Contrasting Different Forms of Price Stickiness: Exchange Rate Overshooting and Beggar Thy Neighbor Policy[1]

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Abstract

There is a growing literature on the real implications of monetary shocks in open economies with nominal rigidities. However, this literature largely ignores the role of the *type* of price stickiness and labor market imperfections. We extend the two country Obstfeld and Rogoff (1995) setting and show that the impact of a money supply shock on the national economy and the spillover effects to other countries depend crucially on (i) the form of price or wage stickiness as well as on (ii) the structure of the labor market. With sticky retail prices, the exchange rate overshoots even though uncovered interest rate parity is violated and an unexpected monetary expansion leads to a "beggar thy neighbor" effect. Exactly the opposite occurs if wholesale prices in the producer's currency are sticky. In this case a positive money supply shock causes positive spillover effects. The impact of wage stickiness depends crucially on the structure of the labor market. If the labor market is dominated by trade unions, a positive money supply shock leads qualitatively to same spillover dynamics and exchange rate dynamics as under sticky wholesale prices. If on the other hand, firms have all bargaining power in the labor market the opposite output dynamics and exchange rate dynamics follows a money expansion.

1 Introduction

The Great Depression triggered policy interest in the impact of one country's monetary policy on the neighboring country's economy and on the exchange rate. The term "beggar thy neighbor policy" was coined during that period. More formal analyzes of such macroeconomic interdependence were only possible decades later after a Keynesian analytical framework assuming sticky wages was developed by Fleming (1962) and Mundell (1961) and (1963) . Models based on this framework predict that a domestic monetary expansion leads to a reduction in foreign output (e.g. Mussa (1979)). This occurs since a domestic monetary expansion triggers a depreciation in the home currency. This raises the price of foreign goods, thereby leading to a substitution away from foreign goods and a reduction in production abroad. However, the Mundell-Fleming framework lacks microfoundation and is static. Consequently, no coherent welfare analysis can be conducted. A static model also restricts the analysis to comparative statics and does not allow one to explicitly analyze the dynamic aspects of the current account and the dynamics of the exchange rate.

Until recently dynamic models either departed from a general equilibrium framework by ignoring income effects or they focused on competitive dynamic models where firms and individuals take equilibrium prices as given (e.g. Lucas (1982) and Stockman (1980)). Money is neutral in models with frictionless markets and rational individuals. In addition, price stickiness is hard to justify in a competitive environment.

Obstfeld and Rogoff (1995) and Svensson and van Wijnbergen (1989) moved away from the price-taking assumption by incorporating monopolistic competition to the international finance literature. In contrast to the earlier partial equilibrium Keynesian models, these general equilibrium models take income effects into account and provide a thorough microfoundation. This makes it possible to conduct a welfare analysis. However, Obstfeld and Rogoff (1995) implicitly assume a special form of price stickiness since they assume that the purchasing power parity always holds. The extended model in Obstfeld and Rogoff (1996) is also restricted to a special form of labor market with powerful trade unions. Thus, the importance of the *form* of price stickiness and labor market imperfections has been largely ignored in the published literature.

Our paper shows that the form of price stickiness and the structure of the labor market are crucial in understanding the impact of an unanticipated money supply shock on the international economy. We distinguish between two different forms of price stickiness in the goods market: a *sticky retail price setting* wherein prices are fixed for one period in the consumers' currency and a *sticky wholesale price setting* where prices are sticky in the producers' currency. We also examine the case of *sticky wages* wherein we show that the impact of a money supply shock is determined by the structure of the labor market.

Our model builds on Obstfeld and Rogoff (1995) and extends it in various ways. It describes a two country world, home and foreign, that is populated by workers that pro-

vide labor to firms. We depart from the simpler yeoman analysis in Obstfeld and Rogoff (1995). In our model firms sell their output on the goods market and hire workers from the labor market. We assume market imperfections in both markets. This allows us to study price as well as wage stickiness. Each firm produces in only one of the two countries and is in monopolistic competition with firms both abroad and at home. Unlike Obstfeld and Rogoff (1995), who assume that firms set the price only in their own currency, we assume that firms are able to price discriminate between countries.[1] There are also frictions on the labor market. In Obstfeld and Rogoff (1996) and Hau (1998) workers are represented by monopolistically competitive trade unions which hold the market power. While there is a relatively broad agreement among economists that a monopolistic market structure is an accurate description of the goods market this is much less the case for labor markets. To provide a contrast to the existing models, we focus on the other extreme and assume that firms are monopsonists in the labor market.[2] Finally, our model assumes that there is a complete home bias in the ownership of firms.

Given the distortions in both markets, prices are higher in our model relative to the social optimum. A positive monetary expansion has an immediate effect on the national economy. With sticky prices, nominal wages will adjust while real prices decrease. This leads to more production in the country that expands its money supply and suggests a current account surplus. The analysis illustrates that the magnitude and directions of spillover effects and the dynamics of the world economics depend crucially on the form of price stickiness. Furthermore, if nominal wages are sticky, a money supply increase leads to higher prices and thus to lower real wages. This also affects the country's output as well as its current account deficit. These effects can be either negative or positive depending on the structure of the labor market. If the labor market is dominated by trade unions as in Obstfeld and Rogoff (1996), wages in the steady state equilibrium are too high in comparison to the social optimum. A money supply increase reduces real wages and thus leads to the same effects as in the sticky wholesale price setting. On the other hand, if firms hold the market power on the labor market, wages are already too low relative to the social optimum and an unexpected money supply shock has negative implications.

In an open economy, monetary policy decisions in one country affect the welfare of other economies as well. We show that both the size of spillover effects on foreign consumption and production and their direction depends crucially on the type of nominal stickiness assumed. In the sluggish wholesale price setting, Obstfeld and Rogoff's (1995)

[1] We believe that price discrimination is a more realistic assumption and it also allows us to study different sorts of price stickiness. There is a significant amount of evidence that borders have a much bigger effect on price disparities than for example transport costs, (Engel and Rogers 1996).

[2] Monopsonistic market power of firms is certainly an extreme assumption, but labour economists have previously argued that it is realistic in many settings. For example, it has been used to explain the positive employment effect of the introduction of minimum wages (Card and Krueger 1995),(Manning 1995), the positive relationship between firm size and wages (Green, Machin, and Manning 1996), and the persistent differences across firms in wages and vacancy rates (Boal and Ransom 1997). In a recent empirical study of the labour market for nurses, Staiger, Spetz, and Phibbs (1999) also found significant market power on the side of the hospitals.

result is confirmed even though we do not assume the law of one price. The spillovers are positive. On the other hand, if retail prices are sticky, the foreign country's welfare is unambiguously negatively affected by monetary expansions at home. This reinstates the traditional Keynesian notion of *"Beggar Thy Neighbor"* policies. Foreign consumption is negatively correlated with money expansions at home whilst the equilibrium labor input is positively correlated with it. Under a sticky wholesale price setting, the correlations with money supply of both consumption and production vary from the short to the long-run. While consumption is initially positively affected by a foreign money expansion, it is negatively correlated in the long-run. The opposite is true for production.

Under the sticky wage setting, the structure of the labor market determines the impact of a monetary expansion. The effects are either qualitatively similar to the case of sticky wholesale prices if workers are represented by powerful trade unions, or they are almost the mirror image of what happens under sticky wholesale prices. In the latter case, foreign production is negatively correlated in the long-run to home money expansions. Consumption abroad declines in the short-run but increases in the long-run.

Empirical evidence on the spillover effects appears to be inconclusive. McKibbin and Sachs (1991) argue that the spillover effects of monetary policy on real variables are small while Canzoneri and Minford (1986) claim that they are reasonably big and negative. It is important to understand the size and direction of spillover effects before one can discuss the need for international monetary coordination.

The form of price stickiness also affects the exchange rate dynamics. In our model the nominal exchange rate moves immediately regardless of whether wages, wholesale or retail prices are sticky. Under sticky wholesale prices, it jumps by less than the magnitude of the monetary expansion and immediately reaches its new steady state value. In contrast, under the sticky retail price setting the exchange rate jumps by more than the monetary expansion and returns to the old steady state level in the long-run. This *exchange rate overshooting* is qualitatively different from the classical overshooting in Dornbusch (1976). For Dornbusch-type overshooting to occur, the uncovered nominal interest rate parity (UIP) and long-run purchasing power parity needs to hold. In contrast, our overshooting occurs exactly when the uncovered nominal interest rate parity (UIP) and short-run PPP are violated. Our type of overshooting seems to be vindicated by the data. Rogoff (1996) has shown that periods of exchange rate overshooting coincide with periods of extreme violations of both PPP and UIP. If wages are sticky, the exchange rate moves more than the money supply but there is no overshooting. The exchange rate immediately reaches its new steady state as in the case of sticky wholesale prices. The volatility of the real exchange rate, as measured by the relative price of a consumption basket in the two countries, displays the same volatility as the nominal exchange rate in the case of sticky retail prices. This is in line with the empirical findings of Rogoff (1996). Under sticky wholesale prices and under sticky wages, the real exchange rate does not move at all because the law of one price always holds.

The empirically established J-curve effect shows that the trade balance is negatively correlated with current and future exchange rates while it is positively correlated with past exchange rates. In our model, the current account is initially positive if either of the two prices are sticky but turns out to be negative under wage stickiness. In the long-run, the sign of the current account is reversed and turns negative under sticky prices and positive under sticky wages. It is worthwhile to note that while the cross-correlation of the trade balance with the current exchange rate has different signs under sticky wages and sticky prices, the cross-correlation of the terms of trade and the trade balance is always positive. Even under sticky wages, where the exchange rate is negatively correlated the prices move far enough to allow the terms of trade to be positively correlated with the trade balance. Our findings extend the findings of Backus, Kehoe, and Kydland (1994) to monetary shocks. They found that while the J-curve effect can be reconciled with permanent productivity shocks, it is not possible to reconcile the negative correlation with fiscal shocks. In our model the efficiency gains from monetary disturbances are also only short-term even though they lead to permanent effects due to international lending.

To the best of our knowledge, our paper is the first to explicitly illustrate the importance of different types of price stickiness as well as labor market imperfections.

The remaining paper is organized as follows. Section 2 introduces the model and Section 3 analyzes the steady state. Section 4 introduces nominal rigidities. Section 4.1 discusses the effects of monetary disturbances under different kinds of price stickiness and illustrates a new form of exchange rate overshooting. Section 4.2 discusses the welfare spillovers of monetary expansions under different forms of price stickiness and the role of the labor market imperfections under sticky wages. Conclusions are presented in Section 5. Proofs not presented in the text are in the Appendix.

2 The Model

2.1 Consumers' Problem

The world is a 1×1 square in our model. A fraction n of the population lives in the home country and a fraction $(1-n)$ abroad. There is also a continuum of firms on the interval $[0,1]$. All firms produce different goods. A measure of n firms produce at home and a measure $(1-n)$ in the foreign country. Home firms are symmetrically owned by home citizens and foreign firms by foreign citizens. Each inhabitant works in one firm located in his country but consumes the whole range of home and foreign produced goods. The group of potential workers for each firm is of measure one. All citizens maximize an additively separable utility function with a common discount rate δ,

$$U = \sum_{t=1}^{\infty} \left(\frac{1}{1+\delta} \right)^t u(C_t^h, \frac{M_t^h}{p_t^h}, L_t^h).$$

As in Obstfeld and Rogoff (1996), the flow utility is Cobb Douglas in money and in the composite consumption good. The marginal disutility of labor is constant κ.

$$u(C_t^h, \frac{M_t^h}{p_t^h}, L_t^h) = \ln C_t^h(z) + \chi \ln \frac{M_t^h(z)}{p_t^h} - \frac{\kappa}{2} L_t^h(z)^2$$

The citizens derive positive utility from holding real money in their own currency. Holding more cash saves them trips to their bank. The flow utility exhibits constant elasticity of substitution (CES) of ρ among the different commodities. The composite consumption good is, therefore, given by

$$C_t^h(z) = \left[\int_0^1 c_t^h(k,z)^{\frac{\rho-1}{\rho}} dk \right]^{\frac{\rho}{\rho-1}}$$

and the price index is defined as

$$p_t^h = \left[\int_0^1 p_t^h(k)^{1-\rho} \right]^{\frac{1}{1-\rho}}.$$

The superscript h refers to the home country and f to the foreign country.
The budget constraint for an individual agent of type z is given by

$$p_t^h C_t^h + p_t^h \frac{1}{1+r_t} B_t^h + M_t^h = L_t^h(z) w_t^h(z) + \pi_t^h + M_{t-1}^h + p_t^h B_{t-1}^h - p_t^h \tau_t^h,$$

where τ_t^h are real government transfers, B_t^h denotes the face value of bond holdings between period t to $t+1$. Given the interest rate r_t the present value of the bond is $\frac{1}{1+r_t} B_t^h$. w is the nominal wage and π_t^h is the share of profits from home firms that the agent holds stocks of.

As in Obstfeld and Rogoff (1995) (1996) citizens are not allowed to trade their shares of the firms. However they can trade real bonds in order to smooth their consumption. Agents choose their labor supply, their consumption stream, their money holdings and their bond holdings.

The government's revenue comes from seigniorage. We will assume throughout this analysis that the government balances its budget in each period.[3]

$$M_t^h - M_{t-1}^h = p_t^h \tau_t^h$$

The consumption side is identical to the formulation used in Obstfeld and Rogoff (1996).

[3] We do not really have to assume this. As long as the government spends all its revenue on transfers or buys the same consumption baskets as the economy's agents, Ricardian equivalence in the model ensures that a temporary deficit or surplus has no effect.

2.2 Firms' Problem

As in the standard framework, we assume that companies are monopolistic competitors in the goods market. Each good k is produced by firm k only. Furthermore, we assume that each company is a monopsonist in the labor market. This is a crucial assumption as it leads to very different dynamics in our model under sticky wages compared to the standard framework. The dynamics under sticky prices are largely unaffected by this assumption. The empirical evidence suggests that this is a reasonable assumption. For example, Boal and Ransom (1997), Staiger et al. (1999) find that the market power is typically with the employers rather than with the employees. Therefore, it can be misleading to shift the market power to the workers for modelling purposes.

We assume that producers can differentiate between foreign and home markets while setting prices. The production function for an individual home firm k takes the simple constant returns to scale form

$$\begin{aligned} y^{hh}(k) &= L^{hh}(k) \text{ for the home market } h \text{ and} \\ y^{hf}(k) &= L^{hf}(k) \text{ for the foreign (export) market } f. \end{aligned}$$

The firm k maximizes its profit $\pi^h(k)$, which depends not only on the prices it sets but also on the exchange rate E

$$\max_{L^{hh},L^{hf}} \pi^h(k) = p^h(k)L^{hh}(k) + Ep^f(k)L^{hf}(k) - w^h\left(L^{hh}(k) + L^{hf}(k)\right),$$

subject to

home goods demand:	$p^h(k) = p^h(k; L^{hh}(k))$,
foreign goods demand:	$Ep^f(k) = Ep^f(k; L^{hf}(k))$,
labor supply:	$w^h = w^h(L^{hh}(k) + L^{hf}(k))$.

In the next section we solve the consumers' and producers' optimization problem under the assumption that both prices and wages are flexible.

3 Steady State Analysis

We analyze the steady state by assuming that all prices are flexible. Maximizing the consumers' utility and the entrepreneurs' profits in this setting leads us to a system of equations that determines the steady state equilibrium.

Proposition 1 *The symmetric equilibrium of the economy is fully determined by the following eight equations and their foreign counterparts. (all variables are per capita)*

1. $C^h_{t+1}(z) = \left(\frac{1+r_t}{1+\delta}\right) C^h_t(z)$ *(consumption Euler equation),*
2. $\frac{M^h_t(z)}{p^h_t} = \chi C^h_t \frac{1+i^h_t}{i^h_t}$ *, where* $1 + i^h_t = \frac{p^h_{t+1}}{p^h_t}(1 + r_t)$ *(money demand),*
3. $L^h_t = \frac{1}{\kappa}\frac{1}{C^h_t}\frac{w^h_t}{p^h_t}$ *(labor supply),*

4. $p_t^h = \left[np_t^h(h)^{1-\rho} + (1-n)p_t^h(f)^{1-\rho}\right]^{\frac{1}{1-\rho}}$ *(price index),*

5. $C_t^h = \frac{p_t^h(h)}{p_t^h}L^{hh} + \frac{Ep_t^f(h)}{p_t^h}L^{hf} + B_{t-1}^h - \frac{B_t^h}{1+r_t}$ *(budget constraint),*

6. $L_t^{hh} = \left[\frac{p_t(h)}{p_t^h}\right]^{-\rho} nC_t^h$, $L_t^{hf} = \left(\frac{p_t^f(h)}{p_t^f}\right)^{-\rho}(1-n)C_t^f$
(goods demand for home and export goods market),

7. $L_t^h = L_t^{hh} + L_t^{hf}$ *(total labor demand),*

8. $L_t^{hh} = \left(2\frac{\rho}{\rho-1}\frac{w_t^h}{p_t^h}\right)^{-\rho} nC_t^h$, $L_t^{hf} = \left(2\frac{\rho}{\rho-1}\frac{w_t^h}{Ep_t^f}\right)^{-\rho}(1-n)C_t^f$
(labor demand for home and export goods market).

This system of equations is almost identical to the system in Obstfeld and Rogoff (1996). The only differences occur in the labor supply and demand equations as well as in the goods supply equation. We give entrepreneurs monopsonistic power in the labor market, thereby reducing the labor demand by a factor of 2^ρ. The reduced supply enables the entrepreneurs to charge a markup that is double that in Obstfeld and Rogoff (1996). Additionally, we allow firms to discriminate in prices between home and foreign markets, i.e. they can choose the labor input that serves the domestic and export markets separately. The consumers' CES utility function leads to a simple markup pricing by firms. A comparison of the goods and the labor demand functions (equation 6 and 8) shows that entrepreneurs always set prices that are higher by a factor of $(2\frac{\rho-1}{\rho})$ than the production costs. Since the costs of serving the two markets are determined by the home wage, the price firms charge in the two countries is the same. Effectively, a Purchasing Power Parity (PPP) or a no arbitrage condition holds even though it has not been assumed ($Ep^f(h) = p^h(h)$). This result is proven formally in the next lemma[4].

Lemma 1 *Purchasing Power Parity ($p^h = Ep^f$) holds when prices and wages are flexible, even though firms can price discriminate.*

Proof. The firm's profit maximization problem is given by

$$\max_{L^h, L^{hh}} L^{hh}p^h(h) + (L^h - L^{hh})(p^f(h)E) - wL^h$$

subject to

(1) inverse goods demands in both countries
$p^h(h) = \left(\frac{nC^h}{L^{hh}}\right)^{\frac{1}{\rho}} p^h$ and $p^f(h) = \left(\frac{nC^h}{L^{hh}}\right)^{\frac{1}{\rho}} p^f$ and

(2) labor supply function
$w^h = \frac{1}{\kappa}\frac{C^h}{L^h}p^h$.

The first order conditions (FOC) are given by

$$\left(p^h(h) - p^f(h)E\right) + L^{hh}\frac{\partial p^h(h)}{\partial L^{hh}} - L^{hf}E\frac{\partial p^f(h)}{\partial L^{hf}} = 0$$

[4]This result would hold for any utility function that gives rise to isoelastic demand functions.

and

$$p^f(h)E - w - L^h \frac{\partial w^h}{\partial L^h} = 0$$

The assumption of the constant elasticity utility function ensures that the demand functions are isoelastic.

$$\frac{\partial p^h(h)}{\partial L^{hh}} \frac{L^{hh}}{p^h(h)} = L^{hf} E \frac{\partial p^f(h)}{\partial L^{hf}} \frac{L^{hf}}{Ep^f(h)} = -\frac{1}{\rho}$$

Substituting these relations into the second and third terms of the first FOC shows that the relative price that ensures the optimal allocation between foreign and home market, is given by

$$p^h(h) = Ep^f(h).$$

As long as the first FOC holds, firms set the same price in both markets. Since this holds for all individual prices it is also valid for the price indices. Hence, as long as prices are flexible, PPP holds even though it is not assumed.■

However, we will see in Lemma 5 presented in the next section that purchasing power parity need not hold if certain prices are sticky.

In an international equilibrium the bond market has to clear, i.e. $nB_t^h = (1-n)\, B_t^f =: B_t$. The international bond market can be thought of as follows. Consumers submit demand schedules to an international intermediary. These schedules specify how many consumption baskets they are willing to lend or borrow for a given interest rate. The international intermediary determines the interest rate such that the bond market clears and collects and delivers the consumption baskets.

It is difficult to determine the steady state of the economy unless we assume that bond holdings are internationally balanced. Hence, we adopt the strategy of determining the symmetric steady state and later on log-linearize the system of equations of Proposition 1 around this steady state.

Proposition 2 *The symmetric steady state in which the bond holdings are internationally balanced is given by*

1. $\bar{L}_0^h = \bar{L}_0^f = \bar{C}_0^h = \bar{C}_0^f = \sqrt{\frac{1}{\kappa}\frac{1}{2}\frac{\rho-1}{\rho}}$,
2. $\bar{r}_0 = \delta$,
3. $\bar{p}_0^h = \frac{\bar{M}_0^h}{\chi}\frac{1}{\bar{L}^h}\frac{\delta}{1+\delta} = \frac{\bar{M}_0^h}{\bar{M}_0^f}\bar{p}_0^f$,
4. $\bar{w}_0^h = \frac{1}{2}\frac{\rho-1}{\rho}\bar{p}_0^h = \frac{\bar{p}_0^h}{\bar{p}_0^f}\bar{w}_0^f$,

5. $\bar{E}_0 = \frac{\bar{p}_0^h}{\bar{p}_0^f} = \frac{\bar{M}_0^h}{\bar{M}_0^f}$.

Proof. see Appendix.■

The scale of production is reduced and the real wage is depressed due to the market imperfections inherent in monopolistic goods market and monopsonistic labor markets. The real interest rate is entirely determined by the exogenous time preference of the agents and the exchange rate depends solely on the relative money supply. Money is neutral in this flexible price steady state and does not have any effect on real variables.

The markup, $\bar{p}_0^h = 2\frac{\rho}{\rho-1}\bar{w}_0^h$, in our model is twice as high as in Obstfeld and Rogoff (1996). Because companies are able to use their market power to set wages, they set them too low. This in turn leads to a lower scale of production by a factor of $\sqrt{2}$.

As mentioned earlier, we log-linearize the model around the symmetric steady state. $\widehat{\overline{x}}$ approximates the percentage change from the symmetric steady state. We drop the subscript t from all equations which apply only within a period.

Lemma 2 *The log-linearized system of equations around the symmetric steady state with* $B = 0$ *is given by*

1. $\widehat{\overline{C}}^h_{t+1} = \widehat{\overline{C}}^h_t + \frac{\delta}{1+\delta}\hat{r}_t$ *(consumption Euler equation),*

2. $\hat{M}^h_t - \widehat{\overline{p}}^h_t = \widehat{\overline{C}}^h_t - \frac{\hat{r}_t}{1+\delta} - \frac{\hat{p}^h_{t+1} - \hat{p}^h_t}{\delta}$ *(money demand),*

3. $\widehat{\overline{L}}^h = -\widehat{\overline{C}}^h + \hat{w}^h - \hat{p}^h$ *(labor supply),*

4. $\widehat{\overline{p}}^h = n\widehat{\overline{p}}^h(h) + (1-n)\widehat{\overline{p}}^h(f)$ *(price index),*

5. $\widehat{\overline{C}}^h + \widehat{\overline{p}}^h = \widehat{\overline{L}}^h + n\widehat{\overline{p}}^h(h) + (1-n)\left(\widehat{\overline{p}}^h(f) + \widehat{\overline{E}}\right) + \frac{1}{n}\frac{\delta}{1+\delta}\frac{dB}{\overline{C}_0^h}$ *(budget constraint),*

6. $\widehat{\overline{L}}^{hh} = -\rho\left(\widehat{\overline{p}}^h(h) - \widehat{\overline{p}}^h\right) + \widehat{\overline{C}}^h$, $\widehat{\overline{L}}^{hh} = -\rho\left(\widehat{\overline{p}}^f(f) - \widehat{\overline{p}}^f\right) + \widehat{\overline{C}}^f$
(goods demand for home and export market),

7. $\widehat{\overline{L}}^h = n\widehat{\overline{L}}^{hh} + (1-n)\widehat{\overline{L}}^{hf}$ *(total labor demand),*

8. $\widehat{\overline{L}}^{hh} = -\rho\left(\widehat{\overline{w}}^h - \widehat{\overline{p}}^h\right) + \widehat{\overline{C}}^h$, $\widehat{\overline{L}}^{hf} = -\rho\left(\widehat{\overline{w}}^h - \widehat{\overline{p}}^f - \widehat{\overline{E}}\right) + \widehat{\overline{C}}^f$
(labor demand for home and export market).

The log-linearization allows us to understand the reaction of the economy to exogenous wealth and money shocks. We will use the equations later in order to determine the long-run effects of monetary expansions if either wages or prices are sticky in the short-term. For convenience, we first determine the difference in the growth rates of domestic

and foreign variables and only later determine the growth rates of individual countries' consumption and production.

The next proposition states that world output, i.e. the aggregate of home and foreign output, is independent of the intercountry wealth distribution in the steady state. Any change would have to come from a change in the real wages in the two countries. Changes in real wages affects the consumption-leisure trade-off. However, any percentage increase in the home real wage increases production costs and also the foreign price index. This in turn reduces the wage rate abroad. Foreign workers face the same leisure-consumption trade-off and thus they reduce their production. In short, a production increase in one country leads to an offsetting effect on output in the other country and thus the world production remains the same. This result holds as long as we assume that the wage is always a constant share of output. This is the case in our model because agents in both countries have the same preferences and they have CES utility function for different goods.

The distribution of leisure and consumption changes after an international redistribution of wealth. This is brought about by a change in the terms of trade. The indebted country's products become cheaper abroad, thereby allowing it to sell more goods to make interest payments.

Proposition 3 *A one-time redistribution of the bond holdings by dB does not affect aggregate world consumption or production but leads to the following permanent changes in home consumption, home employment, exchange rate and terms of trade.*

1. $\widehat{\overline{L}}^w = \widehat{\overline{C}}^w = 0,$
2. $\widehat{\overline{C}}^h = \widehat{\overline{C}}^w + (1-n)(\widehat{\overline{C}}^h - \widehat{\overline{C}}^f) = \frac{1+\rho}{2\rho}\frac{1}{n}\frac{\delta}{1+\delta}\frac{dB}{\overline{C}_0^h},$
3. $\widehat{\overline{L}}^h = \widehat{\overline{L}}^w + (1-n)(\widehat{\overline{L}}^h - \widehat{\overline{L}}^f) = -\frac{1}{2}\frac{1}{n}\frac{\delta}{1+\delta}\frac{dB}{\overline{C}_0^h},$
4. $\widehat{\overline{E}} = \left[\hat{M}^h - \hat{M}^f\right] - \frac{1+\rho}{2\rho}\frac{1}{n(1-n)}\frac{\delta}{1+\delta}\frac{dB}{\overline{C}_0^h},$
5. $\widehat{\overline{p}}^h(h) - \widehat{\overline{E}} - \widehat{\overline{p}}^f(f) = \widehat{\overline{w}}^h - \widehat{\overline{E}} - \widehat{\overline{w}}^f = \frac{1}{2\rho}\frac{1}{n(1-n)}\frac{\delta}{1+\delta}\frac{dB}{\overline{C}_0^h}.$

Proof. see Appendix.■

Home agents consume more as a reaction to an exogenous wealth transfer towards the home country. The extent of the increase in consumption depends positively on the substitutability between home and foreign goods. Consumption does not change as much as the income from bond holdings since agents also choose to work less. The home wage rises relative to the foreign wage and the exchange rate falls to lower the price of foreign goods at home and to increase the price of home goods abroad. Thus the foreign country is able to repay its interest payments. Not surprisingly, an exogenous change in the money supply does not affect any real variables. The exchange rate moves according to the relative money supply in the two countries.

4 The Economy under Nominal Rigidities

So far we have kept prices and wages flexible and have found that a money supply shock has no real effect. It only alters the nominal prices, wages and the exchange rate. In other words, with flexible prices and wages, money is "neutral", and since a money shock does not change the dynamics, it is even "super-neutral".

This result changes fundamentally if we assume that price adjustment is sluggish. With sticky prices a money shock will not only affect the short-run real variables but will also cause the economy to settle in a different steady state. We will look at a situation where the economy in period zero is in the symmetric steady state as described by Proposition 2. A monetary supply shock occurs in period one and nominal wages/prices are held fixed for that period. In period two all nominal prices and wages adjust and the economy reaches a new steady state. The new steady state can be characterized by the new levels of bond holdings and money supplies (B, M^h, M^f).

We distinguish between three different types of price stickiness:

- nominal retail price stickiness,
- nominal wholesale price stickiness, and
- nominal wage stickiness given certain labor market imperfections.

Retail prices are the prices that are paid by the consumers in the two countries. By wholesale prices we mean the prices that producers charge in their own currency.

We follow the methodology developed in Obstfeld and Rogoff (1995) to derive the dynamic equilibrium with nominal rigidities. We log-linearize the system around the symmetric steady state to determine the short-term dynamics and to take into account the fact that certain prices are fixed between periods zero and one. We denote the first order percentage change of a variable x in the shock period by $\hat{x}$.

The economy reaches its new steady state in period two. As in the previous section we denote the percentage deviation between the new steady state and the original symmetric steady state by $\widehat{\overline{x}}$. After the money shock at the beginning of period one, agents immediately adjust their net international bond holdings B. All variables stay constant from period two onward. Bond holdings do not change from period one to period two because agents hold their net wealth constant.[5] Any steady state of the economy is fully characterized by the money supply and the international bond holdings (the only real

[5] Unlike Obstfeld and Rogoff (1995) we define B_t as the face value of the bond. Obstfeld and Rogoff (1995) denote the bond price by F_t. In their formulation F_t would jump twice since the interest paid out in period 2 differs from the steady state interest payments. Nevertheless, log-linearisation around $\bar{F} = 0$ makes the difference of the interest payments in the first two steady state periods of second order. Hence, it does not enter the calculations in Obstfeld and Rogoff (1995).

state variables). Therefore, the steady state from period two onwards is the same as the steady state under flexible prices if

(1) the money supply changes in the same way, and

(2) the bond holdings are exogenously changed to the levels that endogenously arise under price stickiness.

If one knows the money shock and the endogenous redistribution of bonds, the change in period two can be fully characterized by the long-run relationships in Proposition 3.

Because of the intertemporal nature of the model, the short-run solution also involves the long-run changes in the variables consumption $\hat{c}$, the price index $\hat{p}^h$ and the interest rate $\hat{r}$. The money demand depends on future price levels and agents want to smooth their consumption path. To determine the short-run changes we will hence need the long-run budget constraint and the linearized long-run money demand equation from Lemma 2 in addition to the equations in Lemma 3.

Lemma 3 *For a given form of price/wage stickiness the log-linearized system of equations around the symmetric steady state with $B = 0$ is given by*

1. $\widehat{\overline{C}}^h = \hat{C}^h + \frac{\delta}{1+\delta}\hat{r}$ *(consumption Euler equation),*
2. $\hat{M}^h - \hat{p}^h = \hat{C}^h - \frac{\hat{r}}{1+\delta} - \frac{\widehat{\overline{p}}^h - \hat{p}^h}{\delta}$ *(money demand),*
3. $\hat{L}^h = -\hat{C}^h + \hat{w}^h - \hat{p}^h$ *(labor supply),*
4. $\hat{p}^h = n\hat{p}^h(h) + (1-n)\hat{p}^h(f)$ *(price index),*
5. $\hat{C}^h + \hat{p}^h = \hat{L}^h + n\hat{p}^h(h) + (1-n)\left(\hat{E} + \hat{p}^f(h)\right) - \frac{1}{n}\frac{dB}{\overline{C}_0^h}$ *(budget constraint),*
6. $\hat{L}^{hh} = -\rho\left(\hat{p}^h(h) - \hat{p}^h\right) + \hat{C}^h$, $\hat{L}^{hf} = -\rho\left(\hat{p}^f(h) - \hat{p}^f\right) + \hat{C}^f$
   (goods demand for home and foreign market),
7. $\hat{L}^h = n\hat{L}^{hh} + (1-n)\hat{L}^{hf}$ *(total labor demand),*
8. *(labor demand equations are replaced by equations which* ***vary with the form of price stickiness****).*

The labor demand equation in Lemma 2 is replaced by $\hat{p}^h(h) = \hat{p}^h(f) = 0$ in the case of sticky retail prices. Under sluggish wholesale prices, i.e. when prices are sticky in the producers' currency, the additional equation is given by $\hat{p}^h(h) = \hat{p}^f(f) = 0$. Similarly, if wages are sticky, it is given by $\hat{w}^h = \hat{w}^f = 0$.

The labor demand equation also varies depending on the form of price stickiness. With both forms of price stickiness, the monopolists always supply the goods demand as long as they earn a positive markup. The monopolists need not be concerned that additional supply reduces the price. The labor demand, therefore, results directly from the goods demand equation. In the case of sticky prices, the labor demand is determined by the

labor supply at this fixed wage.

Note that the budget constraint in the short-run differs from the long-run budget constraint. Fixing the prices or wages leads to a temporary change in real income which agents smooth by saving or dissaving in the international bond market.

4.1 Exchange Rate Overshooting and Uncovered Interest Rate Parity

This section illustrates the exchange rate dynamics, purchasing power parity and the uncovered interest rate parity under the different forms of price stickiness. The main focus is exchange rate overshooting under sticky retail prices, which is different from the classical Dornbusch-type overshooting.

The nominal interest rates are the same in period one regardless of the form of price stickiness. This is true because we assume a Cobb-Douglas relationship between money and consumption. This gives rise to a constant unit consumption elasticity of the money demand.

Lemma 4 also shows that the inflation rate from period one to period two has to be the same in both countries.

Lemma 4 *Both countries always face the same ex-ante nominal interest rate* $i^h = i^f$. *Furthermore, they experience the same inflation rates between period one and period two. That is* $\frac{p_2^h}{p_1^h} = \frac{p_2^f}{p_1^f}$.

Proof. In the steady state, the nominal interest rate coincides with the real interest rate. Both countries always face the same real interest rate. This is also true in the shock period.

Since the real interest rate is identical in both countries and the consumption elasticity is assumed to be unity, it follows that the ratio of the consumption levels is the same in the shock period and in the long run. That is, $\frac{C_1^h}{C_1^f} = \frac{C_2^h}{C_2^f}$. This in turn implies that the ratio of home and foreign real balances in period two and one only depends on relative nominal interest rates and not on consumption. Since in the long run both countries face the same nominal interest rate, the ratio of the real balances is given by (equation 2 of Proposition 1)

$$\frac{M_2^h}{M_2^f}\frac{p_2^f}{p_2^h}\frac{M_1^f}{M_1^h}\frac{p_1^h}{p_1^f} = \frac{i_1^h}{1+i_1^h}\frac{1+i_1^f}{i_1^f}$$

Furthermore, any difference in the relative nominal interest rates at home and abroad has to result from different inflation rates, because the real rates are the same. Suppose now that the inflation rate at home were higher than abroad. Because the money supply

stays constant ($M_1^h = M_2^h$, $M_1^f = M_2^f$), this would mean that real balances at home fall relative to real balances abroad from period one to period two. The left hand side of the equation above would be smaller than one. At the same time the higher inflation rate at home would induce a positive nominal interest rate differential in the short term while the nominal interest rate is the same in the long run. This change in the relative interest rate would lead to a rise in the real balances held at home relative to those held abroad because the opportunity cost of holding money would fall by more for the home agent than for the foreign agent. The right hand side of the above equation would be greater than one. This implies that the inflation rates and hence the nominal interest rates have to be the same in the two countries.■

As pointed out earlier the last lemma depends on the assumption that the utility function in money and consumption is of a Cobb-Douglas form. The results would change smoothly if we assume a variable consumption elasticity of money demand.

The next lemma analyzes whether PPP, which holds under flexible prices, still applies when prices are sticky.

Lemma 5 *In the long-run, purchasing power parity ($p^h = Ep^f$) holds under any form of price stickiness. In the short-run, it still holds under sticky wholesale prices and under sticky wages but not under sticky retail prices.*

Proof. In the long-run, firms can adjust their prices and the result that PPP holds under flexible prices applies (Lemma 1). If prices are not flexible, the first order condition becomes irrelevant in the short-term. Nevertheless, it is true that PPP holds under sticky wholesale prices. The argument is as follows. PPP holds in the initial steady state because prices and wages are flexible. In the shock period, the relative price of the same goods in the home and the foreign market moves only with the exchange rate. Hence, the no arbitrage condition continues to hold for each good and, therefore, also for the price levels.

This is obviously not true under fixed retail prices because the exchange rate moves in the shock period ($\hat{E} \neq 0$). It is intuitively easy to understand why the exchange rate jumps under sticky retail prices. Under sticky retail prices, the price of consumption stays constant in the shock period. There is no substitution between home and foreign goods. Hence, production is the same in both countries. Now, suppose the exchange rate does not move. This would imply that home and foreign agents have the same real income and, therefore, there is no international borrowing. Consequently, they both consume the same amount. Both also face the same nominal interest rates (Lemma 4). Given all these symmetries, they would demand the same amount of real money. This cannot be an equilibrium because the money supply differs. (For an explicit proof see Proposition 6).■

Note that the result that monetary shocks would not lead to deviations from PPP under wholesale price stickiness is not restricted to our case of CES utility functions over

the different goods. Only the result that PPP holds in the steady state hinges on CES between different goods.

These two lemmas allow us to show that both interest rate parity and exchange rate overshooting depend on which form of price stickiness is assumed.[6]

Proposition 4 *While the exchange rate overshoots its long-run value under sticky retail prices, it immediately reaches its new steady state value under sticky wholesale prices as well as under sticky wages.*

Proof. Lemma 4 states that the nominal interest rate is always the same in both countries. Using this fact and the equation for the relative change in real money holdings - as stated in Lemma 4's proof - we get $\frac{p_2^f}{p_2^h}\frac{p_1^h}{p_1^f} = 1$. Since PPP holds both in the long run and in the short run under sticky wholesale prices and sticky wages, this equation implies that $\frac{E_1}{E_2} = 1$, i.e. the exchange rate jumps immediately to its long term level. If retail prices are sticky the equation implies that $\frac{E_0}{E_2} = 1$. That is, the long run exchange rate coincides with the short run exchange rate.■

Intuitively, under sticky retail prices the exchange rate has to return to its original level since PPP holds in both steady states and inflation from period zero to period two is the same in both countries. From period zero to period one, inflation is zero due to retail price stickiness. Lemma 4 shows that both countries experience the same inflation rate from period one to period two.

Both the results that the long term exchange rate is not affected by money supply shocks under sticky retail prices and that there is no overshooting if one of the other two prices are sticky depend on the assumption of a Cobb-Douglas relationship between real money and consumption. If we instead assume a different consumption elasticity of money demand, both results would not hold with strict equality. Nevertheless the qualitative insights would still be the same.

Proposition 5 *Uncovered nominal interest rate parity holds under sticky wholesale prices and sticky wages but is violated under sticky retail prices.*

Proof.

The interest rate parity condition in the shock period is given by

$1 + i_t^h = \frac{E_{t+1}}{E_t}\left(1 + i_t^f\right)$

The proof is self evident from Lemma 4 and Proposition 4.■

[6] Betts and Devereux (1996) also consider a model in which firms price discriminate between home and foreign markets. However, their model is de facto static since they do not allow international bond trading. They find a one-off jump in the exchange rate but no overshooting. The increase in the exchange rate exceeds the one in Obstfeld and Rogoff (1995). The authors claim that the difference is due to pricing to market while we show that it is due to different forms of price stickiness.

The last proposition illustrates that our overshooting phenomenon under sticky retail prices also holds, even though the uncovered interest rate parity is violated. This is quite distinct from the classical Dornbusch overshooting literature. UIP as well as long-run PPP are necessary for their overshooting result. In our setting the exchange rate overshoots exactly then when UIP is violated which is in line with empirical findings. Deviations of UIP are surveyed in Engel (1996). Faust and Roger's (1999) VAR analysis shows that huge deviations from UIP occur when the exchange rate overshoots. This is exactly our outcome under sticky retail prices.

4.2 Winners and Losers of an Unanticipated Money Shock

In this section we analyze the impact of an unanticipated money supply shock on the two countries' welfare. As was outlined in the introduction, we are specifically interested in understanding the spillovers of one country's monetary policy on the foreign country's welfare. The analysis in this section does not stop at pointing out the conditions under which countries could engage in profitable beggar thy neighbor policies. We investigate the welfare responses of monetary expansions under different forms of price stickiness and different labor market structures. We focus specifically on the labor market because we believe that there is relatively broad agreement on how the goods market interacts with monetary policy shocks. The same can't be said of the labor market.

Before we go into the discussion of the distribution of welfare it is useful to analyze what causes in changes of aggregate world welfare after a monetary shock . The economy is not at the Pareto frontier in the flexible price equilibrium (steady state). This is due to welfare losses caused by monopolistic and monopsonistic distortions. These welfare losses can be viewed as the result of a coordination failure. A social planner would set wages equal to prices. The outcome would Pareto dominate the steady state outcome in Proposition 2. We will see that monetary policy under sticky nominal prices or wages can coordinate the agents in such a manner that the outcome is Pareto improved. Different monetary policy is optimal depending on which prices are sticky and which real imperfection causes the flexible price equilibrium to be suboptimal. Furthermore we show that the distribution of the welfare gain or loss between the two countries depends crucially on the set of prices or wages which do not adjust. We organize the results as follows. In section 4.2.1 we compare the outcomes under sticky retail and sticky wholesale prices and in section 4.2.2 we compare the setting of sticky wholesale prices with the one under sticky wages. The reason for this is twofold. First the sticky wholesale price scenario turns out to be identical to the Obstfeld and Rogoff (1995) setting which we regard as our reference point in the literature. Second, this division allows us to separate different issues. In the first section we see that, depending on the nominal rigidity, there are two different channels that influence the distribution of an aggregate welfare gain between the countries. In the second section we argue that the sticky wholesale price scenario is isomorphic to a setting in which wages are set by monopolistic unions. We compare that scenario with sticky wages in an economy where firms are the wages setters. We point out that in a sticky wage setting the structure of the labor market has important implications

for welfare gains and losses after a money shock, if wages are sticky.

4.2.1 Sticky Retail Prices versus Sticky Wholesale Prices

If prices are sticky, world welfare is positively affected by an unanticipated positive money shock. An increase in money supply effectively reduces real prices. At lower real prices, consumers demand more goods and producers, having lost their price setting power, are willing to meet any demand they face, as long as the money shock is not too big. This leads to lower deadweight losses and higher consumer surplus. This is true under both forms of sticky prices. As illustrated in Appendix A.3, the response of world output is the same. We will see that what differs is the distribution of welfare gains.

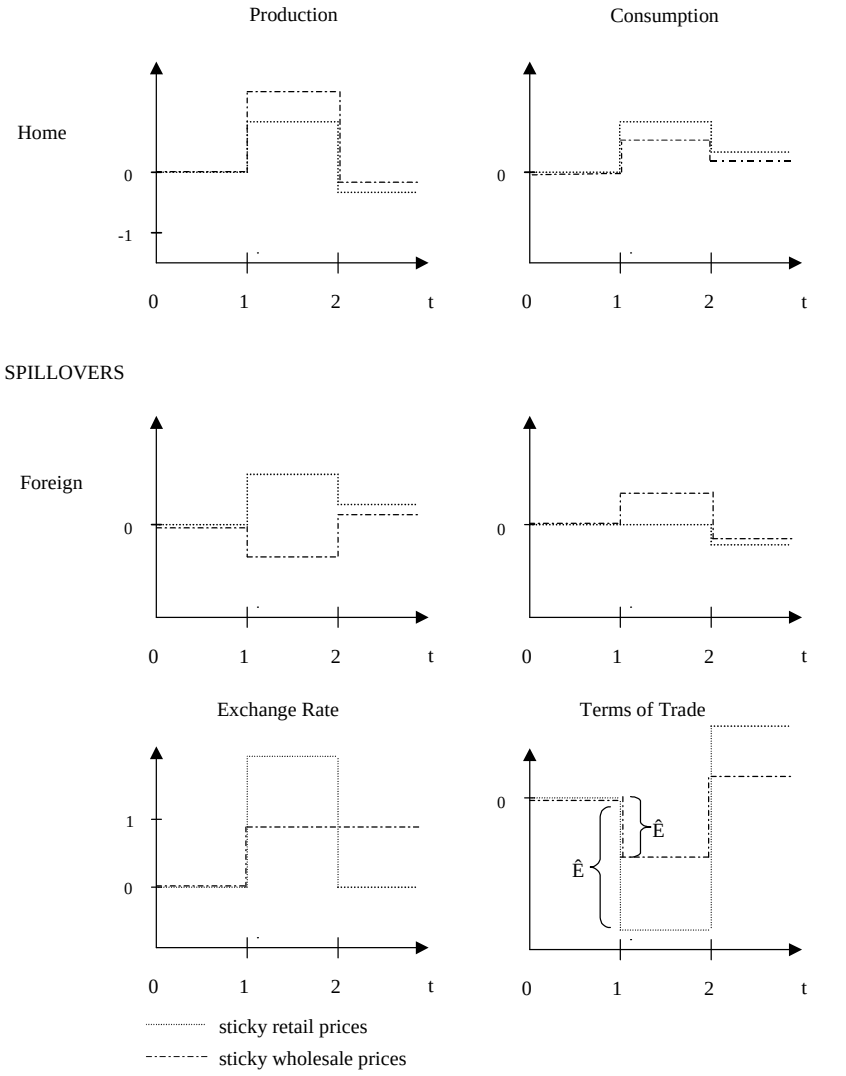
Under sticky wholesale prices producers only keep the price in their own currency constant. This implies that price changes in the short-run are given by $\hat{p}^h(h) = \hat{p}^f(f) = 0$, $\hat{p}^f(h) = -\hat{E}$ and $\hat{p}^h(f) = \hat{E}$. The prices of exported goods change with the exchange rate. Under sticky retail prices, firms keep prices fixed both in their own and in the foreign currency $p^h(h) = \hat{p}^f(h) = \hat{p}^f(f) = \hat{p}^h(f) = 0$. This implies that the relative price of foreign and home goods does not change in either of the two countries.

These differences in price adjustment imply that money shocks propagate through two different channels.

- If the wholesale prices are held constant and the exchange rate appreciates, home produced goods become cheaper relative to foreign produced goods, both at home and abroad. As a result, consumers substitute home for foreign goods. Because the price is fixed in the currency of the producer, the per unit revenue for a firm is the same for sales abroad and at home.

- Under sticky retail prices, consumers have no reason to substitute one good for the other since the prices they face do not change. Suppose the exchange rate depreciates immediately. Under sticky retail prices the depreciation allows domestic exporters to earn more in their own currency per unit exported than per unit sold domestically. They sell their products at the same foreign retail price and convert the revenues into the home currency at a more favorable exchange rate. Their unit price for exported goods increases in real terms as well since the domestic consumer prices do not change. For foreigners, who export to the home country, an increase in the exchange rate reduces their returns in the foreign currency and in real terms.

As we will see, these differing propagation mechanisms have important implications for consumption and production abroad and at home. Consequently, the welfare implications of a money supply increase differ substantially. To highlight these effects more clearly, let us assume for the rest of this subsection that only the home country expands its money supply while the foreign money supply stays constant. Since we are mainly interested in the qualitative differences the explicit calculations are stated in the Appendix A.4



The ordinate measures the respective % increase relative to the % increase in money.

Figure 1: Impulse Response Functions

and A.5. Instead we show the impulse response function under the two forms of price stickinesses in Figure 1.

The differences in short term *consumption* rates can be easily understood if we keep in mind the fact that the nominal interest rate has to be the same in the two countries to keep the money markets in equilibrium (Lemma 4). This implies that the difference in short term consumption growth rates must be entirely determined by the difference in the real money balances given the money demand equations. Under sticky retail prices, home real money balances change by $\hat{M}^h$ while foreign balances do not change at all because the consumption price indices do not change. Hence, home consumption goes up by as much as money and foreign consumption stays constant. In short, all the additional demand occurs at home. In contrast, under sticky wholesale prices the home price index rises due to the depreciation of the home currency, which makes imported goods more expensive. This causes real balances to rise by less that the money supply. That is why home consumption grows less in this scenario than under sticky retail prices. Foreign real money balances increase because imports become cheaper. Hence, while foreign consumption stays constant under sticky retail prices, it rises under sticky wholesale prices.

On the *production* side, there is no substitution between home and foreign produced goods in either of the two countries in the sticky retail price setting. This means that the labor input has to increase by equal amounts in both countries. Under sticky wholesale prices, home goods become cheaper in both countries leading to an increase in home output relative to foreign output.

Under sticky prices, the additional *income* which is necessary to afford the higher consumption comes from the reduced deadweight losses mentioned above. Having seen how production and consumption reacts in the two countries it is obvious that the distribution of the gains depends strongly on the exact type of price stickiness. Under sticky retail prices the real export revenues per unit increase for home and decrease for foreign residents for the reasons mentioned above. This enables home residents to consume more than their foreign counterparts without working harder. Home residents lend to the foreign country because their short term income is higher than in the long run. The opposite is true for foreigners. Under sticky wholesale prices, the relative price of foreign and home produced goods can change leading to the substitution explained above. Relative income between home and foreign residents changes due to relative changes in per unit revenues as well as changes in the quantity adjustments in production. For foreigners the real price of their imports per unit decreases. Hence, their real income resulting from their production activity, increases. This allows them to participate in the aggregate world efficiency gain. Although home residents earn less in real terms for each unit exported, their real income rises as well, because of the sharp increase in their production.

The changes in the *long run* are essentially determined by the short term capital flows. Because money is neutral in the long run, all real variables only depend on the bond holdings in the two countries. Under both forms of price stickiness, home citizens lend money to foreign residents because the home country is always the main benefi-

ciary in terms of income of the monetary expansion. The effect is stronger under sticky retail prices than it is under sticky wholesale prices. In the long run the borrowing country will pay the interest on the short term borrowing. To be less or better off in the long run has an effect on both labor input and consumption because agents equalize the marginal utility of leisure and the marginal utility of consumption. Foreign producers not only work harder to pay the interest but also consume less. Home citizens not only spend this additional (interest) income on additional consumption but they also work less.

What do these dynamics imply for the change in *welfare*? Since the impact of a money supply shock in our model under sticky wholesale prices is the same as the one in Obstfeld and Rogoff (1996), we find that agents in both countries are equally well off. Both experience the same welfare gain. However, this is certainly not true under sticky retail prices. Foreigners always consume weakly less than before but work strictly more. Thus they must be worse off than they were initially. Home agents fully benefit from the increased consumer surplus fully. They are better off than in the case of sticky wholesale prices.

In short, the *'beggar thy neighbor'* strategy is surely optimal in a setting with sluggish retail prices.

4.2.2 The Role of the labor Market under Sticky Wages

The effect of wage stickiness on the response of open economies to money supply shocks crucially depends on the structure of the labor market. We show that, if nominal wages are sticky, a monetary expansion can have either an expansionary or a contradictory effect on output.

Obstfeld and Rogoff (1996) consider a labor market which is dominated by trade unions. Each trade union represents a certain type of worker and the trade unions compete monopolistically with each other. The labor demand is determined by the production function of the firms that would like to employ a certain fraction of each type of worker. Firms are wage-takers, whereas trade unions have some monopolistic power. Note that, the reaction to an unanticipated money shock of our economy under sticky wholesale prices is exactly the same as the reaction in the Obstfeld-Rogoff economy with sticky wages and monopolistic unions.[7] Therefore in this section we interpret the outcome under sticky wholesale prices as a sticky wage economy, in which workers' unions have the market power in the labor market.

The Obstfeld-Rogoff (1996) assumption that the labor market is dominated by monopolistic trade unions is questionable. In order to provide a contrast to this assumption and to highlight the importance of the labor market structure we deliberately chose the

[7] A model with monopolistic trade unions is identical to a model with monopolistic firms. Instead of firms which restrict the output in order to keep the goods price high, trade unions restrict their labour supply in order to keep the real wage rate high.

other extreme. In our setting, firms are monopsonists in the labor market, i.e. they take into account the fact that the wage rate increases if they demand more labor. Workers - who are now not represented by trade unions - just take the wage level as given. As pointed out before, the monoponistic setting is often used in labor economics.

The outcome of an economy with monpsonistic firms and sticky wages is in sharp contrast to the outcome given monopolistic unions and sticky wages. The scale of the economy is not demand determined like it is in the case with monopolistic unions but restricted by the labor supply. The labor demand equation is replaced by an assumption of fixed wages ($w^h = w^f = 0$). These equations together with Lemma 3 allow us to analyze the dynamics explicitly. Since we are only interested in the qualitative differences here, we delegate the detailed Proposition to Appendix A.6. Figure 2 shows the impulse response functions to an unanticipated positive home money supply shock of consumption and production at home and abroad and of the terms of trade and the exchange rate. To highlight the importance of the labor market structure, we plot the impulse responses under sticky wages given monoponistic labor market and contrasts it with the economy under sticky wholesale prices - now interpreted as a sticky wage economy where trade unions set wages.

If firms set wages, increasing the home money supply causes upward price pressure at home. Due to the stickiness of nominal wages, higher consumer prices result in lower real wages. Workers substitute consumption for leisure and work fewer hours. The resulting contraction in the production of home-made products has at least two effects. First, it reduces the income of home citizens. The interest rate rises because theses citizens try to borrow from abroad in expectation of higher future income. Second, home products become more expensive relative to imported foreign products. The exchange rate rises, as the demand for foreign products and, hence, for foreign currency rises.

Though a high exchange rate should make imported home-produced goods cheaper abroad, the opposite happens because the price $p^h(h)$ skyrockets. The calculations of the terms of trade highlight this. Consequently, foreign consumers also substitute home-produced goods with foreign goods. Higher demand for their foreign products and higher prices for the imported goods increases their price index too. Foreigners reduce their consumption in favor of more savings and lend a larger amount to the home citizens. The high real interest rates in period one makes it worthwhile for them to reduce their consumption but to keep their production constant, even though the real wages decline abroad too. This short term dynamics is in sharp contrast to the impact of a money shock under sticky wholesale prices (which we have argued coincides given the dynamics with monopolistic trade unions). While the world output increases after a positive home money supply shock if unions set wages, it decreases if it is firms that set wages. And while the short term capital flow is from the home country to the foreign country in the former case, capital flows from the foreign country to the home country in the latter case.

Because the short term capital flows in different directions and the real variables in the long term are solely determined by the countries' asset positions, the long run differs sub-

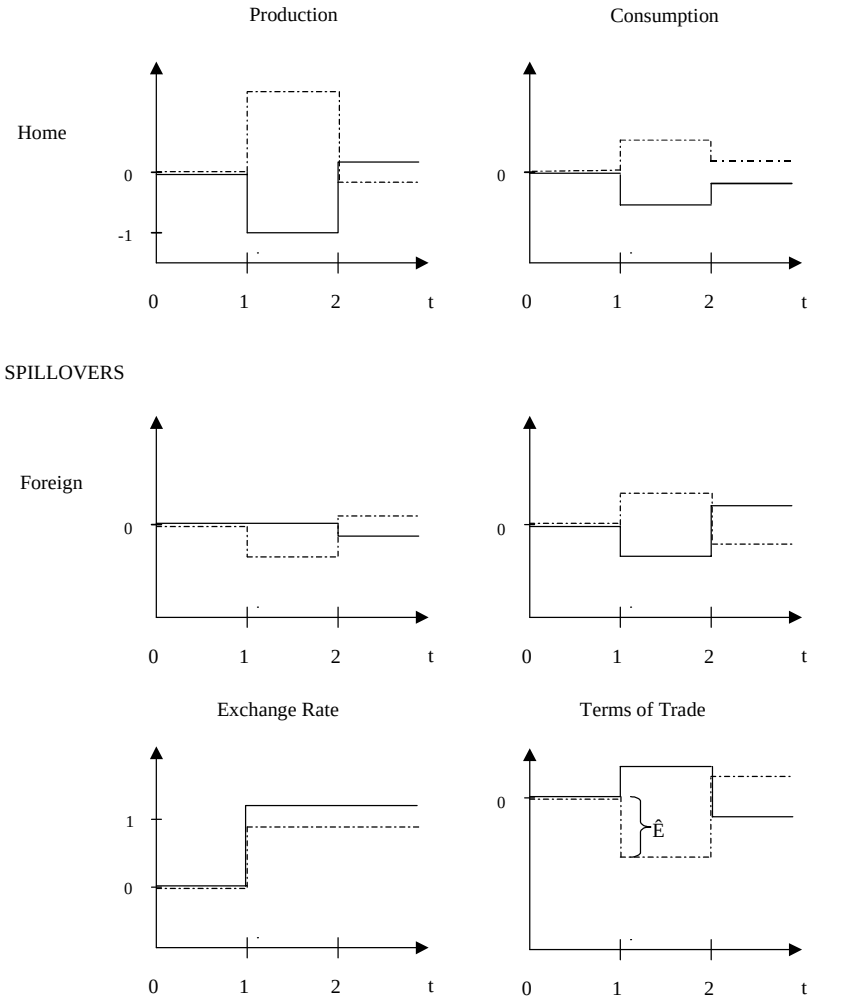


Figure 2: Impulse Response Functions

stantially as well. If firms set wages, foreigners will receive interest payments in the form of home-produced goods from period two onward. Therefore, in the long-run, production at home has to increase whereas consumption declines. The opposite is true abroad. This is almost the mirror image to what happens in the long run if unions set the wage. Note that the monopsonistic labor market setting with sticky wages replicates the empirical regularity known as the J-curve effect. Empirically it is often found that after an exchange rate appreciation the trade balance becomes negative for a while before bouncing back and leading to a long-run trade balance surplus. In period one the exchange rate and the trade balance are negatively correlated. However the J-curve effect is also often claimed to be associated with a short term negative correlation between the terms of trade and the trade balance Backus, Kehoe, and Kydland (1994). In our model even if firms set prices this correlation is positive because prices overcompensate the nominal depreciation. This causes the terms of trade to appreciate even though the nominal exchange rate depreciates. In welfare terms, both the home country and the foreign country are worse off after an unanticipated monetary expansion at home.

To understand why difference in the labor market structure give rise to very different dynamics, it is important to think about how the money shock affects real and nominal wages.

The overall impact of a money expansion depends on whether the steady state wage rate is above or below the wage rate in a world without any labor market distortions. In the economy with trade unions the real and the nominal wage level is higher than the non-distortionary wage. We define the non-distortionary nominal wage as the equilibrium wage that would prevail if there were no imperfections in the labor market and both firms and workers were wage takers. This wage level is an important benchmark. A positive money supply shock raises the efficient non-distortionary nominal wage level while the actual nominal wage is fixed. In the setting with monopolistic unions, the gap between the paid nominal wage and the non-distortionary wage level, given the increased money supply, is reduced for one period. This leads to a more efficient outcome with higher output.

In contrast to the setting with unions the steady state nominal wage in a monopsonistic labor market is too low in comparison to the non-distortionary wage level defined above. A positive money supply shock increases the non-distortionary efficient wage level. Yet the nominal wage remains the same due to nominal wage stickiness. In other words, the gap between the wage level actually paid in the economy and the non-distortionary wage level widens. Consequently, output shrinks. This is the exact opposite effect to the one obtained in a setting where the labor market is dominated by trade unions.

Instead of looking at 'nominal wages relative to total money supply, the difference between both settings can also be illustrated using the real shadow price of leisure. This shadow price reflects the marginal unit of consumption necessary to compensate the worker for an additional marginal disutility of labor. In a world without labor markets imperfections, this shadow price would coincide with the real wage rate. In a setting

with trade unions, the real wage is higher than the non-distortionary shadow real wage. A positive monetary shock increases the price of consumption, while the nominal wage is fixed. Thus it lowers the real wage, moving it closer to the non-distortionary level. This leads the economy closer to the efficient level, to more production and higher welfare. On the other hand, in an economy where firms are monopsonists, the real shadow price of labor coincides with the real wage and is lower than the non-distortionary wage. A positive monetary shock again raises the price of consumption and leads to lower real wages. Since the real wage was already too low, the economy moves even further away from the non-distortionary level and output contracts.

This discussion highlights the point that in any labor market setting, the effect of a money supply shock on output depends crucially on whether the steady state real wage rate is above or below the non-distortionary wage rate.

5 Conclusion

The main message of this paper is that the *form* of price stickiness matters. Given the empirical regularities like the violation of PPP in the short-run and of the uncovered interest rate parity (UIP) etc., it seems plausible that the stickiness of retail prices is very important. Retail price stickiness leads to large spillover effects and reinstates the "beggar thy neighbor" policy. This analysis also provides an argument for an international coordination of monetary policy to prevent monetary authorities from getting into a race of competitive devaluations. In our setting, sticky retail prices also lead to exchange rate overshooting even though the UIP is violated. Therefore, it provides a qualitatively different explanation of exchange rate overshooting than Dornbusch (1976). This paper also illustrates the point that the effect of a monetary expansion on the world economy depends crucially on the *structure* of the labor market if wages are sticky. While there is widespread agreement that firms enjoy monopolistic power in the goods market, there is much less agreement on how to model the labor market.

Some extensions are left for future research. It would be interesting to extend the analysis to a setting where monetary shocks occur with positive probabilities. An analysis along the lines of Obstfeld and Rogoff (1999) seems promising. Interesting insights might also emerge from an analysis of asymmetric forms of price stickiness, such as when wholesale prices are sticky in the home country while abroad retail prices do not adjust. Introducing productivity shocks bundled with a certain form of price stickiness might lead to slightly different results, especially when monetary policy lags the productivity shocks. Another worthwhile extension would be to find an appropriate empirical test that allows us to discriminate between different forms of price stickiness and to empirically estimate their relative importance. But these are all tasks for the future.

A Appendix A

A.1 Proof of Proposition 2

Let us assume that labor and consumption are identical in the two countries. The consumption Euler equation as usual determines the real interest rate

$r = \delta$.

The budget constraint in the symmetric steady state is given by

$C^h = \frac{p^h(h)}{p^h} L^{hh} + \frac{Ep^f(h)}{p^h} L^{hf}$.

Since the no arbitrage condition holds, it simplifies to

$C^h = \frac{p^h(h)}{p^h} L^h$.

The labor market equilibrium and the world goods market equilibrium imply

$L^{hh} + L^{hf} = L^h = L^f = L^{ff} + L^{fh}$

and

$L^{hh} + \frac{(1-n)}{n} L^{fh} = C^h = C^f = L^{ff} + \frac{n}{(1-n)} L^{hf}$.

The last two equations imply that

$nL^{hf} = (1-n)L^{fh}$.

Since the capital account is balanced by assumption the current account has to be balanced

$nL^{hf} Ep^f(h) - (1-n)L^{fh} p^h(f) = 0$.

which implies that the terms of trade are zero

$p^h(h) - p^f(f)E = 0$.

This implies for the price index that

$p^h = p^h(h)$.

The labor supply equation together with the markup formula and the budget constraint implies the scale of production

$L^h = \sqrt{\frac{1}{\kappa} \frac{1}{2} \frac{\rho - 1}{\rho}} = L^f$.

The money demand equation is given by

$p^h = \frac{M^h}{\chi} \frac{1}{L^h} \frac{\delta}{1+\delta}$

Dividing this by the foreign equivalent leads to

$E = \frac{p^h}{p^f} = \frac{p^h(h)}{p^f(f)} = \frac{M^h}{M^f}$.

A.2 Proof of Proposition 3

Taking the differences of the linearized equations of home and foreign variables allows us to write these as a function of the exogenous wealth transfer dB.

1. $\widehat{\overline{p}}^h - \widehat{\overline{E}} - \widehat{\overline{p}}^f = \widehat{\overline{w}}^h - \widehat{\overline{E}} - \widehat{\overline{w}}^f = \frac{1}{2\rho} \frac{1}{n(1-n)} \frac{\delta}{1+\delta} \frac{dB}{\overline{C}_0^h}$,

2. $\widehat{\overline{C}}^h - \widehat{\overline{C}}^f = \frac{1+\rho}{2\rho} \frac{1}{n(1-n)} \frac{\delta}{1+\delta} \frac{dB}{\overline{C}_0^h}$,

3. $\widehat{\overline{L}}^h - \widehat{\overline{L}}^f = -\frac{1}{2} \frac{1}{n(1-n)} \frac{\delta}{1+\delta} \frac{dB}{\overline{C}_0^h}$,

4. $\widehat{\overline{E}} = \left[\hat{M}^h - \hat{M}^f\right] - \frac{1+\rho}{2\rho} \frac{1}{n(1-n)} \frac{\delta}{1+\delta} \frac{dB}{\overline{C}_0^h}$.

Adding the labor supply functions weighted by the country size and using the price levels leads to

$\widehat{\overline{L}}^w := n\widehat{\overline{L}}^h + (1-n)\widehat{\overline{L}}^f = -n\widehat{\overline{C}}^h - (1-n)\widehat{\overline{C}}^f = -\widehat{\overline{C}}^w$.

Since world production and world consumption has to be equal it follows that

$\widehat{\overline{L}}^w = \widehat{\overline{C}}^w = 0$.

The changes of consumption and labor are derived from

$\widehat{\overline{C}}^h = \widehat{\overline{C}}^w + (1-n)(\widehat{\overline{C}}^h - \widehat{\overline{C}}^f) = \frac{1+\rho}{2\rho}\frac{1}{n}\frac{\delta}{1+\delta}\frac{dB}{\overline{C}_0^h}$,

$\widehat{\overline{L}}^h = \widehat{\overline{L}}^w + (1-n)(\widehat{\overline{L}}^h - \widehat{\overline{L}}^f) = -\frac{1}{2}\frac{1}{n}\frac{\delta}{1+\delta}\frac{dB}{\overline{C}_0^h}$.

A.3 Proof for Short-term World Changes

Adding the consumption Euler equations weighted by the country size leads to

$\hat{C}^w = -\frac{\delta}{1+\delta}\hat{r}$.

Calculate the world long-term and short-term money demand functions

$\hat{M}^w := n\hat{M}^h + (1-n)\hat{M}^f = \widehat{\overline{C}}^w + n\widehat{\overline{p}}^h + (1-n)\widehat{\overline{p}}^f$ (long-term),

$\hat{M}^w + \frac{1}{\delta}\left(n\widehat{\overline{p}}^h + (1-n)\widehat{\overline{p}}^f\right) - \hat{C}^w = \left(\frac{\delta+1}{\delta}\right)\left(n\hat{p}^h + (1-n)\hat{p}^f\right) - \frac{\hat{r}}{1+\delta}$ (short-term).

Substituting the long-term relationship into the short-term one leads to

$\left(\frac{\delta+1}{\delta}\right)\hat{M}^w - \hat{c}^w = \left(\frac{\delta+1}{\delta}\right)\left(n\hat{p}^h + (1-n)\hat{p}^f\right) - \frac{\hat{r}}{1+\delta}$.

This relationship can be used to determine the short-term growth rates of world consumption in the three cases.

- sticky wages

  Use the labor supply to replace the short-term price changes

  $\left(\frac{\delta+1}{\delta}\right)\hat{M}^w - \hat{C}^w = \left(\frac{\delta+1}{\delta}\right)\left(-\hat{C}^w - \hat{L}^w\right) + \frac{\hat{C}^w}{\delta}$,

  and finally since $\hat{C}^w = \hat{L}^w$,

  $\hat{C}^w = -\hat{M}^w$.

- sticky retail prices

  retail prices do not change in the short-term, hence

  $\left(\frac{\delta+1}{\delta}\right)\hat{M}^w - \hat{C}^w = \frac{\hat{C}^w}{\delta}$ or

  $\hat{C}^w = \hat{M}^w$.

- sticky wholesale prices

  $\left(\frac{\delta+1}{\delta}\right)\hat{M}^w - \hat{C}^w = \left(\frac{\delta+1}{\delta}\right)\left(n\hat{p}^h + (1-n)\hat{p}^f\right) + \frac{\hat{C}^w}{\delta}$,

  and, hence, again

  $\hat{C}^w = \hat{M}^w$.

A.4 Dynamics under Sticky Retail Prices

Proposition 6 *Under sticky retail prices, money supply shocks give rise to an endogenous change in international net bond holdings given by*

$\frac{dB}{\bar{C}_0^h} = \frac{2\rho(1+\delta)}{(1+\rho)\delta} n\,(1-n)\left[\hat{M}^h - \hat{M}^f\right]$.

Changes in each country's consumption, production, exchange rates and terms of trade are given by

- *in the short-run*

  $\hat{C}^h = \hat{M}^h$,

  $\hat{L}^h = \hat{M}^w = n\hat{M}^h + (1-n)\hat{M}^f$,

  $\hat{E} = \left(1 + \frac{2\rho}{(1+\rho)\delta}\right)\left[\hat{M}^h - \hat{M}^f\right]$,

  $\hat{w}^h - \hat{E} - \hat{w}^f = -\frac{2\rho}{(1+\rho)\delta}\left[\hat{M}^h - \hat{M}^f\right]$,

  $\hat{r} = -\left(\frac{1+\delta}{\delta}\right)\hat{M}^w$,

- *in the long-run*

  $\widehat{\overline{C}}^h = (1-n)\left[\hat{M}^h - \hat{M}^f\right]$,

  $\widehat{\overline{L}}^h = -\frac{\rho}{(1+\rho)}(1-n)\left[\hat{M}^h - \hat{M}^f\right]$,

  $\widehat{\overline{E}} = 0$,

  $\widehat{\overline{p}}^h(h) - \widehat{\overline{E}} - \widehat{\overline{p}}^f(f) = \widehat{\overline{p}}^h(h) - \widehat{\overline{p}}^f(f) = \frac{1}{1+\rho}\left[\hat{M}^h - \hat{M}^f\right]$,

  $\widehat{\overline{w}}^h - \hat{E} - \widehat{\overline{w}}^f = \frac{1}{1+\rho}\left[\hat{M}^h - \hat{M}^f\right]$,

  $\hat{p}^h = n\hat{M}^h + (1-n)\hat{M}^f$.

Proof. We first subtract the foreign short-term equilibrium equations from their home counterparts using Lemma 3. We do not impose sticky retail prices at this stage because we will use these equations in the proofs for sticky wholesale prices and sticky wages. Therefore, we have

$\left(\hat{L}^h - \hat{L}^f\right) = -\rho\left[\left(\hat{p}^h - \hat{p}^f\right) + \left(\hat{p}^f(h) - \hat{p}^h(f)\right)\right]$ (demand),

$\left(\hat{C}^h - \hat{C}^f\right) - \left(\hat{L}^h - \hat{L}^f\right) + \frac{1}{n(1-n)}\frac{1}{1+\delta}\frac{dB}{\bar{C}_0^h} = \left[-\hat{p}^h(f) + \hat{p}^f(h) + \hat{E}\right]$ (budget constraint),

$\left(\hat{M}^h - \hat{M}^f\right) - \left(\hat{p}^h - \hat{p}^f\right) = \left(\hat{C}^h - \hat{C}^f\right) - \frac{1}{\delta}(\widehat{\overline{p}}^h - \widehat{\overline{p}}^f) + \frac{1}{\delta}(\hat{p}^h - \hat{p}^f)$ (money demand),

$\left(\hat{C}^h - \hat{C}^f\right) = \left(\widehat{\overline{C}}^h - \widehat{\overline{C}}^f\right)$(consumption Euler equation),

$\left(\hat{p}^h - \hat{p}^f\right) = -\left(\hat{C}^h - \hat{C}^f\right) - \left(\hat{L}^h - \hat{L}^f\right) + \left(\hat{w}^h - \hat{w}^f\right)$ (labor supply).

Additionally we need the difference between the long-term budget constraints and the long-term money demand equations for the reasons outlined in section 4. We use the fact that PPP always holds in the long-run (Lemma 1). Thus,

$\left(\widehat{\overline{C}}^h - \widehat{\overline{C}}^f\right) - \left(\widehat{\overline{L}}^h - \widehat{\overline{L}}^f\right) - \frac{1}{n(1-n)}\frac{\delta}{1+\delta}\frac{dB}{\bar{C}_0^h} = \left[-\widehat{\overline{p}}^h(f) + \widehat{\overline{E}} + \widehat{\overline{p}}^f(h)\right]$ (budget constraint),

$\left(\hat{M}^h - \hat{M}^f\right) - \widehat{\overline{E}} = \left(\widehat{\overline{C}}^h - \widehat{\overline{C}}^f\right)$(money demand),

$\left(\widehat{\overline{L}}^h - \widehat{\overline{L}}^f\right) = -\rho\left[-\widehat{\overline{p}}^h(f) + \widehat{\overline{E}} + \widehat{\overline{p}}^f(h)\right]$ (long-term demand).

Under the sticky retail price scenario, we know from the proof of Proposition 5 that the exchange rate does not change in the long-run ($\widehat{\overline{E}} = 0$). From the long-run money demand equation and the consumption Euler equation, we conclude that the change in both periods consumption is proportional to the change in the money supply

$\left(\widehat{\overline{C}}^h - \widehat{\overline{C}}^f\right) = \left(\hat{C}^h - \hat{C}^f\right) = \left(\hat{M}^h - \hat{M}^f\right)$.

Substituting this last equation and the long-run demand equation into the long-run budget constraint we arrive at

$\left(\hat{M}^h - \hat{M}^f\right) - \frac{1}{n(1-n)}\frac{\delta}{1+\delta}\frac{dB}{\bar{C}_0^h} = (1-\rho)\left[-\widehat{\overline{p}}^h(f) + \widehat{\overline{E}} + \widehat{\overline{p}}^f(h)\right]$.

Using the expression for the long-term change in the terms of trade that is given in Proposition 3, we can derive the change in net international bond holdings.

$\frac{dB}{\bar{C}_0^h} = \frac{2\rho(1+\delta)}{(1+\rho)\delta} n\,(1-n)\left(\hat{M}^h - \hat{M}^f\right)$.

Substituting this equation into the equations of Proposition 3 we can calculate all the long-run changes of the variables.

For the differences in the short-run, we see from the short-term demand function that under sticky retail prices their is no substitution between foreign and home goods. Thus,

$\left(\hat{L}^h - \hat{L}^f\right) = 0$.

Using the relative short-term changes in consumption, price levels and production it is easy to see from the labor supply that

$\left(\hat{w}^h - \hat{w}^f\right) = \left(\hat{M}^h - \hat{M}^f\right)$.

We can now derive the short-term change in the exchange rate given the short-term budget constraint .

Having derived the differences in short-run changes abroad and at home we use the change in world aggregates, given by Appendix A.3 to calculate the changes in the individual countries. The methodology is the same as in the proof of Proposition 3.■

A.5 Dynamics under Sticky Wholesale Prices

Proposition 7 *Under sticky wholesale prices money supply shocks give rise to an endogenous change in international net bond holdings given by*

$\frac{dB}{\bar{C}_0^h} = \frac{2(\rho-1)(1+\delta)}{(\rho+1)\delta+2} n(1-n)\left[\hat{M}^h - \hat{M}^f\right]$.

Changes in each country's consumption, production, exchange rates and terms of trade are given by

- *in the short- run*

$$\hat{C}^h = \underbrace{\frac{\rho\left[\delta(\rho+1)+2n\right]-(1-n)\left[(1+\rho)\delta\right]}{\rho\left[(\rho+1)\,\delta+2\right]}}_{<1}\hat{M}^h + (1-n)\,\underbrace{\frac{2\rho+(\rho+1)\delta}{\rho\left[(\rho+1)\delta+2\right]}}_{<1}\hat{M}^f,$$

$$\hat{L}^h = \underbrace{\frac{\rho\left[\delta(\rho+1)+2n\right]+(1-n)\left[2\rho^2\right]}{\rho\left[(\rho+1)\delta+2\right]}}_{>1}\hat{M}^h \underbrace{-(1-n)\frac{2\,(\rho-1)}{(\rho+1)\delta+2}}_{<0}\hat{M}^f,$$

$$\hat{E} = \tfrac{\delta(\rho+1)+2\rho}{\rho((1+\rho)\delta+2)}\left[\hat{M}^h-\hat{M}^f\right] = \widehat{\overline{E}},$$

$$\hat{p}^h(h)-\hat{E}-\hat{p}^f(f) = -\hat{E},$$

$$\hat{w}^h-\widehat{E}-\hat{w}^f = \tfrac{2\rho^2(\delta+1)+(\rho-1)\delta}{\rho((\rho+1)\delta+2)}\left[\hat{M}^h-\hat{M}^f\right],$$

$$\hat{C}^w = \hat{L}^w = \hat{M}^w,$$

$$\hat{r} = -\left(\tfrac{1+\delta}{\delta}\right)\hat{M}^w,$$

- *in the long-run*

$$\widehat{\overline{C}}^h = \tfrac{1+\rho}{\rho}\tfrac{(\rho-1)\delta}{(\rho+1)\delta+2}(1-n)\left[\hat{M}^h-\hat{M}^f\right],$$

$$\widehat{\overline{L}}^h = -\tfrac{(\rho-1)\delta}{(\rho+1)\delta+2}(1-n)\left[\hat{M}^h-\hat{M}^f\right],$$

$$\left[\widehat{\overline{p}}^h(h)-\widehat{\overline{E}}-\widehat{\overline{p}}^f(f)\right] = \left[\widehat{\overline{w}}^h-\widehat{\overline{E}}-\widehat{\overline{w}}^f\right] = \tfrac{(\rho-1)\delta}{\rho((\rho+1)\delta+2)}\left[\hat{M}^h-\hat{M}^f\right],$$

$$\widehat{\overline{E}} = \left(\tfrac{(\rho+1)\delta+2\rho}{\rho((\rho+1)\delta+2)}\right)\left[\hat{M}^h-\hat{M}^f\right] = \hat{E},$$

$$\widehat{\overline{C}}^w = \widehat{\overline{L}}^w = 0.$$

Proof. We again use the differences of the short and long-run changes derived at the beginning of the proof for sticky retail prices. Under sticky wholesale prices, we can make use of the results that PPP also holds in the short-run and that the exchange rate immediately reaches its long-term value ($\hat{E} = \widehat{\overline{E}}$).

Substituting the goods and money demand equation into the budget constraint, both for the long and short-run we derive

$$\left(\hat{M}^h-\hat{M}^f\right)-\hat{E} = (\rho-1)\hat{E} - \tfrac{1}{n(1-n)}\tfrac{1}{1+\delta}\tfrac{dB}{\bar{C}_0^h} \text{ (short-term budget)},$$

$$\left(\hat{M}^h-\hat{M}^f\right)-\hat{E} = \tfrac{1+\rho}{2\rho}\tfrac{1}{n(1-n)}\tfrac{1}{1+\delta}\tfrac{\delta dB}{\bar{C}_0^h} \text{ (long-term)}.$$

From these two equations we derive the change in the international bond holdings and the change in the exchange rate.

$$\hat{E} = \left(\tfrac{\delta(\rho+1)+2\rho}{\rho((1+\rho)\delta+2)}\right)\left[\hat{M}^h-\hat{M}^f\right],$$

$$\tfrac{dB}{\bar{C}_0^h} = \tfrac{2(\rho-1)}{(\rho+1)\delta+2}n(1-n)\left[\hat{M}^h-\hat{M}^f\right](1+\delta).$$

Just like in the sticky retail price scenario we can derive all the long-run changes using Proposition 3.

We can derive the short-term difference in production from the short-term demand equation using the expression for the exchange rate. Thus,

$\hat{L}^h - \hat{L}^f = \left(\frac{\delta(\rho+1)+2\rho}{(1+\rho)\delta+2}\right)\left[\hat{M}^h - \hat{M}^f\right]$.

The short-term difference in consumption can then be read from the short-term budget constraint.

$\hat{C}^h - \hat{C}^f = \left(\frac{\rho^2-1}{\rho((1+\rho)\delta+2)}\delta\right)\left[\hat{M}^h - \hat{M}^f\right]$.

Finally, the relative change in wages can be calculated using the labor supply equation.

$\hat{w}^h - \hat{E} - \hat{w}^f = \left(\frac{2\rho^2(\delta+1)+\delta(\rho-1)}{\rho((1+\rho)\delta+2)}\right)\left[\hat{M}^h - \hat{M}^f\right]$.

Having derived the differences in short-run changes abroad and at home, we use the change in world aggregates, given by Appendix A.3 to calculate the changes in the individual countries. The methodology is the same as in the proof of Proposition 3.■

A.6 Dynamics under Sticky Wages with Monopsonistic Firms

Proposition 8 *Under sticky wages money supply shocks give rise to an endogenous change in international net bond holdings given by*

$\frac{dB}{\bar{C}_0^h} = -\frac{2(\rho-1)(1+\delta)}{(1+\rho)\delta+2}n(1-n)\left[\hat{M}^h - \hat{M}^f\right]$.

Changes in each country's consumption, production, exchange rates and terms of trade are given by

- *in the short- run*

$$\hat{C}^h = \underbrace{-\left(n + (1-n)\frac{\rho-1}{\rho}\frac{(\rho+1)\delta}{(\rho+1)\delta+2}\right)}_{<0}\hat{M}^h \underbrace{-(1-n)\left(1 - \frac{\rho-1}{\rho}\frac{(\rho+1)\delta}{(\rho+1)\delta+2}\right)}_{<0}\hat{M}^f,$$

$\hat{L}^h = -\hat{M}^h$,

$\hat{E} = \left(1 + \frac{\rho-1}{\rho}\frac{(\rho+1)\delta}{(\rho+1)\delta+2}\right)\left[\hat{M}^h - \hat{M}^f\right] = \widehat{\overline{E}}$,

$\hat{p}^h(h) - \hat{E} - \hat{p}^f(f) = \frac{1}{\rho}\left[\hat{M}^h - \hat{M}^f\right]$,

$\hat{w}^h - \hat{E} - \hat{w}^f = \left(1 + \frac{\rho-1}{\rho}\frac{(\rho+1)\delta}{(\rho+1)\delta+2}\right)\left[\hat{M}^h - \hat{M}^f\right]$,

$\hat{L}^w = \hat{c}^w = -\hat{M}^w$,

$\hat{r} = \left(\frac{1+\delta}{\delta}\right)\hat{M}^w$,

- *in the long-run*

$\widehat{\overline{C}}^h = -\frac{\rho-1}{\rho}\frac{(\rho+1)\delta}{(\rho+1)\delta+2}(1-n)\left[\hat{M}^h - \hat{M}^f\right]$,

$\widehat{\overline{L}}^h = \frac{(\rho-1)\delta}{(\rho+1)\delta+2}(1-n)\left[\hat{M}^h - \hat{M}^f\right]$,

$\widehat{\overline{E}} = \left(1 + \frac{\rho-1}{\rho}\frac{(\rho+1)\delta}{(\rho+1)\delta+2}\right)\left[\hat{M}^h - \hat{M}^f\right] = \hat{E}$,

$\left[\widehat{\overline{p}}^h(h) - \widehat{\overline{E}} - \widehat{\overline{p}}^f(f)\right] = \left[\widehat{\overline{w}}^h - \widehat{\overline{E}} - \widehat{\overline{w}}^f\right] = -\frac{(\rho-1)}{\rho(\rho+1)\delta+2\rho}\left[\hat{M}^h - \hat{M}^f\right]$,

$\widehat{\overline{L}}^w = \widehat{\overline{C}}^w = 0$.

Proof. We again use the differences in short-term changes that have been derived at the beginning of the proof for changes under sticky retail prices. Just like under sticky wholesale prices, we can make use of the facts that PPP holds in the short-run and that the exchange rate does not overshoot (Proposition 5). The crucial difference under sticky wages is that the scale of production is determined by the labor supply rather than by the demand.

Using the differences in the long-run money demand equation and the short-run labor supply equations, we can derive the short-term change in labor. Thus,

$\left(\hat{M}^h - \hat{M}^f\right) = \left[\hat{c}^h - \hat{c}^f\right] + \hat{E} = -\left(\hat{L}^h - \hat{L}^f\right)$.

The short-run terms of trade change can be read from the difference in the short-term goods demand equation. Thus,

$\left(\hat{M}^h - \hat{M}^f\right) = \rho\left(\hat{p}^h(h) - \widehat{E} - \hat{p}^f(f)\right)$.

The difference between the two short-term budget constraints leads to

$\left(\hat{C}^h - \hat{C}^f\right) = -\frac{\rho-1}{\rho}\left(\hat{M}^h - \hat{M}^f\right) - \frac{1}{n(1-n)}\frac{1}{1+\delta}\frac{dB}{\bar{c}_0^h}$.

The difference between the long-run budget constraints can be written as

$\left(\widehat{\overline{C}}^h - \widehat{\overline{C}}^f\right) = \frac{1+\rho}{2\rho}\frac{1}{n(1-n)}\frac{\delta}{1+\delta}\frac{dB}{\bar{c}_0^h}$.

We derive the change in the bond holdings and the change in consumption, by substituting the last two equations into each other. Thus,

$\frac{dB}{\bar{C}_0^h} = -\frac{2(\rho-1)(1+\delta)}{(1+\rho)\delta+2}n(1-n)\left[\hat{M}^h - \hat{M}^f\right]$,

$\widehat{\overline{C}}^h - \widehat{\overline{C}}^f = -\left(\frac{\rho-1}{\rho}\frac{1}{\delta+2\frac{\rho}{\rho+1}}\delta\right)\left[\hat{M}^h - \hat{M}^f\right]$.

Just like in the sticky price scenarios, the long-term changes can now be calculated using Proposition 3.

The change in the exchange rate can be read from the long-run money demand equation using the change in consumption. It is

$\widehat{\overline{E}} = \left(1 + \frac{\rho-1}{\rho}\frac{1}{\delta+2\frac{\rho}{\rho+1}}\delta\right)\left[\hat{M}^h - \hat{M}^f\right]$.

Having derived the differences in short-run changes abroad and at home, we use the change in world aggregates, given by Appendix A.3 to calculate the changes in the individual countries. The methodology is the same as in the proof of Proposition 3.■

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