* + \frac{1-\mu^*}{\mu^*}\right)\right\}\dot{l}^s - \frac{1}{2}\left\{\frac{1}{\delta}\left(\beta + \frac{(1-\mu)(1-2\gamma)}{\mu}\right) - \frac{1}{\delta^*}\left(\beta^* - \frac{(1-\mu^*)(1-2\gamma^*)}{\mu^*}\right)\right\}\dot{l}^d + \left\{\frac{(1-\mu)(1-\gamma)}{\mu\delta} + \frac{(1-\mu^*)(1-\gamma^*)}{\mu^*\delta^*}\right\}(\dot{m} - \dot{p}_R) + \left\{\frac{(1-\mu)\gamma}{\mu\delta} + \frac{(1-\mu^*)\gamma^*}{\mu^*\delta^*}\right\}(\dot{m}^* - \dot{p}_R^*) \quad \text{(C15)}$$

$$\begin{aligned}\overline{q}+\overline{q}^* &= f_0+f_0^*+\Big(f_1+f_2\gamma-f_1^*-(1-\gamma^*)f_2^*\Big)\overline{\tau} \\ &\quad -\frac{1}{2}\Big(f_2+f_2^*\Big)\overline{l}^s+\frac{1}{2}\Big(f_2(2\gamma-1)+f_2^*(2\gamma^*-1)\Big)\overline{l}^d \\ &\quad +\Big(f_2(1-\gamma)+f_2^*(1-\gamma^*)\Big)(m-p_R) \\ &\quad +\Big(f_2\gamma+f_2^*\gamma^*\Big)(m^*-p_R^*)\end{aligned} \tag{C16}$$

In the following we use the abbreviations

$$\nu_1 = \frac{1}{\delta}\left((1-\beta)(1-\alpha)+\frac{(1-\mu)\gamma}{\mu}\right) \tag{C17}$$

$$\nu_1^* = \frac{1}{\delta^*}\left((1-\beta^*)(1-\alpha^*)+\frac{(1-\mu^*)(1-\gamma^*)}{\mu^*}\right) \tag{C18}$$

$$\nu_2 = \frac{1}{\delta}\left(\beta+\frac{1-\mu}{\mu}\right) \tag{C19}$$

$$\nu_2^* = \frac{1}{\delta^*}\left(\beta^*+\frac{1-\mu^*}{\mu^*}\right) \tag{C20}$$

$$\nu_3 = \frac{1}{\delta}\left(\beta+\frac{(1-\mu)(1-2\gamma)}{\mu}\right) \tag{C21}$$

$$\nu_3^* = \frac{1}{\delta^*}\left(\beta^*-\frac{(1-\mu^*)(1-2\gamma^*)}{\mu^*}\right) \tag{C22}$$

$$\nu_4 = \frac{(1-\mu)(1-\gamma)}{\mu\delta} \tag{C23}$$

$$\nu_4^* = \frac{(1-\mu^*)(1-\gamma^*)}{\mu^*\delta^*} \tag{C24}$$

$$\nu_5 = \frac{(1-\mu)\gamma}{\mu\delta} \tag{C25}$$

$$\nu_5^* = \frac{(1-\mu^*)\gamma^*}{\mu^*\delta^*} \tag{C26}$$

The difference and the sum of the dynamic supply functions, i.e. equations (C7) and (C15) respectively, can then be written in the following short form:

$$\begin{aligned} q-q^* &= \overline{q}-\overline{q}^*+(\nu_1+\nu_1^*)\dot{\tau}-\frac{1}{2}(\nu_2-\nu_2^*)\dot{l}^s-\frac{1}{2}(\nu_3+\nu_3^*)\dot{l}^d \\ &\quad +(\nu_4-\nu_4^*)(\dot{m}-\dot{p}_R)+(\nu_5-\nu_5^*)(\dot{m}^*-\dot{p}_R^*)\end{aligned} \tag{C27}$$

$$\begin{aligned} q+q^* &= \overline{q}+\overline{q}^*+(\nu_1-\nu_1^*)\dot{\tau}-\frac{1}{2}(\nu_2+\nu_2^*)\dot{l}^s-\frac{1}{2}(\nu_3-\nu_3^*)\dot{l}^d \\ &\quad +(\nu_4+\nu_4^*)(\dot{m}-\dot{p}_R)+(\nu_5+\nu_5^*)(\dot{m}^*-\dot{p}_R^*)\end{aligned} \tag{C28}$$

Substituting (C27) for $q-q^*$ in the *IS* and *LM* equation (C5) and (C7) respectively yields the dynamic state equations for the difference system:

$$\begin{aligned}
&\Big(\lambda(\nu_1+\nu_1^*)+a_2(1-(\alpha+\alpha^*))\Big)\dot{\tau}-\frac{\lambda}{2}(\nu_2-\nu_2^*)\dot{l}^s \\
&-\frac{\lambda}{2}(\nu_3+\nu_3^*)\dot{l}^d+\lambda(\nu_4-\nu_4^*)(\dot{m}-\dot{p}_R) \\
&+\lambda(\nu_5-\nu_5^*)(\dot{m}^*-\dot{p}_R^*)+\lambda(\overline{q}-\overline{q}^*)\ = \\
&\qquad 2c_0+g-g^*+\Big(-2c_3+(a_1-2c_1)(\psi\gamma+\psi^*(1-\gamma^*))\Big)\tau \\
&\qquad +\frac{1}{2}(a_1-2c_1)\Big(\psi(2\gamma-1)-\psi^*(2\gamma^*-1)\Big)l^d \\
&\qquad -\frac{1}{2}(a_1-2c_1)(\psi-\psi^*)l^s+(a_1-2c_1)\big(\psi\gamma-\psi^*\gamma^*\big)(m^*-p_R^*) \\
&\qquad +(a_1-2c_1)\Big(\psi(1-\gamma)-\psi^*(1-\gamma^*)\Big)(m-p_R)
\end{aligned} \tag{C29}$$

$$\begin{aligned}
l^d+(2-(\alpha+\alpha^*))\tau \ &= \ l_1(\overline{q}-\overline{q}^*)+\Big(l_2+l_1(\nu_1+\nu_1^*)\Big)\dot{\tau} \\
&\quad +\Big(l_2-\frac{1}{2}l_1(\nu_3+\nu_3^*)\Big)\dot{l}^d-\frac{1}{2}l_1(\nu_2-\nu_2^*)\dot{l}^s \\
&\quad +l_1(\nu_4-\nu_4^*)(\dot{m}-\dot{p}_R)+l_1(\nu_5-\nu_5^*)(\dot{m}^*-\dot{p}_R^*) \\
&\quad -l_2(\dot{m}-\dot{m}^*)
\end{aligned} \tag{C30}$$

The dynamic equation of motion of the aggregate system results from the combination of the *IS* and *LM* equation (C12), (C14) and then substituting the aggregate supply function

(C28) for $q+q^*$:

$$\Big\{\big(a_2l_1+l_2(1-a_1)\big)(\nu_1-\nu_1^*)-a_2l_2(\alpha-\alpha^*)\Big\}\dot{\tau} \tag{C31}$$
$$+\Big\{\big(a_2l_1+l_2(1-a_1)\big)\Big(-\frac{1}{2}(\nu_2+\nu_2^*)\Big)+a_2l_2\Big\}\dot{l}^s$$
$$+\big(a_2l_1+l_2(1-a_1)\big)\Big(-\frac{1}{2}(\nu_3-\nu_3^*)\Big)\dot{l}^d$$
$$+\big(a_2l_1+l_2(1-a_1)\big)(\nu_4+\nu_4^*)(\dot{m}-\dot{p}_R)$$
$$+\big(a_2l_1+l_2(1-a_1)\big)(\nu_5+\nu_5^*)(\dot{m}^*-\dot{p}_R^*)$$
$$+\big(a_2l_1+l_2(1-a_1)\big)(\overline{q}+\overline{q}^*) \;=$$
$$a_2l_2(\dot{m}+\dot{m}^*)+l_2(g+g^*)+2a_0l_2-2d_0a_1l_2-2l_0a_2$$
$$+\Big(l_2a_1(\psi\gamma-\psi^*(1-\gamma^*))-a_2(\alpha-\alpha^*)\Big)\tau$$
$$+\frac{1}{2}l_2a_1\Big(\psi(2\gamma-1)+\psi^*(2\gamma^*-1)\Big)l^d$$
$$+\Big(a_2-\frac{1}{2}l_2a_1(\psi+\psi^*)\Big)l^s+l_2a_1\Big(\psi\gamma+\psi^*\gamma^*\Big)(m^*-p_R^*)$$
$$+l_2a_1\Big(\psi(1-\gamma)+\psi^*(1-\gamma^*)\Big)(m-p_R)$$

The matrix representation of the dynamic state equations (C29), (C30), (C31) in deviational form is given by

$$\overline{\mathbf{B}}\begin{pmatrix}\dot{l}^s\\ \dot{\tau}\\ \dot{l}^d\end{pmatrix}=\overline{\mathbf{C}}\begin{pmatrix}l^s-\overline{l}^s\\ \tau-\overline{\tau}\\ l^d-\overline{l}^d\end{pmatrix} \tag{C32}$$

where the matrices $\overline{\mathbf{B}}=(\overline{b}_{ij})_{1\le i,j\le 3}$ and $\overline{\mathbf{C}}=(\overline{c}_{ij})_{1\le i,j\le 3}$ are defined by

$$\overline{b}_{11} = \big(a_2l_1+l_2(1-a_1)\big)\Big(-\frac{1}{2}(\nu_2+\nu_2^*)\Big)+a_2l_2 \tag{C33}$$
$$\overline{b}_{12} = \big(a_2l_1+l_2(1-a_1)\big)(\nu_1-\nu_1^*)-a_2l_2(\alpha-\alpha^*) \tag{C34}$$
$$\overline{b}_{13} = -\frac{1}{2}\Big(a_2l_1+l_2(1-a_1)\Big)(\nu_3-\nu_3^*) \tag{C35}$$
$$\overline{b}_{21} = -\frac{\lambda}{2}(\nu_2-\nu_2^*) \tag{C36}$$
$$\overline{b}_{22} = \lambda(\nu_1+\nu_1^*)+a_2\big(1-(\alpha+\alpha^*)\big) \tag{C37}$$
$$\overline{b}_{23} = -\frac{\lambda}{2}(\nu_3+\nu_3^*) \tag{C38}$$
$$\overline{b}_{31} = -\frac{1}{2}l_1(\nu_2-\nu_2^*) \tag{C39}$$
$$\overline{b}_{32} = l_2+l_1(\nu_1+\nu_1^*) \tag{C40}$$
$$\overline{b}_{33} = l_2-\frac{1}{2}l_1(\nu_3+\nu_3^*) \tag{C41}$$

$$\bar{c}_{11} = a_2 - \frac{1}{2} l_2 a_1 (\psi + \psi^*) \tag{C42}$$

$$\bar{c}_{12} = l_2 a_1 \big(\psi\gamma - \psi^*(1-\gamma^*)\big) - a_2(\alpha - \alpha^*) \tag{C43}$$

$$\bar{c}_{13} = \frac{1}{2} l_2 a_1 \big(\psi(2\gamma - 1) + \psi^*(2\gamma^* - 1)\big) \tag{C44}$$

$$\bar{c}_{21} = -\frac{1}{2}(a_1 - 2c_1)(\psi - \psi^*) \tag{C45}$$

$$\bar{c}_{22} = -2c_3 + (a_1 - 2c_1)\big(\psi\gamma + \psi^*(1-\gamma^*)\big) \tag{C46}$$

$$\bar{c}_{23} = \frac{1}{2}(a_1 - 2c_1)\big(\psi(2\gamma - 1) - \psi^*(2\gamma^* - 1)\big) \tag{C47}$$

$$\bar{c}_{31} = 0 \tag{C48}$$

$$\bar{c}_{32} = 2 - (\alpha + \alpha^*) \tag{C49}$$

$$\bar{c}_{33} = 1 \tag{C50}$$

In the special case $\gamma = \gamma^* = 1$, i.e., if raw materials imports are completely denominated in terms of the foreign currency, (C32) is equivalent to the dynamic system (A27). In the other polar case $\gamma = \gamma^* = 0$ it is equivalent to (B19).

The steady state system that results from the dynamic state equations and the long run supply functions is given by the following equations:

$$\begin{aligned}
&\lambda\Big(f_1 + f_2\gamma + f_1^* + (1-\gamma^*)f_2^*\Big)\bar{\tau} - \frac{1}{2}\lambda(f_2 - f_2^*)\bar{l}^s \\
&+ \frac{1}{2}\lambda\Big(f_2(2\gamma - 1) - f_2^*(2\gamma^* - 1)\Big)\bar{l}^d + \lambda(f_0 - f_0^*) \\
&+ \lambda\Big(f_2(1-\gamma) - f_2^*(1-\gamma^*)\Big)(m - p_R) \\
&+ \lambda\Big(f_2\gamma - f_2^*\gamma^*\Big)(m^* - p_R^*) + \lambda(\nu_4 - \nu_4^*)(\dot{m} - \dot{p}_R) \\
&+ \lambda(\nu_5 - \nu_5^*)(\dot{m}^* - \dot{p}_R^*) \; = \\
&\qquad \Big(-2c_3 + (a_1 - 2c_1)(\psi\gamma + \psi^*(1-\gamma^*))\Big)\bar{\tau} \\
&\qquad + \frac{1}{2}(a_1 - 2c_1)\Big(\psi(2\gamma - 1) - \psi^*(2\gamma^* - 1)\Big)\bar{l}^d \\
&\qquad - \frac{1}{2}(a_1 - 2c_1)(\psi - \psi^*)\bar{l}^s + 2c_0 + g - g^* \\
&\qquad + (a_1 - 2c_1)\Big(\psi\gamma - \psi^*\gamma^*\Big)(m^* - p_R^*) \\
&\qquad + (a_1 - 2c_1)\Big(\psi(1-\gamma) - \psi^*(1-\gamma^*)\Big)(m - p_R)
\end{aligned} \tag{C51}$$

$$
\begin{aligned}
\bar{l}^d + (2-(\alpha+\alpha^*))\bar{\tau} &= l_1\Big(f_1 + f_2\gamma + f_1^* + (1-\gamma^*)f_2^*\Big)\bar{\tau} \\
&\quad - \frac{1}{2}l_1(f_2 - f_2^*)\bar{l}^s \\
&\quad + \frac{1}{2}l_1\Big(f_2(2\gamma-1) - f_2^*(2\gamma^*-1)\Big)\bar{l}^d \\
&\quad + l_1\Big(f_2(1-\gamma) - f_2^*(1-\gamma^*)\Big)(m-p_R) \\
&\quad + l_1\big(f_2\gamma - f_2^*\gamma^*\big)(m^*-p_R^*) + l_1\big(\nu_4-\nu_4^*\big)(\dot{m}-\dot{p}_R) \\
&\quad + l_1\big(\nu_5-\nu_5^*\big)(\dot{m}^*-\dot{p}_R^*) - l_2(\dot{m}-\dot{m}^*) + l_1(f_0-f_0^*)
\end{aligned} \tag{C52}
$$

$$
\begin{aligned}
&\big(a_2l_1 + l_2(1-a_1)\big)\Big\{f_0 + f_0^* + \Big(f_1 + f_2\gamma - f_1^* - (1-\gamma^*)f_2^*\Big)\bar{\tau} \\
&- \frac{1}{2}(f_2+f_2^*)\bar{l}^s + \frac{1}{2}\Big(f_2(2\gamma-1) + f_2^*(2\gamma^*-1)\Big)\bar{l}^d \\
&+ \Big(f_2(1-\gamma) + f_2^*(1-\gamma^*)\Big)(m-p_R) + \Big(f_2\gamma + f_2^*\gamma\Big)(m^*-p_R^*) \\
&+ (\nu_4+\nu_4^*)(\dot{m}-\dot{p}_R) + (\nu_5+\nu_5^*)(\dot{m}^*-\dot{p}_R^*)\Big\} = \\
&\qquad a_2l_2(\dot{m}+\dot{m}^*) + l_2(g+g^*) + 2a_0l_2 - 2d_0a_1l_2 - 2l_0a_2 \\
&\qquad + \Big(l_2a_1\big(\psi\gamma - \psi^*(1-\gamma^*)\big) - a_2(\alpha-\alpha^*)\Big)\bar{\tau} \\
&\qquad + \frac{1}{2}l_2a_1\Big(\psi(2\gamma-1) + \psi^*(2\gamma^*-1)\Big)\bar{l}^d \\
&\qquad + \Big(a_2 - \frac{1}{2}l_2a_1(\psi+\psi^*)\Big)\bar{l}^s \\
&\qquad + l_2a_1\Big(\psi\gamma + \psi^*\gamma^*\Big)(m^*-p_R^*) \\
&\qquad + l_2a_1\Big(\psi(1-\gamma) + \psi^*(1-\gamma^*)\Big)(m-p_R)
\end{aligned} \tag{C53}
$$

We consider the case of a simultaneous increase of the US-dollar and Euro price of imported crude oil, i.e. $dp_R^* = dp_R > 0$. Then equations (C51), (C52), (C53) lead to the matrix representation

$$
\begin{pmatrix} \bar{f}_{11} & \bar{f}_{12} & \bar{f}_{13} \\ \bar{f}_{21} & \bar{f}_{22} & \bar{f}_{23} \\ \bar{f}_{31} & \bar{f}_{32} & \bar{f}_{33} \end{pmatrix} \begin{pmatrix} d\bar{\tau} \\ d\bar{l}^d \\ d\bar{l}^s \end{pmatrix} = \begin{pmatrix} 2f_{12} \\ -2f_{23} \\ 2f_{32} \end{pmatrix} dp_R \tag{C54}
$$

where

$$\overline{f}_{11} = \lambda(f_1 + f_2\gamma + f_1^* + (1-\gamma^*)f_2^*) + 2c_3 - (a_1 - 2c_1)\big(\psi\gamma + \psi^*(1-\gamma^*)\big) \tag{C55}$$

$$\overline{f}_{12} = \frac{1}{2}\lambda\big(f_2(2\gamma-1) - f_2^*(2\gamma^*-1)\big) - \frac{1}{2}(a_1-2c_1)\big(\psi(2\gamma-1) - \psi^*(2\gamma^*-1)\big) \tag{C56}$$

$$\overline{f}_{13} = -\frac{1}{2}\lambda(f_2 - f_2^*) + \frac{1}{2}(a_1-2c_1)(\psi - \psi^*) \tag{C57}$$

$$\overline{f}_{21} = 2 - \alpha - \alpha^* - l_1\big(f_1 + f_2\gamma + f_1^* + (1-\gamma^*)f_2^*\big) \tag{C58}$$

$$\overline{f}_{22} = 1 - \frac{1}{2}l_1\big(f_2(2\gamma-1) - f_2^*(2\gamma^*-1)\big) \tag{C59}$$

$$\overline{f}_{23} = \frac{1}{2}l_1(f_2 - f_2^*) \tag{C60}$$

$$\overline{f}_{31} = l_2a_1\big(\psi\gamma - \psi^*(1-\gamma^*)\big) - a_2(\alpha - \alpha^*) - \big(a_2l_1 + l_2(1-a_1)\big)\big(f_1 + f_2\gamma - f_1^* - (1-\gamma^*)f_2^*\big) \tag{C61}$$

$$\overline{f}_{32} = \frac{1}{2}\Big\{l_2a_1\big(\psi(2\gamma-1) + \psi^*(2\gamma^*-1)\big) - \big(a_2l_1 + l_2(1-a_1)\big)\big(f_2(2\gamma-1) + f_2^*(2\gamma^*-1)\big)\Big\} \tag{C62}$$

$$\overline{f}_{33} = a_2 - \frac{1}{2}\Big\{l_2a_1(\psi + \psi^*) - \big(a_2l_1 + l_2(1-a_1)\big)(f_2 + f_2^*)\Big\} \tag{C63}$$

and f_{12}, f_{23} and f_{32} are defined in (A53), (A57) and (A59) respectively.

Note that system (C54) is equivalent to the steady state system (A51) if $\gamma = \gamma^* = 1$ and equivalent to (B41) if $\gamma = \gamma^* = 0$. Since

$$\overline{f}_{12} = \overline{f}_{13} + \nu_1 \tag{C64}$$

$$\overline{f}_{22} = 1 + \overline{f}_{23} + \nu_2 \tag{C65}$$

$$\overline{f}_{32} = \overline{f}_{33} - a_2 + \nu_3 \tag{C66}$$

where

$$\nu_1 = \lambda(f_2\gamma - f_2^*\gamma^*) - (a_1 - 2c_1)(\psi\gamma - \psi^*\gamma^*) \tag{C67}$$

$$\nu_2 = -l_1(f_2\gamma - f_2^*\gamma^*) \tag{C68}$$

$$\nu_3 = l_2a_1(\psi\gamma + \psi^*\gamma^*) - \big(a_2l_1 + l_2(1-a_1)\big)(f_2\gamma + f_2^*\gamma^*) \tag{C69}$$

the determinant $|\overline{\mathbf{F}}|$ of the system matrix $\overline{\mathbf{F}} = (\overline{f}_{ij})_{1\le i,j\le 3}$ in (C54) is given by

$$|\overline{\mathbf{F}}| = \overline{f}_{11}\overline{f}_{33} - \overline{f}_{13}\overline{f}_{31} + a_2(\overline{f}_{11}\overline{f}_{23} - \overline{f}_{13}\overline{f}_{21}) + \nu_1(\overline{f}_{23}\overline{f}_{31} - \overline{f}_{21}\overline{f}_{33}) + \nu_2(\overline{f}_{11}\overline{f}_{33} - \overline{f}_{13}\overline{f}_{31}) + \nu_3(\overline{f}_{13}\overline{f}_{21} - \overline{f}_{11}\overline{f}_{23}) \tag{C70}$$

$|\overline{\mathbf{F}}|$ coincides with $|\hat{\mathbf{F}}|$ if $\gamma = \gamma^* = 0$ and equals $|\mathbf{F}|$ if $\gamma = \gamma^* = 1$. The steady state system (C54) has the following solution:

$$\begin{pmatrix} d\overline{\tau} \\ d\overline{l}^d \\ d\overline{l}^s \end{pmatrix} = \frac{1}{|\overline{\mathbf{F}}|} \begin{pmatrix} \begin{matrix}((1+\nu_2)\overline{f}_{33} \\ -\overline{f}_{23}(-a_2+\nu_3))\end{matrix} & \begin{matrix}(-\overline{f}_{33}\nu_1 \\ +\overline{f}_{13}(-a_2+\nu_3))\end{matrix} & \begin{matrix}(\overline{f}_{23}\nu_1 \\ -\overline{f}_{13}(1+\nu_2))\end{matrix} \\ \overline{f}_{23}\overline{f}_{31} - \overline{f}_{21}\overline{f}_{33} & \overline{f}_{11}\overline{f}_{33} - \overline{f}_{13}\overline{f}_{31} & \overline{f}_{13}\overline{f}_{21} - \overline{f}_{11}\overline{f}_{23} \\ \overline{f}_{21}\overline{f}_{32} - \overline{f}_{31}\overline{f}_{22} & \overline{f}_{12}\overline{f}_{31} - \overline{f}_{11}\overline{f}_{32} & \overline{f}_{11}\overline{f}_{22} - \overline{f}_{21}\overline{f}_{12} \end{pmatrix} \cdot \begin{pmatrix} 2f_{12} \\ -2f_{23} \\ 2f_{32} \end{pmatrix} dp_R \tag{C71}$$

Since

$$\overline{f}_{33} = a_2 - f_{32} \tag{C72}$$
$$\overline{f}_{23} = f_{23} \tag{C73}$$
$$\overline{f}_{13} = f_{13} = -f_{12} \tag{C74}$$

equation (C71) implies

$$\begin{aligned} \frac{d\overline{\tau}}{dp_R} &= \frac{1}{|\overline{\mathbf{F}}|}\Big\{2f_{12}\big((1+\nu_2)(a_2-f_{32}) - f_{23}(-a_2+\nu_3)\big) \\ &\quad - 2f_{23}\big(-(a_2-f_{32})\nu_1 - f_{12}(-a_2+\nu_3)\big) \\ &\quad + 2f_{32}\big(f_{23}\nu_1 + f_{12}(1+\nu_2)\big)\Big\} \\ &= \frac{a_2}{|\overline{\mathbf{F}}|}\Big(2f_{12} + 2f_{12}\nu_2 + 2f_{23}\nu_1\Big) \\ &= \frac{a_2}{|\overline{\mathbf{F}}|}\Big(2f_{12} + l_1(a_1-2c_1)(f_2\psi^* - f_2^*\psi)(\gamma^*-\gamma)\Big) \end{aligned} \tag{C75}$$

In the special case $\gamma = \gamma^*$ the multiplier (C75) reduces to $2a_2 f_{12}/|\overline{\mathbf{F}}|$ which is positive if $f_{12} > 0$, i.e., if $\lambda(f_2 - f_2^*) > (a_1 - 2c_1)(\psi - \psi^*)$ holds (cf. (A68)).[64] The determinant (C70) simplifies in the case $\gamma = \gamma^*$ to

$$|\overline{\mathbf{F}}|_{\gamma=\gamma^*} = -\overline{f}_{11}f_{32} + f_{12}\overline{f}_{31} + a_2(\overline{f}_{11}\overline{f}_{22} - \overline{f}_{21}\overline{f}_{12}) \tag{C76}$$

since

$$\overline{f}_{12}\nu_2 + \overline{f}_{23}\nu_1 = \overline{f}_{12}\nu_3 - \overline{f}_{32}\nu_1 = \overline{f}_{23}\nu_3 + \overline{f}_{32}\nu_2 = 0 \tag{C77}$$

if $\gamma = \gamma^*$.

[64] Note that the multiplier (C75) also equals $2a_2 f_{12}/|\overline{\mathbf{F}}|$ if the term $f_2\psi^*$ coincides with $f_2^*\psi$ which is met if both $\sigma = \sigma^*$ and $\delta = \delta^*$ holds.

D Stabilization Policies in Case of Foreign-Currency Denominated Oil Imports

D.1 Complete Stabilization of the Consumer Inflation Rate

The formal solution of the state vector, i.e. equations (A80), (A81), and the determination of the constants A_0, A_1, A_2, $\widetilde{A}_0$, $\widetilde{A}_2$ (cf. (A91) to (A98)) remain unchanged if the rate of change of the domestic money supply is endogenized according to the monetary policy rule

$$\dot{m} = (1-\alpha)\dot{\tau} + \frac{1}{2}\dot{l}^s + \frac{1}{2}\dot{l}^d \tag{D1}$$

If this rule holds both for $0 < t < T$ and $t > T$ it guarantees $\dot{p}^c = 0$ for all $t > 0$. Since $\dot{m}$ is now a function of the rate of change of the three state variables, this leads to adjustments of the elements b_{ij} of the state matrix $\mathbf{B}$ in (A27). The state equation (A9) is independent of $\dot{m}$, while the equations (A10) and (A21) contain the variable $\dot{m}$; the matrix $\mathbf{B}$ in (A27) has therefore to be replaced by $\widetilde{\mathbf{B}} = (\widetilde{b}_{ij})$ where

$$\widetilde{b}_{11} = b_{11} - \frac{1}{2}a_2 l_2 \tag{D2}$$
$$\widetilde{b}_{12} = b_{12} - a_2 l_2 (1-\alpha) \tag{D3}$$
$$\widetilde{b}_{13} = b_{13} - \frac{1}{2}a_2 l_2 \tag{D4}$$
$$\widetilde{b}_{21} = b_{21} \tag{D5}$$
$$\widetilde{b}_{22} = b_{22} \tag{D6}$$
$$\widetilde{b}_{23} = b_{23} \tag{D7}$$
$$\widetilde{b}_{31} = b_{31} - \frac{1}{2}l_2 \tag{D8}$$
$$\widetilde{b}_{32} = b_{32} - l_2(1-\alpha) \tag{D9}$$
$$\widetilde{b}_{33} = b_{33} - \frac{1}{2}l_2 \tag{D10}$$

The complete stabilization of the *foreign* consumer inflation rate $\dot{p}^{*c}$ with the aid of foreign monetary policy leads to the decision rule

$$\dot{m}^* = -(1-\alpha^*)\dot{\tau} + \frac{1}{2}\dot{l}^s - \frac{1}{2}\dot{l}^d \tag{D11}$$

which implies $\dot{p}^{*c} = 0$ for all $t > 0$. The matrices B and C of the state equations (A27) have now to be replaced by $\mathbf{B}' = (b'_{ij})$ and $\mathbf{C}' = (c'_{ij})$ where[65]

$$b'_{11} = b_{11} - \frac{1}{2}a_2 l_2 + \frac{1}{2}\big(a_2 l_1 + l_2(1-a_1)\big)\kappa_6 \tag{D12}$$
$$b'_{12} = b_{12} + a_2 l_2(1-\alpha^*) - (1-\alpha^*)\big(a_2 l_1 + l_2(1-a_1)\big)\kappa_6 \tag{D13}$$

[65] Note that in the case of foreign-currency denominated oil imports the equations (A9) and (A21) depend both on $\dot{m}^*$ and m^* since $p^* - p^*_R$ can be replaced by $-\frac{1}{2}(\bar{l}^s - \bar{l}^d) + m^* - p^*_R$. If $\dot{m}^*$ is defined by (D11) the foreign money supply m^* is also an endogenous variable where the policy rule for m^* results from (D11) by integration. This implies that both state matrices B and C change their structure.

$$b'_{13} = b_{13} + \frac{1}{2}a_2 l_2 - \frac{1}{2}\big(a_2 l_1 + l_2(1-a_1)\big)\kappa_6 \quad \text{(D14)}$$

$$b'_{21} = b_{21} + \frac{1}{2}\lambda\kappa_2 \quad \text{(D15)}$$

$$b'_{22} = b_{22} - \lambda\kappa_2(1-\alpha^*) \quad \text{(D16)}$$

$$b'_{23} = b_{23} - \frac{1}{2}\lambda\kappa_2 \quad \text{(D17)}$$

$$b'_{31} = b_{31} + \frac{1}{2}(l_2 + l_1\kappa_2) \quad \text{(D18)}$$

$$b'_{32} = b_{32} - (l_2 + l_1\kappa_2)(1-\alpha^*) \quad \text{(D19)}$$

$$b'_{33} = b_{33} - \frac{1}{2}(l_2 + l_1\kappa_2) \quad \text{(D20)}$$

$$c'_{11} = c_{11} + \frac{1}{2}l_2 a_1(\psi + \psi^*) = a_2 \quad \text{(D21)}$$

$$c'_{12} = c_{12} - l_2 a_1(\psi + \psi^*)(1-\alpha^*) \quad \text{(D22)}$$

$$c'_{13} = c_{13} - \frac{1}{2}l_2 a_1(\psi + \psi^*) = 0 \quad \text{(D23)}$$

$$c'_{21} = c_{21} + \frac{1}{2}(a_1 - 2c_1)(\psi - \psi^*) = 0 \quad \text{(D24)}$$

$$c'_{22} = c_{22} - (a_1 - 2c_1)(\psi - \psi^*)(1-\alpha^*) \quad \text{(D25)}$$

$$c'_{23} = c_{23} - \frac{1}{2}(a_1 - 2c_1)(\psi - \psi^*) = 0 \quad \text{(D26)}$$

$$c'_{31} = c_{31} \quad \text{(D27)}$$

$$c'_{32} = c_{32} \quad \text{(D28)}$$

$$c'_{33} = c_{33} \quad \text{(D29)}$$

In the case of a *simultaneous* stabilization of the inflation rates $\dot{p}^c$ and $\dot{p}^{*c}$ with the help of the policy rules (D1) and (D11) the state matrices $\mathbf{B}$ and $\mathbf{C}$ have to be replaced by $\mathbf{B}'' = \widetilde{\mathbf{B}} + \mathbf{B}' - \mathbf{B} = (b''_{ij})$ and $\mathbf{C}'$ respectively, where

$$b''_{11} = b_{11} - a_2 l_2 + \frac{1}{2}\big(a_2 l_1 + l_2(1-a_1)\big)\kappa_6 \quad \text{(D30)}$$

$$b''_{12} = b_{12} + a_2 l_2(\alpha - \alpha^*) - (1-\alpha^*)\big(a_2 l_1 + l_2(1-a_1)\big)\kappa_6 \quad \text{(D31)}$$

$$b''_{13} = b_{13} - \frac{1}{2}\big(a_2 l_1 + l_2(1-a_1)\big)\kappa_6 \quad \text{(D32)}$$

$$b''_{21} = b_{21} + \frac{1}{2}\lambda\kappa_2 = b'_{21} \quad \text{(D33)}$$

$$b''_{22} = b_{22} - \lambda\kappa_2(1-\alpha^*) = b'_{22} \quad \text{(D34)}$$

$$b''_{23} = b_{23} - \frac{1}{2}\lambda\kappa_2 = b'_{23} \quad \text{(D35)}$$

$$b''_{31} = b_{31} + \frac{1}{2}l_1\kappa_2 \quad \text{(D36)}$$

$$b''_{32} = b_{32} - l_2(1-\alpha) - (l_2 + l_1\kappa_2)(1-\alpha^*) \quad \text{(D37)}$$

$$b''_{33} = b_{33} - l_2 - \frac{1}{2}l_1\kappa_2 \quad \text{(D38)}$$

Note that the endogenization of domestic and foreign growth rate of money supply according to the policy rules (D1) and (D11) does not result in dynamic instability. Several numerical simulations illustrate that the saddle point stability continuous to hold, but the unstable eigenvalue r_1 increases by a large amount. The strongest rise of r_1 takes place if the domestic and foreign consumer inflation rate are pegged simultaneously at their initial steady state level at all times by utilizing (D1) and (D11).

D.2 Stabilization of the Consumer Inflation Rate for $\mathbf{t > T}$

A change in the determination of the constants A_1, $\widetilde{A}_0$ and $\widetilde{A}_2$ takes place, if the monetary policy rule (D1) only holds for $t > T$ and is credible announced in $t = 0$. This implies $\dot{p}^c = 0$ for $t > T$ but $\dot{p}^c \neq 0$ for $0 < t < T$. In this case the formal solution of the state vector $x = (l^s, \tau, l^d)'$ is given by

$$x = \bar{x}_0 + A_0' h_0 e^{r_0 t} + A_1' h_1 e^{r_1 t} + A_2' h_2 e^{r_2 t} \quad \text{for } 0 < t < T \tag{D39}$$

$$x = \bar{x}_1 + \widetilde{A}_0' \widetilde{h}_0 e^{\widetilde{r}_0 t} + \widetilde{A}_2' \widetilde{h}_2 e^{\widetilde{r}_2 t} \quad \text{for } t > T \tag{D40}$$

where r_0, r_1, r_2 are the eigenvalues and h_0, h_1, h_2 the corresponding eigenvectors of the matrix $\mathbf{G} = \mathbf{B^{-1}C}$ (cf. (A82)), while $\widetilde{r}_0$ and $\widetilde{r}_2$ are the stable eigenvalues and $\widetilde{h}_0$ and $\widetilde{h}_2$ the corresponding eigenvectors of the matrix $\widetilde{\mathbf{G}} = \widetilde{\mathbf{B}}^{\mathbf{-1}}\mathbf{C}$.[66] The constants A_0', A_1', A_2', $\widetilde{A}_0'$ and $\widetilde{A}_2'$ result from the continuity conditions (A87), (A88) which are now of the following form:

$$0 = A_0' + A_1' + A_2' \tag{D41}$$

$$0 = A_0' h_{10} + A_1' h_{11} + A_2' h_{12} \tag{D42}$$

$$\bar{l}_0^s + A_0' h_{10} e^{r_0 T} + A_1' h_{11} e^{r_1 T} + A_2' h_{12} e^{r_2 T} = \bar{l}_1^s + \widetilde{A}_0' \widetilde{h}_{10} e^{\widetilde{r}_0 T} + \widetilde{A}_2' \widetilde{h}_{12} e^{\widetilde{r}_2 T} \tag{D43}$$

$$\bar{\tau}_0 + A_0' h_{20} e^{r_0 T} + A_1' h_{21} e^{r_1 T} + A_2' h_{22} e^{r_2 T} = \bar{\tau}_1 + \widetilde{A}_0' \widetilde{h}_{20} e^{\widetilde{r}_0 T} + \widetilde{A}_2' \widetilde{h}_{22} e^{\widetilde{r}_2 T} \tag{D44}$$

$$\bar{l}_0^d + A_0' e^{r_0 T} + A_1' e^{r_1 T} + A_2' e^{r_2 T} = \bar{l}_1^d + \widetilde{A}_0' e^{\widetilde{r}_0 T} + \widetilde{A}_2' e^{\widetilde{r}_2 T} \tag{D45}$$

It then follows (cf. (A91), (A92))

$$A_0' = \frac{h_{12} - h_{11}}{h_{10} - h_{12}} A_1' \tag{D46}$$

$$A_2' = \frac{h_{11} - h_{10}}{h_{10} - h_{12}} A_1' \tag{D47}$$

and

$$\begin{pmatrix} \phi_1 & -\widetilde{h}_{10} e^{\widetilde{r}_0 T} & -\widetilde{h}_{12} e^{\widetilde{r}_2 T} \\ \phi_2 & -\widetilde{h}_{20} e^{\widetilde{r}_0 T} & -\widetilde{h}_{22} e^{\widetilde{r}_2 T} \\ \phi_3 & -e^{\widetilde{r}_0 T} & -e^{\widetilde{r}_2 T} \end{pmatrix} \begin{pmatrix} A_1' \\ \widetilde{A}_0' \\ \widetilde{A}_2' \end{pmatrix} = \begin{pmatrix} d\bar{l}^s \\ d\bar{\tau} \\ d\bar{l}^d \end{pmatrix} \tag{D48}$$

[66] Note that if the *foreign* monetary policy rule (D11) holds for $t > T$ (which implies $\dot{p}^{*c} = 0$ for $t > T$), then $\widetilde{\mathbf{G}}$ has to be replaced by $\mathbf{G}' = \mathbf{B}'^{\mathbf{-1}}\mathbf{C}'$. If the policy rules (D1) and (D11) hold *simultaneously* for $t > T$ then the relevant matrix is $\mathbf{G}'' = \mathbf{B}''^{\mathbf{-1}}\mathbf{C}'$.

where

$$\phi_1 = h_{11}e^{r_1T} + h_{10}\frac{h_{12}-h_{11}}{h_{10}-h_{12}}e^{r_0T} + h_{12}\frac{h_{11}-h_{10}}{h_{10}-h_{12}}e^{r_2T} \quad \text{(D49)}$$

$$\phi_2 = h_{21}e^{r_1T} + h_{20}\frac{h_{12}-h_{11}}{h_{10}-h_{12}}e^{r_0T} + h_{22}\frac{h_{11}-h_{10}}{h_{10}-h_{12}}e^{r_2T} \quad \text{(D50)}$$

$$\phi_3 = e^{r_1T} + \frac{h_{12}-h_{11}}{h_{10}-h_{12}}e^{r_0T} + \frac{h_{11}-h_{10}}{h_{10}-h_{12}}e^{r_2T} \quad \text{(D51)}$$

The solution is given by

$$A_1' = \frac{1}{\Lambda}\left\{(\widetilde{h}_{20}-\widetilde{h}_{22})d\bar{l}^s + (\widetilde{h}_{12}-\widetilde{h}_{10})d\overline{\tau} + (\widetilde{h}_{10}\widetilde{h}_{22}-\widetilde{h}_{12}\widetilde{h}_{20})d\bar{l}^d\right\} \quad \text{(D52)}$$

$$\widetilde{A}_0' = \frac{e^{-\widetilde{r}_0T}}{\Lambda}\left\{(\phi_2-\phi_3\widetilde{h}_{22})d\bar{l}^s + (-\phi_1+\phi_3\widetilde{h}_{12})d\overline{\tau} + (\phi_1\widetilde{h}_{22}-\phi_2\widetilde{h}_{12})d\bar{l}^d\right\} \quad \text{(D53)}$$

$$\widetilde{A}_2' = \frac{e^{-\widetilde{r}_2T}}{\Lambda}\left\{(-\phi_2+\phi_3\widetilde{h}_{20})d\bar{l}^s + (\phi_1-\phi_3\widetilde{h}_{10})d\overline{\tau} + (-\phi_1\widetilde{h}_{20}+\phi_2\widetilde{h}_{10})d\bar{l}^d\right\} \quad \text{(D54)}$$

where

$$\Lambda = \phi_1(\widetilde{h}_{20}-\widetilde{h}_{22}) + \phi_2(\widetilde{h}_{12}-\widetilde{h}_{10}) + \phi_3(\widetilde{h}_{10}\widetilde{h}_{22}-\widetilde{h}_{12}\widetilde{h}_{20}) \quad \text{(D55)}$$

Note that Λ is independent of the stable eigenvalues $\widetilde{r}_0$ and $\widetilde{r}_2$ of the stabilized system. Since the same holds for the constant A_1' the initial jump of τ does not depend on the eigenvalues $\widetilde{r}_0$ and $\widetilde{r}_2$:

$$\begin{aligned}\tau(0+)-\overline{\tau}_0 &= A_0'h_{20} + A_1'h_{21} + A_2'h_{22} \quad \text{(D56)}\\ &= \left(h_{20}\frac{h_{12}-h_{11}}{h_{10}-h_{12}} + h_{21} + h_{22}\frac{h_{11}-h_{10}}{h_{10}-h_{12}}\right)A_1'\end{aligned}$$

D.3 Complete System Stabilization

Next consider the problem of complete system stabilization, i.e.

$$x = \overline{x}_0 \qquad \text{for } 0 \le t < T \quad \text{(D57)}$$

and

$$x = \overline{x}_1 \qquad \text{for } t > T \quad \text{(D58)}$$

where x is an arbitrary endogenous variable and $\overline{x}_0$ denotes its initial and $\overline{x}_1$ its new steady state level. Dynamic adjustment processes which result from anticipated oil price shocks can be avoided if domestic and foreign monetary policy is able to set the constants A_1, $\widetilde{A}_0$ and $\widetilde{A}_2$ equal to zero (cf. (A96), (A97), (A98)). If $A_1 = 0$ then, according to (A91), (A92), $A_0 = A_2 = 0$ so that the state vector and the other endogenous variables are fixed at their respective initial steady state level during the whole anticipation phase $0 \le t < T$ (cf. (A80)). If $\widetilde{A}_0$ and $\widetilde{A}_2$ can be set equal to zero simultaneously then (D58) holds for all endogenous variable (cf. (A81)). The constants A_1, $\widetilde{A}_0$ and $\widetilde{A}_2$ depend on the steady state change of the state variables, i.e. $d\bar{l}^s$, $d\overline{\tau}$ and $d\bar{l}^d$. In the presence of active monetary policy as response to oil price shocks the total differential $d\overline{z}$ is given by

$$d\overline{z} = \frac{\partial \overline{z}}{\partial p_R^*} dp_R^* + \frac{\partial \overline{z}}{\partial \dot{m}} d\dot{m} + \frac{\partial \overline{z}}{\partial \dot{m}^*} d\dot{m}^* \qquad \text{for } \overline{z} \in \{\overline{l}^s, \overline{\tau}, \overline{l}^d\} \tag{D59}$$

where the multipliers $\frac{\partial \overline{z}}{\partial \dot{m}}$ are defined in (A63), (A64). In the case of passive foreign monetary policy the steady state multipliers $\frac{\partial \overline{z}}{\partial p_R^*}$ are defined in (A68), (A69) and (A70). Complete system stabilization requires a permanent change of the foreign monetary growth rate ($d\dot{m}^* \neq 0$). We must therefore determine the steady state multipliers of foreign monetary policy. A permanent increase in foreign money stock leads to a permanent rise in foreign price level so that – given a fixed level of the US dollar price of imported raw materials – no steady state level of the foreign real factor price $p_R^* - p^*$ exists. Instead, it would decline continuously if $d\dot{m}^* > 0$ holds. In order to guarantee the existence of $\overline{p_R^* - p^*}$ we must give up the assumption that there is no growth in the factor price p_R^* (i.e., $dp_R^* = 0$). We therefore endogenize $\dot{p}_R^*$ according to the pricing rule

$$\dot{p}_R^* = \dot{m}^* \tag{D60}$$

or

$$\dot{p}_R^* = \dot{p}^* \tag{D61}$$

In the first case the state space dynamics, represented by the matrices **B** and **C** in (A27), do not change, while in the second case equation (A8) can be omitted so that the matrices **B** and **C** have to be replaced by $\underline{\mathbf{B}} = (\underline{b}_{ij})$ and $\underline{\mathbf{C}} = (\underline{c}_{ij})$ respectively, where

$$\underline{b}_{11} = -\frac{1}{2}(a_2 l_1 + l_2(1 - a_1)) \left(\frac{\beta}{\delta} + \frac{\beta^*}{\delta^*} \right) + a_2 l_2 \tag{D62}$$

$$\underline{b}_{12} = b_{12} \tag{D63}$$

$$\underline{b}_{13} = \frac{1}{2}(a_2 l_1 + l_2(1 - a_1)) \left(-\frac{\beta}{\delta} + \frac{\beta^*}{\delta^*} \right) \tag{D64}$$

$$\underline{b}_{21} = \lambda \left(-\frac{\beta}{2\delta} + \frac{\beta^*}{2\delta^*} \right) \tag{D65}$$

$$\underline{b}_{22} = b_{22} \tag{D66}$$

$$\underline{b}_{23} = \lambda \left(-\frac{\beta}{2\delta} - \frac{\beta^*}{2\delta^*} \right) \tag{D67}$$

$$\underline{b}_{31} = l_1 \left(-\frac{\beta}{2\delta} + \frac{\beta^*}{2\delta^*} \right) \tag{D68}$$

$$\underline{b}_{32} = b_{32} \tag{D69}$$

$$\underline{b}_{33} = l_2 + l_1 \left(-\frac{\beta}{2\delta} - \frac{\beta^*}{2\delta^*} \right) \tag{D70}$$

$$\underline{c}_{11} = a_2 \tag{D71}$$
$$\underline{c}_{12} = c_{12} \tag{D72}$$
$$\underline{c}_{13} = 0 \tag{D73}$$
$$\underline{c}_{21} = 0 \tag{D74}$$
$$\underline{c}_{22} = c_{22} \tag{D75}$$
$$\underline{c}_{23} = 0 \tag{D76}$$
$$\underline{c}_{31} = c_{31} = 0 \tag{D77}$$
$$\underline{c}_{32} = c_{32} = 2 - (\alpha + \alpha^*) \tag{D78}$$
$$\underline{c}_{33} = c_{33} = 1 \tag{D79}$$

The steady state multipliers of $\dot{m}^*$ are dependent upon the chosen endogenization of $\dot{p}^*_R$. If $\dot{p}^*_R = \dot{m}^*$ holds, the **F**-matrix in (A51) does not change, and the long run multipliers of $\dot{m}^*$ result from the equation

$$\mathbf{F}\begin{pmatrix} d\overline{\tau} \\ d\overline{l}^d \\ d\overline{l}^s \end{pmatrix} = \begin{pmatrix} 0 \\ l_2 \\ -a_2 l_2 \end{pmatrix} d\dot{m}^* \tag{D80}$$

It then follows (cf. (A62))

$$\frac{d\overline{\tau}}{d\dot{m}^*} = -\frac{2f_{12}a_2l_2}{|\mathbf{F}|} < 0 \qquad (\text{if } f_{12} > 0) \tag{D81}$$
$$\frac{d\overline{l}^d}{d\dot{m}^*} = \frac{l_2}{|\mathbf{F}|}\big(f_{11}f_{33} + f_{12}f_{31} + a_2(f_{11}f_{23} + f_{12}f_{21})\big) \tag{D82}$$

$$\frac{d\overline{l}^s}{d\dot{m}^*} = \frac{l_2}{|\mathbf{F}|}\big(f_{12}f_{31} - f_{11}f_{32} - a_2(f_{11}f_{22} - f_{12}f_{21})\big) \tag{D83}$$
$$\frac{d(\overline{m^* - p^*})}{d\dot{m}^*} = -\frac{a_2l_2f_{11}}{|\mathbf{F}|} < 0 \tag{D84}$$
$$\frac{d(\overline{p^*_R - p^*})}{d\dot{m}^*} = \frac{d(\overline{m^* - p^*})}{d\dot{m}^*} \tag{D85}$$
$$\frac{d(\overline{p^*_R + e - p})}{d\dot{m}^*} = -\frac{d\overline{\tau}}{d\dot{m}^*} + \frac{d(\overline{p^*_R - p^*})}{d\dot{m}^*} = \frac{a_2l_2}{|\mathbf{F}|}(2f_{12} - f_{11}) \tag{D86}$$
$$\frac{d\overline{q}}{d\dot{m}^*} = (f_1 + f_2)\frac{d\overline{\tau}}{d\dot{m}^*} - f_2\frac{d(\overline{p^*_R - p^*})}{d\dot{m}^*} = \frac{a_2l_2}{|\mathbf{F}|}\big(-2f_{12}(f_1 + f_2) + f_2f_{11}\big) \tag{D87}$$
$$\frac{d\overline{q}^*}{d\dot{m}^*} = -f^*_1\frac{d\overline{\tau}}{d\dot{m}^*} - f^*_2\frac{d(\overline{p^*_R - p^*})}{d\dot{m}^*} = \frac{a_2l_2}{|\mathbf{F}|}(2f_{12}f^*_1 + f^*_2f_{11}) > 0 \tag{D88}$$

In contrast to domestic monetary policy foreign monetary policy is efficient in the long run if the raw materials pricing rule $\dot{p}_R^* = \dot{m}^*$ holds.

In case $\dot{p}_R^* = \dot{p}^*$ the steady state system has the following structure:

$$\underline{\mathbf{F}} \begin{pmatrix} d\overline{\tau} \\ d\bar{l}^d \\ d\bar{l}^s \end{pmatrix} = \begin{pmatrix} 2f_{12} & 0 & 0 \\ -2f_{23} & -l_2 & l_2 \\ 2f_{32} & -a_2 l_2 & -a_2 l_2 \end{pmatrix} \begin{pmatrix} dp_R^* \\ d\dot{m} \\ d\dot{m}^* \end{pmatrix} \tag{D89}$$

where

$$\underline{\mathbf{F}} = \begin{pmatrix} f_{11} & 0 & 0 \\ f_{21} & 1 & 0 \\ f_{31} & 0 & a_2 \end{pmatrix} \tag{D90}$$

The determinant $|\underline{\mathbf{F}}|$ equals $a_2 f_{11}$ which is in general smaller than the determinant of the original $\mathbf{F}$-matrix (cf. (A51)):

$$|\underline{\mathbf{F}}| < |\mathbf{F}| \tag{D91}$$

The solution of (D89) is given by

$$\begin{pmatrix} d\overline{\tau} \\ d\bar{l}^d \\ d\bar{l}^s \end{pmatrix} = \begin{pmatrix} 1/f_{11} & 0 & 0 \\ -f_{21}/f_{11} & 1 & 0 \\ -f_{31}/(a_2 f_{11}) & 0 & 1/a_2 \end{pmatrix} \begin{pmatrix} 2f_{12} & 0 & 0 \\ -2f_{23} & -l_2 & l_2 \\ 2f_{32} & -a_2 l_2 & -a_2 l_2 \end{pmatrix} \begin{pmatrix} dp_R^* \\ d\dot{m} \\ d\dot{m}^* \end{pmatrix} \tag{D92}$$

This leads to the steady state multipliers

$$\frac{\partial \overline{\tau}}{\partial p_R^*} = \frac{2f_{12}}{f_{11}} \tag{D93}$$

$$\frac{\partial \bar{l}^d}{\partial p_R^*} = -\frac{2f_{12}f_{21}}{f_{11}} - 2f_{23} = -\frac{2}{f_{11}}(f_{12}f_{21} + f_{11}f_{23}) \tag{D94}$$

$$\frac{\partial \bar{l}^s}{\partial p_R^*} = \frac{2}{a_2 f_{11}}(f_{11}f_{32} - f_{12}f_{31}) \tag{D95}$$

$$\frac{\partial \overline{(m-p)}}{\partial p_R^*} = \frac{1}{a_2 f_{11}}(f_{11}f_{32} - f_{12}f_{31}) - \frac{1}{f_{11}}(f_{21}f_{12} + f_{23}f_{11}) \tag{D96}$$

$$\begin{aligned} \frac{\partial \overline{(m^*-p^*)}}{\partial p_R^*} &= \frac{1}{a_2 f_{11}}\Big(f_{11}f_{32} - f_{12}f_{31} + a_2(f_{21}f_{12} + f_{23}f_{11})\Big) \\ &= \frac{1}{a_2 f_{11}}(a_2 f_{11} - |\mathbf{F}|) \end{aligned} \tag{D97}$$

where $|\mathbf{F}| = f_{12}f_{31} - f_{11}f_{32} + a_2(f_{11}f_{22} - f_{12}f_{21})$ (cf. (A61))

$$\frac{\partial \overline{(p_R^* - p^*)}}{\partial p_R^*} = 1 \tag{D98}$$

$$\frac{\partial \overline{(p_R^* + e - p)}}{\partial p_R^*} = -\frac{\partial \overline{\tau}}{\partial p_R^*} + 1 = -\frac{2f_{12}}{f_{11}} + 1 \tag{D99}$$

$$\frac{\partial \overline{q}}{\partial p_R^*} = \frac{2(f_1 + f_2)}{f_{11}} f_{12} - f_2 = \frac{a_2}{|\underline{\mathbf{F}}|}\Big((2f_{12} - f_{11})f_2 + 2f_{12}f_1\Big) \tag{D100}$$

$$\frac{\partial \overline{q}^*}{\partial p_R^*} = -\frac{2f_1^* f_{12}}{f_{11}} - f_2^* = -\frac{a_2}{|\underline{\mathbf{F}}|}\big(2f_{12}f_1^* + f_{11}f_2^*\big) \tag{D101}$$

$$\frac{\partial \overline{\tau}}{\partial \dot{m}} = \frac{\partial \overline{\tau}}{\partial \dot{m}^*} = 0 \tag{D102}$$

$$\frac{\partial \overline{l}^d}{\partial \dot{m}} = -\frac{\partial \overline{l}^d}{\partial \dot{m}^*} = -l_2 \tag{D103}$$

$$\frac{\partial \overline{l}^s}{\partial \dot{m}} = \frac{\partial \overline{l}^s}{\partial \dot{m}^*} = -l_2 \tag{D104}$$

$$\frac{\partial(\overline{m-p})}{\partial \dot{m}} = \frac{\partial(\overline{m^*-p^*})}{\partial \dot{m}^*} = -l_2 \tag{D105}$$

$$\frac{\partial(\overline{m^*-p^*})}{\partial \dot{m}} = \frac{\partial(\overline{m-p})}{\partial \dot{m}^*} = 0 \tag{D106}$$

$$\frac{\partial \overline{x}}{\partial \dot{m}} = \frac{\partial \overline{x}}{\partial \dot{m}^*} = 0 \quad \text{for } \overline{x} \in \{\overline{p_R^* - p^*}\,, \overline{p_R^* + e - p}\,, \overline{q}\,, \overline{q}^*\} \tag{D107}$$

Foreign monetary policy has now the same classical properties as domestic monetary policy. Since $|\underline{\mathbf{F}}| < |\mathbf{F}|$ holds in general, the contractionary steady state output effects of an oil price shock are increased, if the raw materials pricing rule $\dot{p}_R^* = \dot{m}^*$ is replaced by the pricing equation $\dot{p}_R^* = \dot{p}^*$ (cf. (A75), (A76)).

Complete system stabilization requires the neutralization of the anticipation effects of an announced increase of the US dollar price of imported raw materials, i.e. $A_1 = 0$. According to (A96) this is the case if the domestic central bank credibly announces the following change of the growth rate of money supply to take effect at the date T of realization of the oil price shock:

$$d\dot{m}^{announced} = \frac{1}{l_2\big(h_{22}(1-h_{10}) - h_{20}(1-h_{12})\big)} \cdot \Big\{(h_{22}-h_{20})\frac{\partial \overline{l}^s}{\partial p_R^*} + (h_{10}-h_{12})\frac{\partial \overline{\tau}}{\partial p_R^*} + (h_{12}h_{20} - h_{10}h_{22})\frac{\partial \overline{l}^d}{\partial p_R^*}\Big\} \cdot dp_R^* \tag{D108}$$

In case of the pricing rule $\dot{p}_R^* = \dot{m}^*$ the steady state multipliers of p_R^* are of the form (A68), (A69) and (A70), while in case $\dot{p}_R^* = \dot{p}^*$ they have to be replaced by (D93), (D94) and (D95). If $\dot{p}_R^* = \dot{m}^*$ holds, the components h_{ij} $(i = 1, 2)$ belong to the eigenvectors h_j $(j = 0, 2)$ of the matrix $\mathbf{G} = \mathbf{B}^{-1}\mathbf{C}$ (cf. (A82)) while in case $\dot{p}_R^* = \dot{p}^*$ they result from the matrix $\underline{\mathbf{G}} = \underline{\mathbf{B}}^{-1}\underline{\mathbf{C}}$, where the matrices $\underline{\mathbf{B}}$ and $\underline{\mathbf{C}}$ are defined by (D62) to (D79). Numerical simulations show that $d\dot{m}^{ann.}$ changes sign, if the materials pricing rule $\dot{p}_R^* = \dot{m}^*$ is replaced by $\dot{p}_R^* = \dot{p}^*$:

$$d\dot{m}^{ann.}|_{\dot{p}_R^* = \dot{m}^*} < 0 < d\dot{m}^{ann.}|_{\dot{p}_R^* = \dot{p}^*} \tag{D109}$$

The reason is that in case $\dot{p}_R^* = \dot{m}^*$ the anticipation of a future increase of the US dollar price of oil leads on impact to a fall in τ, i.e., $\tau(0+) < \overline{\tau}_0$, while just the opposite holds, i.e. $\tau(0+) > \overline{\tau}_0$, if $\dot{p}_R^* = \dot{p}^*$. The neutralization of the anticipation effects of a future oil price increase therefore requires the credible announcement of a contractionary domestic monetary policy, if $\dot{p}_R^* = \dot{m}^*$ holds, i.e, $d\dot{m}^{ann.} < 0$, while $d\dot{m}^{ann.}$ must be positive in case $\dot{p}_R^* = \dot{p}^*$. Instead of the announcement of an expansionary domestic monetary policy, which may result in time inconsistency problems (since $d\dot{m}^{realized}$ is always negative), the stabilization condition $A_1 = 0$ in case $\dot{p}_R^* = \dot{p}^*$ can also be realized with the help of the following announced *foreign* monetary policy (which is negative in general):

$$d\dot{m}^{*\,announced} = \frac{1}{l_2\big(h_{22}(1+h_{10}) - h_{20}(1+h_{12})\big)} \cdot \Big\{(h_{22}-h_{20})\frac{\partial \bar{l}^s}{\partial p_R^*} + (h_{10}-h_{12})\frac{\partial \overline{\tau}}{\partial p_R^*} + (h_{12}h_{20} - h_{10}h_{22})\frac{\partial \bar{l}^d}{\partial p_R^*}\Big\} \cdot dp_R^* \quad \text{(D110)}$$

If this policy is credible, it leads on impact to a fall of the domestic terms of trade τ so that a jump in τ can be prevented.

As long as the above reaction of domestic or foreign monetary policy in T is considered credible and therefore anticipated by the private sector all endogenous variables remain up to T in their initial respective steady state position. A complete stabilization in the period after the occurrence of the oil price shock, i.e. the removal of any adjustment dynamics for $t > T$, requires an unanticipated deviation from the announced monetary policy and a sudden and simultaneous implementation of a growth rate of domestic and foreign money supply such that

$$\widetilde{A}_0 = \widetilde{A}_2 = 0 \quad \text{(D111)}$$

holds (cf. (A81)). In the case of unanticipated exogenous shocks we have to set $T = 0$ in (A97) and (A98)[67] leading to

$$\widetilde{A}_0\Big|_{T=0} = \frac{1}{d(h_{10}-h_{12})}\big(k_1 d\bar{l}^s + k_2 d\bar{l}^d\big) \quad \text{(D112)}$$

$$\widetilde{A}_2\Big|_{T=0} = \frac{1}{d(h_{10}-h_{12})}\big(-k_1 d\bar{l}^s + k_3 d\bar{l}^d\big) \quad \text{(D113)}$$

where

$$\begin{aligned} k_1 &= (h_{12}-h_{11})(h_{22}-h_{20}) - (h_{21}-h_{22})(h_{10}-h_{12}) && \text{(D114)}\\ &= -\big((h_{11}-h_{10})(h_{22}-h_{20}) - (h_{10}-h_{12})(h_{20}-h_{21})\big) \\ k_2 &= (h_{12}-h_{11})(h_{12}h_{20}-h_{10}h_{22}) - (h_{10}-h_{12})(h_{11}h_{22}-h_{21}h_{12}) && \text{(D115)}\\ k_3 &= (h_{11}-h_{10})(h_{12}h_{20}-h_{10}h_{22}) - (h_{10}-h_{12})(h_{10}h_{21}-h_{11}h_{20}) && \text{(D116)} \end{aligned}$$

In case $T = 0$ the constants $\widetilde{A}_0$ and $\widetilde{A}_2$ only depend on the steady state change of the state variables l^s and l^d, i.e. are independent of $d\overline{\tau}$. Since in general $k_2 \neq -k_3$ holds, the

[67] Note that the realization of $dp_R^* > 0$ in T leads to dynamic adjustments that are equivalent to an unanticipated increase of p_R^*. The reason is that without active monetary policy in T the state vector must jump at time T from the initial steady state on the new stable saddle path in oder to guarantee a convergent adjustment process (cf. (A100)). The jump in T then coincides with the initial jump of the forward-looking variable τ in case $T = 0$.

condition

$$\widetilde{A}_0\Big|_{T=0} = \widetilde{A}_2\Big|_{T=0} = 0 \tag{D117}$$

is met, if domestic and foreign monetary policy is able to set

$$d\bar{l}^s = d\bar{l}^d = 0 \tag{D118}$$

simultaneously. First consider this stabilization condition under the pricing rule $\dot{p}_R^* = \dot{m}^*$. The condition $d\bar{l}^s = d\bar{l}^d = 0$ is equivalent to

$$\begin{pmatrix} -l_2 & \dfrac{\partial \bar{l}^s}{\partial \dot{m}^*} \\ -l_2 & \dfrac{\partial \bar{l}^d}{\partial \dot{m}^*} \end{pmatrix} \begin{pmatrix} d\dot{m} \\ d\dot{m}^* \end{pmatrix} = - \begin{pmatrix} \dfrac{\partial \bar{l}^s}{\partial p_R^*} \\ \dfrac{\partial \bar{l}^d}{\partial p_R^*} \end{pmatrix} dp_R^* \tag{D119}$$

where the multipliers $\frac{\partial \bar{l}^s}{\partial \dot{m}^*}$ and $\frac{\partial \bar{l}^d}{\partial \dot{m}^*}$ are defined in (D83) and (D82) respectively, while the corresponding steady state multipliers of p_R^* are given in (A70) and (A69). Solving (D119) for $d\dot{m}$ and $d\dot{m}^*$ yields the solution vector

$$\begin{pmatrix} d\dot{m} \\ d\dot{m}^* \end{pmatrix} = -\frac{1}{\widetilde{\Delta}} \begin{pmatrix} \dfrac{\partial \bar{l}^d}{\partial \dot{m}^*} & -\dfrac{\partial \bar{l}^s}{\partial \dot{m}^*} \\ l_2 & -l_2 \end{pmatrix} \begin{pmatrix} \dfrac{\partial \bar{l}^s}{\partial p_R^*} \\ \dfrac{\partial \bar{l}^d}{\partial p_R^*} \end{pmatrix} dp_R^* \tag{D120}$$

where the determinant $\widetilde{\Delta}$ is given by

$$\widetilde{\Delta} = -l_2 \left(\frac{\partial \bar{l}^d}{\partial \dot{m}^*} - \frac{\partial \bar{l}^s}{\partial \dot{m}^*} \right) = 2l_2 \frac{\partial (\overline{m^* - p^*})}{\partial \dot{m}^*} = -\frac{2a_2 l_2^2 f_{11}}{|\mathbf{F}|} < 0 \tag{D121}$$

We then get the following monetary policy reaction functions:

$$\begin{aligned} d\dot{m}|_{\dot{p}_R^* = \dot{m}^*} &= -\frac{1}{\widetilde{\Delta}} \left(\frac{\partial \bar{l}^d}{\partial \dot{m}^*} \frac{\partial \bar{l}^s}{\partial p_R^*} - \frac{\partial \bar{l}^s}{\partial \dot{m}^*} \frac{\partial \bar{l}^d}{\partial p_R^*} \right) dp_R^* \qquad \text{(D122)} \\ &= -\frac{1}{\widetilde{\Delta}} \left\{ \left(\frac{\partial \bar{l}^d}{\partial \dot{m}^*} - \frac{\partial \bar{l}^s}{\partial \dot{m}^*} \right) \frac{\partial \bar{l}^d}{\partial p_R^*} + \left(\frac{\partial \bar{l}^s}{\partial p_R^*} - \frac{\partial \bar{l}^d}{\partial p_R^*} \right) \frac{\partial \bar{l}^d}{\partial \dot{m}^*} \right\} dp_R^* \\ &= -\frac{2}{\widetilde{\Delta}} \left(-\frac{\partial (\overline{m^* - p^*})}{\partial \dot{m}^*} \frac{\partial \bar{l}^d}{\partial p_R^*} + \frac{\partial (\overline{m^* - p^*})}{\partial p_R^*} \frac{\partial \bar{l}^d}{\partial \dot{m}^*} \right) dp_R^* \\ &= -\frac{2}{\widetilde{\Delta}|\mathbf{F}|} \left(a_2 l_2 f_{11} \frac{\partial \bar{l}^d}{\partial p_R^*} + \left(a_2 f_{11} - |\mathbf{F}| \right) \frac{\partial \bar{l}^d}{\partial \dot{m}^*} \right) dp_R^* \end{aligned}$$

$$d\dot{m}^*|_{\dot{p}_R^*=\dot{m}^*} = -\frac{1}{\widetilde{\Delta}}\left(l_2\frac{\partial\bar{l}^s}{\partial p_R^*} - l_2\frac{\partial\bar{l}^d}{\partial p_R^*}\right)dp_R^* = -\frac{2l_2}{\widetilde{\Delta}}\frac{\partial(\overline{m^*-p^*})}{\partial p_R^*}dp_R^* \tag{D123}$$

$$= -\frac{\partial(\overline{m^*-p^*})/\partial p_R^*}{\partial(\overline{m^*-p^*})/\partial \dot{m}^*}\cdot dp_R^*$$

$$= \frac{a_2 f_{11} - |\mathbf{F}|}{a_2 l_2 f_{11}}\cdot dp_R^* < 0 \qquad \text{if } |\mathbf{F}| > a_2 f_{11} = |\underline{\mathbf{F}}|$$

Generally $d\dot{m}|_{\dot{p}_R^*=\dot{m}^*} < 0$ holds where

$$\left|d\dot{m}^{announced}\right| < \left|d\dot{m}|_{\dot{p}_R^*=\dot{m}^*}\right| \tag{D124}$$

i.e. the realized domestic monetary policy at time T is stronger restrictive than the one announced.

In case $\dot{p}_R^* = \dot{p}^*$ the monetary policy rules that prevent adjustment dynamics for $t > T$ result from

$$\begin{pmatrix} -l_2 & -l_2 \\ -l_2 & l_2 \end{pmatrix}\begin{pmatrix} d\dot{m} \\ d\dot{m}^* \end{pmatrix} = -\begin{pmatrix} \frac{\partial\bar{l}^s}{\partial p_R^*} \\ \frac{\partial\bar{l}^d}{\partial p_R^*} \end{pmatrix} dp_R^* \tag{D125}$$

with $\frac{\partial\bar{l}^s}{\partial p_R^*}$ and $\frac{\partial\bar{l}^d}{\partial p_R^*}$ defined by (D95) and (D94) respectively. It follows

$$d\dot{m}|_{\dot{p}_R^*=\dot{p}^*} = \frac{1}{2l_2}\left(\frac{\partial\bar{l}^s}{\partial p_R^*} + \frac{\partial\bar{l}^d}{\partial p_R^*}\right)dp_R^* = \frac{1}{l_2}\frac{\partial(\overline{m-p})}{\partial p_R^*}dp_R^* \tag{D126}$$

$$= -\frac{1}{l_2 f_{11}}\left(\frac{1}{a_2}(f_{12}f_{31} - f_{11}f_{32}) + (f_{21}f_{12} + f_{23}f_{11})\right)$$

$$d\dot{m}^*|_{\dot{p}_R^*=\dot{p}^*} = \frac{1}{l_2}\frac{\partial(\overline{m^*-p^*})}{\partial p_R^*}dp_R^* = \frac{1}{l_2 a_2 f_{11}}\big(a_2 f_{11} - |\mathbf{F}|\big)dp_R^* \tag{D127}$$

Just as the domestic monetary policy rule the following relationship holds between the announced and actually realized *foreign* monetary policy:

$$\left|d\dot{m}^{*\,announced}\right| < \left|d\dot{m}^*|_{\dot{p}_R^*=\dot{p}^*}\right| \tag{D128}$$

Obviously, the foreign monetary policy rules $d\dot{m}^*|_{\dot{p}_R^*=\dot{m}^*}$ and $d\dot{m}^*|_{\dot{p}_R^*=\dot{p}^*}$ coincide. Note that the same holds for the domestic monetary reaction functions, i.e.,

$$d\dot{m}|_{\dot{p}_R^*=\dot{m}^*} = d\dot{m}|_{\dot{p}_R^*=\dot{p}^*} \tag{D129}$$

since $d\dot{m}|_{\dot{p}_R^*=\dot{m}^*}$ can be rewritten in the following form:

$$
\begin{aligned}
d\dot{m}|_{\dot{p}_R^*=\dot{m}^*} &= \frac{1}{a_2 l_2^2 f_{11}} \left(a_2 l_2 f_{11} \frac{\partial \bar{l}^d}{\partial p_R^*} + \big(a_2 f_{11} - |\mathbf{F}|\big) \frac{\partial \bar{l}^d}{\partial \dot{m}^*} \right) dp_R^* \qquad \text{(D130)} \\
&= \frac{1}{a_2 l_2^2 f_{11}} \Big\{ - \frac{2a_2^2 l_2 f_{11}}{|\mathbf{F}|}(f_{12}f_{21} + f_{23}f_{11}) + \frac{l_2}{|\mathbf{F}|}(a_2 f_{11} - |\mathbf{F}|) \cdot \\
&\quad \cdot \Big(f_{11}(a_2 - f_{32}) + f_{12}f_{31} + a_2\big(f_{11}(1-f_{22}) + f_{12}f_{21}\big)\Big)\Big\} dp_R^* \\
&= \frac{1}{a_2 l_2 f_{11}|\mathbf{F}|} \Big\{ - 2a_2^2 f_{11}(f_{12}f_{21} + f_{23}f_{11}) + (a_2 f_{11} - |\mathbf{F}|) \cdot \\
&\quad \cdot \Big(2a_2 f_{11} + f_{12}f_{31} - f_{11}f_{32} - a_2(f_{11}f_{22} - f_{21}f_{12})\Big)\Big\} dp_R^* \\
&= \frac{1}{a_2 l_2 f_{11}|\mathbf{F}|} \Big\{ - 2a_2^2 f_{11}(f_{12}f_{21} + (1-f_{22})f_{11}) + (a_2 f_{11} - |\mathbf{F}|) \cdot \\
&\quad \cdot \Big(2a_2 f_{11} + |\mathbf{F}| - 2a_2(f_{11}f_{22} - f_{21}f_{12})\Big)\Big\} dp_R^* \\
&= \frac{1}{a_2 l_2 f_{11}|\mathbf{F}|} \Big\{ - 2a_2^2 f_{11}(f_{12}f_{21} - f_{11}f_{22}) - a_2 f_{11}|\mathbf{F}| - |\mathbf{F}|^2 \\
&\quad - 2a_2(a_2 f_{11} - |\mathbf{F}|)(f_{11}f_{22} - f_{12}f_{21})\Big\} dp_R^* \\
&= \frac{1}{a_2 l_2 f_{11}|\mathbf{F}|} \Big\{ - |\mathbf{F}|(a_2 f_{11} + |\mathbf{F}|) + 2a_2|\mathbf{F}|(f_{11}f_{22} - f_{12}f_{21})\Big\} dp_R^* \\
&= \frac{1}{a_2 l_2 f_{11}} \Big\{ 2a_2(f_{11}f_{22} - f_{12}f_{21}) - (a_2 f_{11} + |\mathbf{F}|)\Big\} dp_R^* \\
&= \frac{1}{a_2 l_2 f_{11}} \Big\{ a_2(f_{11}f_{22} - f_{12}f_{21}) - a_2 f_{11} + f_{11}f_{32} - f_{12}f_{31}\Big\} dp_R^* \\
&= \frac{1}{l_2 f_{11}} \Big\{ \frac{1}{a_2}(f_{11}f_{32} - f_{12}f_{31}) - f_{11}(1-f_{22}) - f_{12}f_{21}\Big\} dp_R^* \\
&= -\frac{1}{l_2 f_{11}} \Big\{ \frac{1}{a_2}(f_{12}f_{31} - f_{11}f_{32}) + f_{12}f_{21} + f_{11}f_{23}\Big\} dp_R^* \ = \ d\dot{m}|_{\dot{p}_R^*=\dot{p}^*}
\end{aligned}
$$

In case $\dot{p}_R^* = \dot{m}^*$ foreign monetary policy has long run real effects while it is neutral if $\dot{p}_R^* = \dot{p}^*$ holds. Since complete system stabilization requires $d\dot{m}^* < 0$ the contractionary steady state output effects of $dp_R^* > 0$ are reinforced if the pricing rule $\dot{p}_R^* = \dot{m}^*$ is assumed. Moreover, the total output effects under both materials pricing rules are identical:

$$
\begin{aligned}
d\overline{x}|_{\dot{p}_R^*=\dot{m}^*} &= \left.\frac{\partial \overline{x}}{\partial p_R^*}\right|_{\dot{p}_R^*=\dot{m}^*} dp_R^* + \left.\frac{\partial \overline{x}}{\partial \dot{m}^*}\right|_{\dot{p}_R^*=\dot{m}^*} d\dot{m}^* \qquad \text{(D131)} \\
&= d\overline{x}|_{\dot{p}_R^*=\dot{p}^*} = \left.\frac{\partial \overline{x}}{\partial \dot{p}_R^*}\right|_{\dot{p}_R^*=\dot{p}^*} d\dot{p}_R^* \quad \text{for } \overline{x} \in \{\overline{q}, \overline{q}^*\}
\end{aligned}
$$

This result holds, since the total steady state change of the terms of trade and the real factor prices does not depend on the chosen endogenization of $\dot{p}_R^*$:

$$\begin{aligned} d\overline{\tau}|_{\dot{p}_R^*=\dot{m}^*} &= \left.\frac{\partial \overline{\tau}}{\partial p_R^*}\right|_{\dot{p}_R^*=\dot{m}^*} dp_R^* + \left.\frac{\partial \overline{\tau}}{\partial \dot{m}^*}\right|_{\dot{p}_R^*=\dot{m}^*} d\dot{m}^* \\ &= \frac{2f_{12}a_2}{|\mathbf{F}|}dp_R^* - \frac{2f_{12}a_2l_2}{|\mathbf{F}|} \cdot \frac{a_2f_{11}-|\mathbf{F}|}{l_2a_2f_{11}}dp_R^* \\ &= \frac{2f_{12}a_2}{|\mathbf{F}|}\left(1-\frac{a_2f_{11}-|\mathbf{F}|}{a_2f_{11}}\right)dp_R^* \;=\; \frac{2f_{12}a_2}{|\mathbf{F}|}\cdot\frac{|\mathbf{F}|}{a_2f_{11}}\cdot dp_R^* \\ &= \frac{2f_{12}}{f_{11}}dp_R^* \;=\; \left.\frac{\partial \overline{\tau}}{\partial p_R^*}\right|_{\dot{p}_R^*=\dot{p}^*} dp_R^* = d\overline{\tau}|_{\dot{p}_R^*=\dot{p}^*} \end{aligned} \tag{D132}$$

$$\begin{aligned} d(\overline{p_R^*-p^*})\big|_{\dot{p}_R^*=\dot{m}^*} &= d(\overline{p_R^*-m^*})\big|_{\dot{p}_R^*=\dot{m}^*} + d(\overline{m^*-p^*})\big|_{\dot{p}_R^*=\dot{m}^*} \\ &= \left.\frac{\partial(\overline{p_R^*-m^*})}{\partial p_R^*}\right|_{\dot{p}_R^*=\dot{m}^*} dp_R^* + \frac{1}{2}\left(d\bar{l}^s - d\bar{l}^d\right)\big|_{\dot{p}_R^*=\dot{m}^*} \\ &= dp_R^* \qquad (\text{since } d\bar{l}^s = d\bar{l}^d = 0 \text{ in case of} \\ &\qquad\qquad \text{complete system stabilization}) \\ &= d(\overline{p_R^*-p^*})\big|_{\dot{p}_R^*=\dot{p}^*} \qquad \left(\text{since } \left.\frac{\partial(\overline{p_R^*-p^*})}{\partial p_R^*}\right|_{\dot{p}_R^*=\dot{p}^*} = 1\right) \end{aligned} \tag{D133}$$

$$\begin{aligned} d(\overline{p_R^*+e-p})\big|_{\dot{p}_R^*=\dot{m}^*} &= -\,d\overline{\tau}|_{\dot{p}_R^*=\dot{m}^*} + d(\overline{p_R^*-p^*})\big|_{\dot{p}_R^*=\dot{m}^*} \\ &= \left(-\frac{2f_{12}}{f_{11}}+1\right)dp_R^* \;=\; d(\overline{p_R^*+e-p})\big|_{\dot{p}_R^*=\dot{p}^*} \end{aligned} \tag{D134}$$

According to equations (17) and (18) it follows that

$$d\overline{q}|_{\dot{p}_R^*=\dot{m}^*} = d\overline{q}|_{\dot{p}_R^*=\dot{p}^*} \tag{D135}$$

and

$$d\overline{q}^*|_{\dot{p}_R^*=\dot{m}^*} = d\overline{q}^*|_{\dot{p}_R^*=\dot{p}^*} \tag{D136}$$

must hold. Since $d\dot{m}|_{\dot{p}_R^*=\dot{m}^*} = d\dot{m}|_{\dot{p}_R^*=\dot{p}^*}$ and $d\dot{m}^*|_{\dot{p}_R^*=\dot{m}^*} = d\dot{m}^*|_{\dot{p}_R^*=\dot{p}^*}$ so that – in addition –

$$\begin{aligned} d\overline{x}|_{\dot{p}_R^*=\dot{m}^*} &= d\overline{x}|_{\dot{p}_R^*=\dot{p}^*} \\ &\text{for } \overline{x} \in \left\{\overline{\dot{p}}, \overline{\dot{p}^c}, \overline{\dot{p}^*}, \overline{\dot{p}^{*c}}, \overline{\dot{e}}, \overline{\dot{w}}, \overline{\dot{w}^*}, \overline{i-\dot{p}^c}, \overline{i^*-\dot{p}^{*c}}, \overline{i}, \overline{i}^*, \overline{y}, \overline{y}^*\right\} \end{aligned} \tag{D137}$$

holds, we can conclude that the new steady state of the completely stabilized system is independent of the underlying pricing rule for raw materials inputs.[68] Several numerical simulations illustrate that for the realized monetary response functions

$$d\dot{m} < d\dot{m}^* < 0 \tag{D138}$$

[68] Analogous results hold in the case of domestic-currency denominated oil.

holds. This implies a steady state fall of the domestic inflation rates that is stronger than the long run decline of the corresponding foreign rates:

$$d\bar{\dot{p}} = d\overline{\dot{p}^c} = d\bar{\dot{w}} < d\overline{\dot{p}^*} = d\overline{\dot{p}^{*c}} = d\overline{\dot{w}^*} < 0 \tag{D139}$$

The steady state change of the depreciation rate $\dot{e}$ must therefore be negative:

$$d\bar{\dot{e}} = d\dot{m} - d\dot{m}^* < 0 \tag{D140}$$

D.4 System Stabilization for t > T

Let us finally discuss the problem of complete system stabilization in the period after the occurrence of the oil price shock, i.e. the avoidance of any adjustment dynamics for $t > T$. In this case condition (D58) is required to hold while adjustment processes during the anticipation period $0 < t < T$ are now admissible. Condition (D58) is met if a coordinated and *anticipated* simultaneous monetary action is able to set the constants $\widetilde{A}_0$ and $\widetilde{A}_2$ equal to zero simultaneously (cf. (D111)). In the case of the pricing rule $\dot{p}_R^* = \dot{m}^*$ and with $T > 0$ we have $\widetilde{A}_0 = \widetilde{A}_2 = 0$ if and only if

$$\begin{pmatrix} \lambda_1 & \lambda_2 & \lambda_3 \\ \lambda_4 & \lambda_5 & \lambda_6 \end{pmatrix} \begin{pmatrix} d\bar{l}^s \\ d\bar{\tau} \\ d\bar{l}^d \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \tag{D141}$$

where

$$\begin{aligned}
\lambda_1 &= \frac{h_{12} - h_{11}}{h_{10} - h_{12}}(h_{22} - h_{20})e^{-r_1 T} - (h_{21} - h_{22})e^{-r_0 T} && \text{(D142)}\\
\lambda_2 &= (h_{12} - h_{11})\big(e^{-r_1 T} - e^{-r_0 T}\big) && \text{(D143)}\\
\lambda_3 &= \frac{h_{12} - h_{11}}{h_{10} - h_{12}}(h_{12}h_{20} - h_{10}h_{22})e^{-r_1 T} - (h_{11}h_{22} - h_{21}h_{12})e^{-r_0 T} && \text{(D144)}\\
\lambda_4 &= \frac{h_{11} - h_{10}}{h_{10} - h_{12}}(h_{22} - h_{20})e^{-r_1 T} - (h_{20} - h_{21})e^{-r_2 T} && \text{(D145)}\\
\lambda_5 &= (h_{11} - h_{10})\big(e^{-r_1 T} - e^{-r_2 T}\big) && \text{(D146)}\\
\lambda_6 &= \frac{h_{11} - h_{10}}{h_{10} - h_{12}}(h_{12}h_{20} - h_{10}h_{22})e^{-r_1 T} - (h_{10}h_{21} - h_{11}h_{20})e^{-r_2 T} && \text{(D147)}
\end{aligned}$$

Note that in the special case $T = 0$ the constants λ_2 and λ_4 are equal to zero so that in this case (D141) is equivalent to (D118).[69] In (D141) the total change of the state variables is given by (D59). Inserting (D59) into (D141) and rearranging terms leads to the matrix equation

$$\begin{pmatrix} \mu_1 & \mu_2 & \mu_3 \\ \mu_4 & \mu_5 & \mu_6 \end{pmatrix} \begin{pmatrix} dp_R^* \\ d\dot{m} \\ d\dot{m}^* \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \tag{D148}$$

[69] If $T = 0$ then the other constants λ_1, λ_3, λ_5 and λ_6 can be rewritten as $\lambda_1 = -\lambda_4 = \frac{1}{h_{10} - h_{12}} k_1$, $\lambda_3 = \frac{1}{h_{10} - h_{12}} k_2$, $\lambda_6 = \frac{1}{h_{10} - h_{12}} k_3$ where k_1, k_2 and k_3 are defined in (D114) to (D116).

where

$$\mu_1 = \lambda_1 \frac{\partial \bar{l}^s}{\partial p_R^*} + \lambda_2 \frac{\partial \overline{\tau}}{\partial p_R^*} + \lambda_3 \frac{\partial \bar{l}^d}{\partial p_R^*} \quad \text{(D149)}$$

$$\mu_2 = -l_2(\lambda_1 + \lambda_3) \quad \text{(D150)}$$

$$\mu_3 = \lambda_1 \frac{\partial \bar{l}^s}{\partial \dot{m}^*} + \lambda_2 \frac{\partial \overline{\tau}}{\partial \dot{m}^*} + \lambda_3 \frac{\partial \bar{l}^d}{\partial \dot{m}^*} \quad \text{(D151)}$$

$$\mu_4 = \lambda_4 \frac{\partial \bar{l}^s}{\partial p_R^*} + \lambda_5 \frac{\partial \overline{\tau}}{\partial p_R^*} + \lambda_6 \frac{\partial \bar{l}^d}{\partial p_R^*} \quad \text{(D152)}$$

$$\mu_5 = -l_2(\lambda_4 + \lambda_6) \quad \text{(D153)}$$

$$\mu_6 = \lambda_4 \frac{\partial \bar{l}^s}{\partial \dot{m}^*} + \lambda_5 \frac{\partial \overline{\tau}}{\partial \dot{m}^*} + \lambda_6 \frac{\partial \bar{l}^d}{\partial \dot{m}^*} \quad \text{(D154)}$$

Solving (D148) for $d\dot{m}$ and $d\dot{m}^*$ leads to the monetary policy decision rules

$$d\dot{m}|_{\dot{p}_R^*=\dot{m}^*} = -\frac{1}{\Delta_\mu}(\mu_1\mu_6 - \mu_3\mu_4)dp_R^* \quad \text{(D155)}$$

$$d\dot{m}^*|_{\dot{p}_R^*=\dot{m}^*} = \frac{1}{\Delta_\mu}(-\mu_1\mu_5 + \mu_2\mu_4)dp_R^* \quad \text{(D156)}$$

where

$$\Delta_\mu = \mu_2\mu_6 - \mu_3\mu_5 \quad \text{(D157)}$$

Several numerical simulations illustrate that $d\dot{m} < d\dot{m}^* < 0$ holds (cf. (D138)). If the decision rules (D155) and (D156) are credibly announced at $t = 0$ and implemented at $t = T > 0$ they prevent adjustment dynamics in the period after the realization of the oil price increase.

Similar policy rules hold in the case of the raw materials pricing rule $\dot{p}_R^* = \dot{p}^*$. The formulas for the constants $\lambda_1, \ldots, \lambda_6$ remain unchanged where now the eigenvalues and eigenvectors are related to the matrix $\underline{\mathbf{G}} = \underline{\mathbf{B}}^{-1}\underline{\mathbf{C}}$ (cf. (D62) to (D79)). The steady state multipliers of the state variables are of the form (D93), (D94), (D95), (D102), (D103) and (D104). This implies that the constants μ_3 and μ_6 can be simplified to $-l_2(\lambda_1 - \lambda_3)$ and $-l_2(\lambda_4 - \lambda_6)$ respectively so that the policy rules (D155) and (D156) can be rewritten in the following form:

$$d\dot{m}|_{\dot{p}_R^*=\dot{p}^*} = \frac{\mu_1(\lambda_4 - \lambda_6) - \mu_4(\lambda_1 - \lambda_3)}{2l_2(\lambda_3\lambda_4 - \lambda_1\lambda_6)}dp_R^* \quad \text{(D158)}$$

$$d\dot{m}^*|_{\dot{p}_R^*=\dot{p}^*} = \frac{-\mu_1(\lambda_4 + \lambda_6) + \mu_4(\lambda_1 + \lambda_3)}{2l_2(\lambda_3\lambda_4 - \lambda_1\lambda_6)}dp_R^* \quad \text{(D159)}$$

Note that in general $d\dot{m}|_{\dot{p}_R^*=\dot{p}^*} < d\dot{m}|_{\dot{p}_R^*=\dot{m}^*}$ and $d\dot{m}^*|_{\dot{p}_R^*=\dot{p}^*} < d\dot{m}^*|_{\dot{p}_R^*=\dot{m}^*}$ holds, while equality is given if $T = 0$ (cf. (D129), (D130)). In comparison with the case $T = 0$ domestic monetary policy is now stronger contractionary under both pricing rules while the contraction of the foreign growth rate of money supply is slightly weakened.

References

Anderton, R., F. di Mauro, F. Moneta (2004), Understanding the Impact of the External Dimension of the Euro Area: Trade, Capital Flows and other Macroeconomic Linkages. Occasional Paper Series 12, April 2004, European Central Bank.

Aoki, M. (1981), Dynamic Analysis of Open Economies. New York, London, Toronto.

Ball, L. (1994), Credible Disinflation with Staggered Price Setting. American Economic Review 84, 282–289.

Bhandari, J. S. (1981), The Simple Macroeconomics of an Oil-Dependent Economy. European Economic Review 16, 333–354.

Bhandari, J. S., S. J. Turnvosky (1984), Materials Price Increases and Aggregate Adjustment in an Open Economy – A Stochastic Approach. European Economic Review 25, 151–182.

Buiter, W. H., M. Miller (1982), Real Exchange Rate Overshooting and the Output Cost of Bringing down Inflation. European Economic Review 18, 85–123.

Buiter, W. H. (1984), Saddlepoint Problems in Continuous Time Rational Expectations Models – A General Method and Some Macroeconomic Examples. Econometrica 52, 665–680.

Clarida, R., J. Gali, M. Gertler (1999), The Science of Monetary Policy: A New Keynesian Perspective. Journal of Economic Literature 37, 1661–1707.

Clausen, V., H.-W. Wohltmann (2005), Monetary and Fiscal Policy Dynamics in an Asymmetric Monetary Union. International Journal of Money and Finance, forthcoming.

Devereux, M. B., D. D. Purvis (1990), Fiscal Policy and the Real Exchange Rate. European Economic Review 34, 1201–1211.

Eichenbaum, M., C. L. Evans (1995), Some Empircial Evidence on the Effects of Shocks to Monetary Poliy on Exchanges Rates. Quarterly Journal of Economics 110, 975–1009.

Fuhrer, J., G. Moore (1995), Monetary Policy Trade-Offs and the Correlation between Nominal Interest Rates and Real Output. American Economic Review 85 (1), 219–239.

Fukuda, S.-i. (1993), International Transmission of Monetary and Fiscal Policy. A Symmetric N-Country Analysis with Union. Journal of Economic Dynamics and Control 17, 598–620.

Gali, J., M. Gertler (1999), Inflation Dynamics: A Structural Econometric Analysis. Journal of Monetary Economics 44, 195–222.

IMF (2004), IMF Primary Commodity Prices. International Monetary Fund. URL: `http://www.imf.org/external/np/res/commod/index.asp`

Jones, W. D., P. N. Leiby, I. K. Paik (2004), Oil Price Shocks and the Macroeconomy: What Has Been Learned Since 1996. The Energy Journal 25, 1–32.

King (2000), The New IS-LM Model: Language, Logic, and Limits. Federal Reserve Bank of Richmond Economic Quarterly 86, 45–103.

Manasse, P. (1991), Fiscal Policy in Europe: The Credibility Implications of Real Wage Rigidity. Oxford Economic Papers 43, 321–339.

McCallum, B. T. (2001), Should Monetary Policy Respond Strongly to Output Gaps? AEA Papers and Proceedings 91, 258–262.

OECD (2000), EMU – One Year On. Paris.

Romer, D. (1993), Openness and Inflation: Theory and Evidence. Quarterly Journal of Economics 108, 869–904.

Turnovsky, S. J. (1986), Monetary and Fiscal Policy under Perfect Foresight: A Symmetric Two-Country Analysis. Economica 53, 139–157.

Turnovsky, S. J. (2000), Methods of Macroeconomic Dynamics. Second Edition. Cambridge.

van der Ploeg, F. (1990), International Interdependence and Policy Coordination in Economies with Real and Nominal Wage Rigidity. In: Courakis, A. S., M. P. Taylor (eds.), Private Behaviour and Government Policy in Interdependent Economies. Oxford, 403–450.

Wohltmann, H.-W., V. Clausen (2003), Oil Price Shocks and Monetary Policy in an Asymmetric Monetary Union. Economics Working Paper 2003 – 11, Christian-Albrechts-Universität Kiel, Department of Economics.

Yousefi, A., T. S. Wirjanto (2004), The Empirical Role of the Exchange Rate on the Crude-Oil Price Formation. Energy Economics 26, 793 – 799.