DEPARTMENT OF ECONOMICS

Working Paper

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Working Paper No. 2003-12

ISSN 1396-2426

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International Spill-over Effects of Labour Market Rigidities*

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July 29, 2003

Abstract

This paper analyses the implications of real wage rigidities in a stochastic two-country general equilibrium model. It is shown how real wage rigidities in one country affect welfare in both countries. Assuming that the choice of whether or not to adopt flexible wages is in the hands of labour unions within each country, it is found that wages will be flexible in either no, one or both countries. Hence, even in this symmetric model flexible wages in one country and rigid wages in the other may be an equilibrium. Since there are international spillover effects of the choice of wage setting regime, the utilitarian solution is also considered. Interestingly, this does not necessarily entail more real wage flexibility than in the Nash equilibrium.

JEL Classification: E24, E32, F41, F42

Keywords: Real Wage Rigidity, Labour Market Reforms, Spill-over Effects, Open Economy Macroeconomics

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*Comments and suggestions by Torben M. Andersen, Roel M.W.J. Beetsma and participants at the Spring Meeting for Young Economists 2003 in Leuven are gratefully acknowledged.

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1 Introduction

Crucial for how shocks are transmitted between countries is the structure of the labour markets. In Europe there has been a debate on the welfare costs associated with real wage rigidity. Cultural and linguistic barriers will probably prevent a significant rise in European labour market mobility from taking place, and even between regions within the same country the mobility of labour is low, see e.g. Decressin and Fatas (1994). It is widely believed that real wages in Europe are quite rigid, but the degree of real wage flexibility differs considerably between countries in Europe. For a quantification of the degree of real rigidity on the European labour markets see e.g. Berthold et al. (1999), who also discuss how the adoption of a common European currency will affect wage rigidities.

The first objective of this paper is to analyse how the international transmission mechanism is affected by real wage rigidity. Subsequently we perform a rigorous welfare analysis to examine how welfare is affected both by the domestic and the foreign labour market structures. Assuming that the degree of real wage rigidity is determined by labour unions subject to a potential exogenous cost associated with real wage flexibility, we show that even in a world of fully symmetric countries, we can have asymmetric equilibria with flexible wages in one country and a rigid real wages in the other country. This is interesting since in the public debate it is often argued that once a process of labour market reform is undertaken in some European countries, the rest will follow after. Our model suggests that this need not be the case. Finally, we analyse whether an internationally coordinated labour market policy will be welfare improving. We show that this is not necessarily the case.

We will set up a two-country general equilibrium model with stochastic productivity shocks. The model is within the framework often referred to as new open economy macroeconomics. This is a framework that has been applied extensively for the study of stabilization policies, see e.g. Andersen and Spange

(2002) for an analysis of fiscal policy and Obstfeld and Rogoff (2000) for an analysis of monetary policy. A particularly nice feature of the present model is that with log-normally distributed productivity shocks all endogenous variables in the model will be log-normally distributed, and we will be able to obtain an exact solution to the model.

In our model the issue of stabilization policy is disregarded. Instead the important contribution of the present paper is to endogenize the choice of wage setting regime by granting the labour unions permission to decide whether real wages are to be flexible or rigid. If wages are flexible, the unions are able to set wages contingent on the state of the economy resulting from the random productivity shocks. However, the possibility of doing so comes at the cost of having to verify the state of the economy, i.e. the level of productivity in both countries. This is assumed to require some effort which is carried out by the workers.[1] We assume that the labour unions adopt the wage setting procedure that maximizes the expected utility of its members.

The way in which the productivity shocks affect the economy depends critically on whether wages are flexible or rigid. Since disturbances are transmitted across countries through international trade, the wage setting regime also affects trading partners. By specifying a fully micro-founded general equilibrium model we are able to analyse how labour market rigidities affect the domestic as well as the foreign economy. Moreover we can conduct a consistent welfare analysis allowing us to establish conditions under which the different labour market regimes will be chosen by the welfare maximizing unions. Thereby we distinguish ourselves from the vast majority of the literature dealing with wage rigidities and labour market reform, see e.g. Sibert and Sutherland (2000) and Calmfors (2001).

By analysing how labour market structures in one country affect trading

[1] Note the similarity to the litterature on menu cost, see eg. Ball and Romer (1991), except that here the cost is related to the acquisition of information.

partners, our paper is related to the paper by Davis (1998). He sets up a two country model to analyse the interdependencies between a flex wage country and a country with a binding minimum wage. Another interesting paper is the one by Benigno (2003). He analyses how optimal monetary policy within a monetary union is affected by asymmetries in the degree of price rigidity across member countries. Beetsma and Jensen (2002) extend the model of Benigno (2003) to analyse the implications for fiscal policy. Finally Erlandsson (2002) analyses how monetary union affects the incentive of the workers to adopt flexible nominal wages.

We find that real wage flexibility in the domestic country unambiguously leads to lower consumption variance in both countries compared with the case of rigid domestic wages. This is beneficial for the consumers. However, the wage setting regime also affects expected consumption. We show that whether expected counsumption will be highest under flexible or rigid wages depends on the parameters of the model. Abstracting from the cost of state verification, domestic workers prefer domestic wages to be flexible since the welfare gain from lower consumption variance more than outweights the possible loss from lower expected consumption. However, the potentially positive effect of domestic wage rigidity on the expected level of foreign consumption may welfare-dominate the negative effect of higher foreign consumption variance. Hence foreign agents may prefer domestic wages to be rigid even though wage rigidity adds to consumption volatility.

Through its effect on foreign welfare, the domestic wage setting regime affects the incentive of the foreign unions to choose flexible wages. We find that foreign unions are more likely to adopt flexible wages if domestic wages are rigid than if they are flexible. This implies that if the cost of verifying the level of productivity is within a certain interval, the unions in one country will choose flexible wages whereas the unions in the other country will choose rigid wages.

The fact that asymmetric equilibria are possible in this purely symmetric model may come as a surprise. However, when the foreign country has already adopted flexible wages, the additional reduction in volatility that can be gained though real wage flexibility in the domestic country is smaller than if foreign wages had been rigid. Hence, the incentive for one country to adopt flexible wages is decreasing in the degree of real wage flexibility in its trading partners. This result has important predictive suggestions for the outcome of the ongoing process of labour market reforms in Europe, since it implies that the current situation with a high degree of real wage rigidity in some countries and more flexibility in others may in fact be a long run equilibrium.

Since wage setting in one country affects welfare of the other country, the labour market equilibrium is not necessarily equivalent with the utilitarian solution. Hence there may be gains from pursuing an internationally coordinated labour market policy. We show that whether this is indeed the case depends on the cost of state verification. Interestingly, the utilitarian solution does not nessecarily entail more real wage flexibility than the Nash equilibrium. Moreover, we find that the asymmetric equilibrium with flexible wages in one country and rigid wages in the other may be the solution that maximizes the joint welfare of the two countries and hence it may be the outcome of the coordinated policy.

This paper is comprised of six parts. Section 2 sets up the model and derives the supply and demand relations. Section 3 characterizes the equilibrium. Section 4 shows how welfare is affected by real wage rigidity at home and abroad, and section 5 discusses the resulting equilibria in wage setting regimes. Section 6 concludes.

2 Two country model

Consider a two country stochastic general equilibrium model. The two countries that will be denoted home and foreign specialize in production of different commodities, which are tradeables. We assume that goods markets are competitive and that prices are fully flexible. In each country there is a continuum of workers indexed by $[0;1]$, and as in the model of Obstfeld and Rogoff (2000), each worker acts as a monopolistic supplier of a distinctive variety of labour services. For each type of labour there is a union setting the real wage for that particular variety. As described in detail below, wages may be set either with or without knowledge of the current exogenously given level of productivity. The workers subsequently supply the amount of labour demanded by the firms at the given level of productivity. Since the real marginal consumption value of the wage exceeds the marginal disutility of effort, this policy will be optimal for sufficiently small shocks even when wages are set without knowledge of the shocks.[2] In the following we will focus on a single period only since the structure of the model implies that no additional insights could be gained by setting up a fully intertemporal model. The two countries are symmetric, and all foreign variables are denoted by an asterisk.

Firms

The representative domestic firm produces subject to a decreasing returns to scale production function

$$Y = Z\frac{1}{\beta}L^{\beta} \quad , \quad 0 < \beta < 1 \tag{1}$$

where Y denotes production, L is labour input, and Z is the productivity variable. It is assumed that $\frac{Z}{\overline{Z}}$ (current productivity Z relative to its steady state or trend value $\overline{Z}$) is log normally distributed $N(0, \sigma^2)$. Productivity shocks are uncorrelated across countries, and we assume that productivity is observable to firms but not to the consumers. Employment is defined as a composite labour input specified over a continuum of subtypes, i.e.

$$L = \left[\int_0^1 L\left(i\right)^{\frac{\theta-1}{\theta}}\,di\right]^{\frac{\theta}{\theta-1}} , \quad \theta > 1 \tag{2}$$

[2]See Corsetti and Pesenti (2001) for a discussion of the voluntary particiation constraint.

Demand for labour of a given type i is given as

$$L(i) = \left(\frac{W(i)}{W}\right)^{-\theta} L$$

and the costs of acquiring one unit of the composite labour input can be written

$$W = \left[\int_0^1 W(i)^{1-\theta} di\right]^{\frac{1}{1-\theta}}$$

Firms are price and wage takers, and hence, labour demand is given by

$$ZL^{\beta-1} = \frac{W}{P} \tag{3}$$

where W is the wage per unit of labour and P is the price of domestically produced goods.

Households

Each type of labour i has a representative agent with a utility function depending positively on the private consumption bundle (B) and negatively on labour supply (L) and the effort spend on state verification (V), i.e.

$$U(i) = \frac{1}{1-\epsilon} B(i)^{1-\epsilon} - \lambda L(i) - V(i) \quad ; \quad \epsilon > 0, \lambda > 0 \tag{4}$$

The private consumption bundle is defined over the consumption of the domestic (C) and the foreign (C^*) commodity, respectively, i.e.

$$B(i) = \frac{1}{\alpha^\alpha (1-\alpha)^{1-\alpha}} C(i)^\alpha \left(C(i)^*\right)^{1-\alpha} \quad ; \quad \alpha \geq \frac{1}{2}$$

The price index Q is defined as the minimum cost of acquiring one unit of the consumption bundle, i.e.[3]

$$Q = P^\alpha (P^*)^{1-\alpha}$$

The unit elasticity of substitution between domestic and foreign goods implies that even in an intertemporal version of the model with an internationally traded

[3]The foreign price index is given as $Q^* = (P^*)^\alpha P^{1-\alpha}$.

bond, the trade balance would be zero. Hence, starting with zero net foreing assets the situation would keep repeating itself, implying that we do not leave out any intertemporal effects by focusing on only one period. The assumption that $\alpha \geq \frac{1}{2}$ captures a home-bias in preferences, that is, the preference for domestically produced goods is in the aggregate always at least as strong as for foreign produced goods[4]. If I denotes disposable income it follows from utility maximization that demands are given as

$$\begin{aligned} C(i) &= \alpha \frac{I(i)}{P} \\ C(i)^* &= (1-\alpha)\frac{I(i)}{P^*} \end{aligned}$$

The private consumption bundle can thus be written

$$B(i) = \frac{I(i)}{Q}$$

and disposable private income is

$$I(i) = W(i)\,L(i) + \Pi(i)$$

We assume a right to manage structure meaning that wages are set by unions and the workers are subsequently contracted to supply any amount of labour that the firms demand at this wage. We assume that for each type of labour, there is a union setting the real wage $R(i) \equiv \frac{W(i)}{Q}$ for that particular labour type to maximize its expected utility. Later we will show that the optimal wage depends on the realizations of Z and Z^*. Since these shocks are not observable to the unions, they must figure out how to verify them if they want wages to be state dependent, i.e. if they want to set flexible wages. One possibility for the unions would be simply to ask the firms. However, since firms are profit maximizers and profits depend negatively on the real wage, the firms will have

[4]If this assumption is not fulfilled, a domestic productivity shock may reduce the terms of trade, and vice versa for foreign productivity shocks. This case is implausible and therefore ruled out.

an incentive to report the productivity level that will lead workers to demand the lowest possible wage. Hence, the firms cannot credibly inform the agents about the true state of the world.[5] Instead we assume that the unions have the opportunity to employ a team of inspectors that are able to verify the true level of productivity with certainty. Since the optimal wage in a country depends on both Z and Z^*, the unions in one country has to hire inspectors to work in both countries if they want to set state contingent wages. Hence it is reasonable to assume that state verification is costly. We assume that the decision of whether or not to verify the state is made jointly by the unions within a country, such that either all or no unions have knowledge of Z and Z^*.[6] The cost of state verification is equal for all consumers, implying that if wages are flexible they all suffer the same utility loss which we denote Ψ. The way of modelling this cost is a shortcut, and Ψ can be interpreted as the disutility of the work effort that is spent on state verification by the inspectors. Note that Ψ covers the cost of verifying both the domestic and foreign state. The cost of state verification, V, is then given as

$$V = \begin{cases} \Psi > 0 \text{ if wages are flexible} \\ 0 \text{ if wages are rigid} \end{cases}$$

To sum up, the timing of the model is as follows: First the decision is made by the unions whether to verify the state or not. Subsequently the level of productivity is determined by nature and revealed to the firms but not to the workers. Then, if state verification has been chosen, the team of inspectors enters the firms and submits a report to the unions stating the level of productivity in

[5] One might, however, imagine a repeated game in which the firm could build up a reputation for truthtelling, see eg. Tirole (1988) for an introduction to dynamic games.

[6] Townsend (1979) studies optimal contracts under the assumption of asymmetric information and costly state verification. Contrary to us he assumes that the informed player decides whether or not the state should be verified. Under this assumption he finds that the decision of state verification depends on the actual state of the economy. In future research it would be interesting to analyse how our results are affected by the exact process of state verification.

domestic and foreign firms, respectively. The next step is the determination of wages by the unions. We assume that the unions use all available information to set the wage that maximize expected utility of its members. Hence, what distinguishes wage setting with or without state verification is that in the presence of state verification, the values of Z and Z^* are in the information sets of the unions. Since state verification allows the unions to adjust wages to the economic condition we will refer to wages that are set under state verification as flexible wages, whereas without state verification wages are said to be rigid. After wages have been set, the firms decide how much labour to employ, and finally output, prices and consumption are determined.

For all variables and coefficients, we will use superscripts to refer to the prevailing procedure of wage setting whenever this is relevant. If the superscript consists of one letter only, this letter will refer to the wage setting regime in the domestic country if the variable or coefficient is not denoted by an asterisk, and otherwise to the wage setting regime in the foreign country. If the superscript consists of two letters, these letters refer to the wage setting regimes in the domestic and the foreign country, respectively. The possible letters are f and r, denoting the cases of flexible and rigid wages, respectively. The definition of the labour index (2) implies that the real wage is determined by the first order conditions

$$R^r = \frac{\lambda\theta}{\theta-1}\frac{E(L)}{E(B^{-\epsilon}L)} \tag{5}$$

$$R^f = \frac{\lambda\theta}{\theta-1}B^{\epsilon} \tag{6}$$

where, in accordance with our use of superscripts, R^r is the real wage in case of rigid wages and R^f is under flexible wages. Note that with rigid wages, wages are pre-set based on expectations, whereas with flexible wages, wages are set based on actual realizations. Since the wage is the same for all i we have dropped the indexing variable. Since B will be shown to be a function of Z and Z^*, R^f is a function of Z and Z^*. Hence, state verification is necessary if wages are going to be flexible.

In the following a lower case letter will denote the logarithm of the corresponding upper case letter[7]. By exploiting the properties of the log-normal distribution, the following relation between wagess with and without state verification can be derived

$$r^r = Er^f + rp$$

where

$$rp = -\frac{1}{2}\epsilon^2 Var\left(b\right) + \epsilon Cov\left(b, l\right)$$

This term can be interpreted as a risk premium demanded by workers with rigid wages to compensate for the fact that they are not able to adjust labour supply to the economic conditions. Holding everything else equal, higher consumption variance increases the expected marginal value of consumption due to Jensens inequality. This leads the workers to demand lower wages, thereby increasing labour demand and hence income, which allows them to consume more. Oppositely, a positive covariance between consumption and employment means that the workers are required to work the most when their marginal utility of consumption is low. This leads them to demand higher wages. With fixed real wages, consumption and employment are perfectly correlated, and the risk premium can be rewritten as

$$rp = \left(\epsilon - \frac{1}{2}\epsilon^2\right) Var\left(b\right)$$

implying that

$$sign\left(rp\right) = sign\left(2 - \epsilon\right)$$

If the agents are relatively risk averse, i.e. if $\epsilon > 2$, the consumption-variance effect is dominating, implying that the risk premium is negative. Oppositely, if $\epsilon < 2$ the effect of the positive covariance between consumption and labour

[7]For the terms of trade we define $\tau = \log \Gamma$

dominates the consumption-variance effect, and hence the risk premium is positive.

Supply and demand

In equilibrium disposable income is given as

$$I = WL + \Pi = PY$$

Hence, consumption is give as

$$B = \Gamma^{1-\alpha} Y \tag{7}$$

where $\Gamma \equiv \frac{P}{P^*}$ denotes the terms of trade of the domestic country. The equilibrium condition for the domestic product market or the aggregate demand relation reads

$$Y = \alpha Y + (1-\alpha)\,\Gamma^{-1} Y^*$$

Rearranging, the aggregate demand relation can be written

$$\Gamma = \frac{Y^*}{Y} \tag{8}$$

Combining labour demand (3) with the wage setting relations (5) and (6) we have the following aggregate supply relations under flexible and rigid wages respectively

$$Y = \left(\beta^{\frac{1-\beta}{\beta}}\left(\frac{\lambda\theta}{\theta-1}\right)\right)^{\frac{\beta}{\beta(1-\epsilon)-1}} Z^{\frac{1}{1-\beta(1-\epsilon)}}\,\Gamma^{\frac{\beta(1-\epsilon)(1-\alpha)}{1-\beta(1-\epsilon)}} \text{ if wages are flexible} \tag{9}$$

$$Y = Z^{\frac{1}{1-\beta}}\beta^{-1} R^{\frac{-\beta}{1-\beta}}\,\Gamma^{\frac{\beta(1-\alpha)}{1-\beta}} \text{ if wages are rigid} \tag{10}$$

A nice characteristic of the model is that everything is linear in logs, implying that we will not rely on any approximations. Moreover, with jointly log-normally distributed productivity shocks all variables in the model will follow a log-normal distribution. Remembering that a lower case letter denotes the logarithm of the corresponding upper case letter we have that the domestic supply relation can be written

$$y^i = \eta^i + \eta^i_{sz} z + \eta^i_{s\tau} \tau \quad , i = \{f, r\}$$

where

$$\begin{aligned}
\eta^f &\equiv \frac{\beta}{\beta(1-\epsilon)-1} \log\left(\beta^{\frac{1-\beta}{\beta}} \frac{\lambda\theta}{\theta-1}\right) \quad ; \quad \eta^r = -\log\beta - \frac{\beta}{1-\beta} r^r \\
\eta^f_{sz} &\equiv (1-\beta(1-\epsilon))^{-1} > 0 \ ; \quad \eta^r_{sz} = (1-\beta)^{-1} > 0 \\
\eta^f_{s\tau} &\equiv (1-\beta(1-\epsilon))^{-1} \beta(1-\alpha)(1-\epsilon) \lesseqgtr 0 \quad ; \quad \eta^r_{s\tau} = (1-\beta)^{-1} \beta(1-\alpha) > 0
\end{aligned}$$

Considering the partial effects of the variables determining supply, we find that higher productivity always increases supply. If wages are rigid, an increase in the terms of trade, meaning that domestic goods become relatively more expensive, increases supply since it corresponds to a higher markup over wages. However, if wages are flexible, an increase in the terms of trade decreases (increases) supply if $\epsilon > 1$ ($\epsilon < 1$) since the implied increase in private consumption induces a decrease (increase) in labour supply. Similarly the foreign supply relation can be written

$$y^{*i} = \eta^{*i} + \eta^{*i}_{sz} z^* + \eta^{*i}_{s\tau} \tau \quad , i = \{f, r\}$$

where

$$\eta^{*i} = \eta^i \quad ; \quad \eta^{*i}_{sz} = \eta^i_{sz} \quad ; \quad \eta^{*i}_{s\tau} = -\eta^i_{s\tau} \quad , i = \{f, r\}$$

Note that the coefficient to the terms of trade has the opposite sign to that of the home country, for the obvious reason that this is a relative price.

Finally the aggregate demand relation can be written

$$\tau = y^* - y$$

Welfare

It is shown in appendix A that expected utility can be written as

$$EU = \left(\frac{1}{1-\epsilon} - \frac{\beta(\theta-1)}{\theta}\right) E\left(B^{1-\epsilon}\right) - \Psi \tag{11}$$

By exploiting the log-normality of B we can rewrite

$$E\left(B^{1-\epsilon}\right) = \exp\left\{(1-\epsilon)\,Eb + \frac{(1-\epsilon)^2}{2} Var\,(b)\right\}$$

Alternatively we can write

$$E\left(B^{1-\epsilon}\right) = \left[E\,(B)\right]^{1-\epsilon} \cdot \exp\left\{-\frac{(1-\epsilon)\,\epsilon}{2} Var\,(b)\right\} \tag{12}$$

So expected utility can be evaluated by looking at expected consumption and consumption variance. Note that

$$sign\left(\frac{1}{1-\epsilon} - \frac{\beta\,(\theta-1)}{\theta}\right) = sign\,(1-\epsilon)$$

Hence

$$\frac{\partial E\,(U)}{\partial E\,(B)} > 0 \quad ; \quad \frac{\partial E\,(U)}{\partial Var\,(b)} < 0$$

So welfare is increasing in expected counsumption and decreasing in consumption variance.

3 Equilibrium

In the following we will analyse the equilibrium of the log-linearized model. As shown in appendix B, there exists an equilibrium of the form

$$\begin{aligned}
\tau^{ij} - E\tau^{ij} &= \phi^{ij}_{\tau z} z + \phi^{ij}_{\tau z^*} z^* \\
l^{ij} - El^{ij} &= \phi^{ij}_{lz} z + \phi^{ij}_{lz^*} z^* \\
y^{ij} - Ey^{ij} &= \phi^{ij}_{yz} z + \phi^{ij}_{yz^*} z^* \\
b^{ij} - Eb^{ij} &= \phi^{ij}_{bz} z + \phi^{ij}_{bz^*} z^*
\end{aligned}$$

Table 1 summarizes information on the shock-coefficients in the equilibrium relations given above. The content of the second line of the table refers to the procedure of wage setting in the domestic and foreign country, respectively, so these are the superscripts of the associated shock-coefficients. For a given wage setting procedure in the domestic country, the sign of a coefficient is independent of whether foreign real wages are flexible of rigid. Note that when domestic wages are flexible, the parameter ϵ capturing labour supply responses (see(9)) turns out to be critical for the way the home country is affected by shocks. Hence, for ff and fr we consider the cases of $\epsilon < 1$ and $\epsilon > 1$ seperately.

Table 1: Signs of shock-coefficients

	$\epsilon < 1$	$\epsilon > 1$	$\epsilon \lesseqgtr 1$
coefficient	ff or fr	ff or fr	rf or rr
$\phi^{ij}_{\tau z}$	<0	<0	<0
$\phi^{ij}_{\tau z^*}$	>0	>0	>0
ϕ^{ij}_{lz}	>0	<0	>0
$\phi^{ij}_{lz^*}$	>0	<0	>0
ϕ^{ij}_{yz}	>0	>0	>0
$\phi^{ij}_{yz^*}$	>0	<0	>0
ϕ^{ij}_{bz}	>0	>0	>0
$\phi^{ij}_{bz^*}$	>0	>0	>0

Consider a domestic supply shock ($z > 0$). This tends to increase domestic production and consumption and to lower the terms of trade. If the substitution effect dominates the income effect, ($\epsilon < 1$), the unexpectedly high level of productivity leads to an increase in labour supply, whereas the opposite is the case for $\epsilon > 1$. The effect of a foreign productivity shock runs entirely through the terms of trade. A foreign shock ($z^* > 0$) improves the terms of trade, which increases (decreases) domestic employment and output for $\epsilon < 1$ ($\epsilon > 1$). When wages are rigid, the effect of shocks on activity is driven entirely by the firms supply decisions. By lowering the marginal cost of production a domestic shock increases domestic labour demand, leading to higher employment and output and a lower terms of trade. A foreign supply shock improves the terms of trade, leading to higher domestic employment and output. Although the effects are qualitatively unaffected by the manner in which foreign wages are set, the magnitudes depend on whether foreign wages are flexible or rigid.

The mean values of consumption and the terms of trade can be written as

$$E\tau^{ij} = \Xi^{ij}_{E\tau} rp^{ij} \quad ; \quad Eb^{ij} = Eb^{ff} + \Xi^{ij}_{Eb} rp^{ij} \quad , i, j = \{f, r\} \tag{13}$$

Hence, because of the risk premium, the wage setting regime directly affects the expected levels of the endogenous variables in the economy. Table 2 summarizes information on the Ξ-coefficients. The information contained in the first line of the table is the superscripts of the relevant coefficients.

Table 2: Signs of level-coefficients

coefficient	ff	rr	fr	rf
$\Xi^{ij}_{E\tau}$	$= 0$	$= 0$	< 0	> 0
Ξ^{ij}_{Eb}	$= 0$	< 0	< 0	< 0

When wages in both countries are set in the same manner, the model is fully symmetric. Hence the expected terms of trade is not in favour of either of the two countries. When wage setting is asymmetric, the direction of the terms of trade depends on the sign of the risk premium. A negative risk premium implies that wages are lowest in the country with rigid wages. Since labour is the only input in production this implies that the expected costs of production are lowest in the country with rigid wages, implying that the expected terms of trade is in favour of the country with flexible wages. If the risk premium is positive the situation is reversed. Since a country will ceteris paribus prefer a higher terms of trade, the sign of the risk premium determined by the degree of relative risk aversion is important for the welfare spill-overs of the choice of wage setting regime. In the case of rigid wages, by lowering the markup to producers, a positive risk premium and the associated higher real wage pushes expected output below the fully flexible level. This affects expected consumption negatively both domestically and abroad. In appendix B we show that

$$\Xi_{Eb}^{rr} < \Xi_{Eb}^{rf} \leq \Xi_{Eb}^{fr}$$

Hence, for a given risk premium, the effect of the risk premium on consumption is strongest if wages are rigid in both countries. If wages are rigid in one country and flexible in the other, expected consumption is affected the most by the risk premium in the country where wages are rigid except for the special case when there is no home bias in consumer preferences.

4 The welfare effects of labour market structures

Having discussed the basic features of the model, we proceed with a welfare analysis. Assuming that the unions in each country choose the wage setting structure to maximize welfare of the workers within their own country, it is important to analyse how welfare is affected by the choice of wage setting regime. Apart from the direct cost of verifying the state, the choice of wage setting affects the welfare measure in two ways, namely by influencing the expected level of consumption as well as its variance. Taking the degree of wage rigidity in the foreign country as given, we show in appendix D that consumption is less volatile with flexible than with rigid wages. This is not surprising since when wages are rigid, all adjustment to shocks has to fall on quantities. However, depending on ϵ, expected consumption may be highest under either flexible or rigid wages.

Since the risk premium arises as an attempt to hedge against the uncertainty associated with productivity shocks, one would be led to think that the economy is always better off in the case with flexible wages than when wages are rigid when we disregard the cost of state verification. It turns out that this is not obvious here since rigid wages are not the only distortion in the economy. In addition there is the monopoly distortion in the labour market and, except for the special cases in which either utility is logarithmic in consumption, i.e. $\epsilon = 1$, or international integration is complete, that is, $\alpha = \frac{1}{2}$, there is inefficient international consumption risk sharing.[8]

We show in appendix C that the monopoly distortion does not interact with the other distortions, and that it can be removed through appropriate use of a production subsidy financed through a lump sum tax. However, it is not obvious how the distortion due to wage rigidities interacts with the inefficient risk sharing. Hence, except for the special cases of logarithmic utility or complete international integration, we cannot show analytically that the agents prefer wages to be flexible even though the cost of state verification is neglected. Numerically we find that for all reasonable parametervalues, disregarding the cost of state verification, the agents prefer wages to be flexible.[9]

International spillovers

Domestic welfare, as expressed by inserting (12) in (11), is affected by the structure of foreign wage setting in two ways. First there is an effect on the variance of consumption. We show in appendix D that

$$Var\left(b^{ir}\right) > Var\left(b^{if}\right) \quad , i = \{f, r\}$$

So given the domestic wage setting structure, domestic consumption is more volatile if foreign real wages are rigid than if they are flexible. From (12) and (11) this implies that disregarding the level effect, domestic consumers prefer foreign wages to be flexible. However, expected domestic consumption is affected by the foreign wage setting procedure through the risk premium. If $\epsilon > 2$ the risk premium is negative. This implies that expected domestic log-consumption is higher when foreign wages are rigid than when they are flexible, see (13).

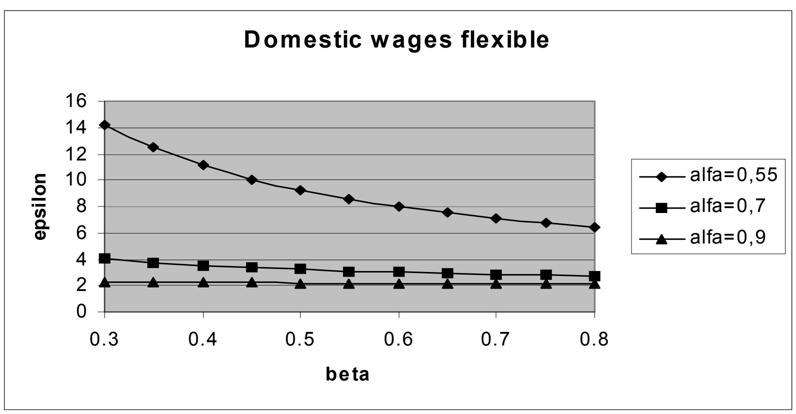
[8]Inefficient risk sharing means that expected utility could be increased by allowing for international trade in state contingent claims. See appendix C for proof. The conditions are similar to those obtained by Obstfeld and Rogoff (2002).

[9]Numerical results are available from the author upon request.

Since also σ_b^2 is highest when foreign wages are rigid and expected consumption is given by

$$EB = \exp\left(Eb + \frac{1}{2}\sigma_b^2\right),$$

we have that for $\epsilon > 2$, expected domestic consumption is highest when foreign wages are rigid. As welfare depends positively on expected counsumption and negatively on consumption variance, this suggests that for sufficiently large values of ϵ, the negative effect on domestic welfare stemming from increased consumption-volatility may be more than outweighed by the level effect, and hence the domestic agents may prefer foreign wages to be rigid. For the case of flexible domestic wages figure 1 reports, as a function of the wage share β, the values of ϵ that ensures that domestic workers are indifferent to whether foreign wages are flexible or rigid. Since the result is sensitive to the import share, we do the calculations for three different values of α. For values of ϵ above the reported values, domestic agents prefer foreign wages to be rigid.



Remembering that β is the wage share and $1-\alpha$ is the import share, reasonable parametervalues could be $\beta = 0.67$ and $\alpha = 0.7$. Empirical estimates used to report values of ϵ somewhere between 1 and 2, see e.g. Mehra and Prescott (1985) and the references therein. However, newer research suggests that the true value is higher. For a recent study see Beetsma and Schotman (2001), who on the basis of a natural experiment estimate the coefficient of relative risk aversion to be as high as 7. Hence, for fully realistic values of the risk aversion parameter, domestic agents benefit from foreign real wage rigidity. This is interesting since one would usually suggest that labour market rigidities have a negative effect on welfare, not just on the economy in which the rigidities prevail, but also on the welfare of its trading partners. Instead we have shown that the rigidities may make unions so modest in their wage demands that the trading partners benefit from the rigidities.

In relatively closed economies the variance of domestic consumption is relatively unaffected by the conditions in the foreign country, explaining why a low import share implies that we only need a value of ϵ slightly above 2 to make domestic agents prefer foreign wages to be rigid. We also observe that the value of ϵ that makes the agents indifferent with respect to foreign wage setting is decreasing in the wage share β.

When domestic real wages are rigid, domestic agents will for all reasonable parametervalues prefer foreign wages to be flexible.[10] This is explained by realizing that when domestic real wages are rigid, domestic wage adjustments cannot, as in the case of flexible wages, be used to mitigate the larger volatility that arises when foreign wages are rigid. Hence the utility loss due to increased volatility cannot for reasonable parametervalues be outweighed by the level effect.

5 Labour market equilibria

Having seen how the structure of wage setting affects the domestic as well as the foreign economy, we now examine how the wage setting structure in the foreign country affects the incentive for the domestic workers to pay the cost

[10]Nummerical results are available from the author upon request.

of state verification. We show in appendix D that the reduction in domestic consumption variance brought about by state verification is smallest if foreign wages are flexible, i.e.

$$\left|var\left(b^{ff}\right)-var\left(b^{rf}\right)\right|<\left|var\left(b^{fr}\right)-var\left(b^{rr}\right)\right| \tag{14}$$

Combining (14) with (12) and (11) we find that disregarding the level effect, a choice of real wage flexibility in the foreign country reduces the incentive of the domestic workers to pay the price of state verification. However, we have to consider the level effect in order to obtain the full picture. Here we rely on numerical illustrations. It turns out that for all reasonable parametervalues the level effect does not overturn the result, implying that the incentive to adopt flexible wages is largest if foreign wages are rigid.[11] The intuition behind the result is that when the foreign country has already adopted flexible wages, the additional reduction in volatility that can be gained though real wage flexibility in the domestic country is smaller than if foreign wages had been rigid.

Nash equilibria in wage setting

Prior to any action taking place, the unions within each country have to decide upon whether wages are to be flexible or rigid. The possible equilibria can be illustrated in the following normal form game (table 3), where for each country there are two possible actions, flexibel (f) or rigid (r). The payoff's are evaluated in terms of expected utility, EU^{ij}.

Table 3: Equilibria in wage setting regimes

		Foreign	
		$flexible$	$rigid$
Home	$flexible$	EU^{ff}, EU^{ff}	EU^{fr}, EU^{rf}
	$rigid$	EU^{rf}, EU^{fr}	EU^{rr}, EU^{rr}

[11] Nummerical results are available from the author upon request.

Basically there are three interesting equilibrium candidates, namely 1) ff, 2) fr or rf and 3) rr. Let $\widetilde{EU}$ denote the expected utility associated with a given wage setting regime if one disregards the cost of state verification, i.e.

$$\widetilde{EU} \equiv EU + V$$

Moreover, define

$$\underline{\Psi}^{NE} \equiv \left(\widetilde{EU^{ff}} - \widetilde{EU^{rf}}\right) \quad ; \quad \overline{\Psi}^{NE} \equiv \left(\widetilde{EU^{fr}} - \widetilde{EU^{rr}}\right)$$

The fact that the incentive for unions within a country to adopt flexible wages is largest when wages in the other country are rigid implies that $\underline{\Psi}^{NE} < \overline{\Psi}^{NE}$. Hence, conditions for the different combinations to be chosen as Nash equilibria are as follows.

- ff will be the Nash equilibrium if $\Psi < \underline{\Psi}^{NE}$
- fr and rf will be Nash equilibria if $\underline{\Psi}^{NE} < \Psi < \overline{\Psi}^{NE}$
- rr will be the Nash equilibrium if $\Psi > \overline{\Psi}^{NE}$

The conditions are straightforward. If the cost of making wages state contingent is so high that it is not even worthwhile for one country to do so, we end up in the equilibrium with rigid wages in both countries. The asymmetric equilibrium in which wages are rigid in one country and flexible in the other is reached if the cost of state verification is such that when both countries have rigid wages it is optimal for one country to pay the cost of state verification, but given that one country has paid the cost, the gain from real wage flexibility is too small for the other country also to pay.

Disregarding the cost of state verification the flex wage country is better off than the country with rigid wages in the asymmetric equilibrium, but since the flex-wage country is also the country that has to bear the cost of state verification, we cannot generally determine which country enjoys the highest welfare. Also, since the model is symmetric ex-ante, we cannot say whether fr or rf will be reached. Finally, if Ψ is so low that even when real wages are state contingent in one country it is optimal for the labour unions in the other country also to set flexible wages, real wages will be flexible in both countries. Note that the inequality $\underline{\Psi}^{NE} < \overline{\Psi}^{NE}$ rules out multiple equilibria.

It is quite interesting that even in this model that is fully symmetric ex ante, we can have asymmetric labour-market equilibria. Relating our model to the debate on European labour markets and interpreting state verification as undertaking a labour market reform, our model suggests that the current situation with substantial differences in the degree of real rigidity across countries may be a long run equilibrium. This is contrary to the often heard argument that when a sufficient fraction of the countries have undertaken labour market reforms, the rest will follow after.

Social planners solution

Having derived the Nash equilibria in wage setting regimes, it is of interest to analyse which wage setting structure would be chosen by a central planner assigning equal weight to each country. Defining

$$\underline{\Psi}^{SP} \equiv \left(2\widetilde{EU^{ff}} - \widetilde{EU^{fr}} - \widetilde{EU^{rf}}\right) \quad ; \quad \overline{\Psi}^{SP} \equiv \left(\widetilde{EU^{fr}} + \widetilde{EU^{rf}} - 2\widetilde{EU^{rr}}\right)$$

we find that

- ff will be chosen by the central planner if $\Psi < \underline{\Psi}^{SP}$
- fr or rf will be chosen by the central planner if $\underline{\Psi}^{SP} < \Psi < \overline{\Psi}^{SP}$
- rr will be chosen by the central planner if $\Psi > \overline{\Psi}^{SP}$

First note that

$$\left(\widetilde{EU^{ff}} - \widetilde{EU^{rf}}\right) < \left(\widetilde{EU^{fr}} - \widetilde{EU^{rr}}\right) \Longrightarrow \overline{\Psi}^{SP} > \overline{\Psi}^{NE}$$

This inequality shows that when the alternative is rigid wages in both countries, then under the usual parameter restrictions the social planner is willing to pay a higher price of unilateral state verification than the unions are. This is because state verification in one country is welfare improving for both countries if we disregard the cost of verifying the state. In the following we will define the effect of state verification in one country on welfare of the other country as the spill-over effect of state verification. Hence, when the alternative is rigid wages in both countries there are positive spill-over effects of state verification. When labour market structures are chosen by the labour unions, the unions in one country does not internalize this spill-over effect.

Now consider the case in which domestic wages are flexible. In this case domestic consumers are not necessarily better off if foreign wages are flexible rather than rigid. Hence when wages are flexible in the domestic country, the spill-over effect of state verification in the foreign country can go in both directions. If $EU^{fr} < EU^{ff}$ there is a positive spill-over effect of foreign state verification even if domestic wages are flexible. In this case the social planner is more inclined to pay the foreign state verification cost than the unions since he internalizes the spill-over effect, implying that $\underline{\Psi}^{SP} > \underline{\Psi}^{NE}$. However, if $EU^{fr} > EU^{ff}$ we have a negative spill-over effect of state verification since the welfare of domestic consumers are lower when foreign wages are flexible than when they are rigid. Since this externality is internalized by the social planner it implies that $\underline{\Psi}^{SP} < \underline{\Psi}^{NE}$.

We have demonstrated that since there are international spillover effects of labour market structures, the Nash equilibrium does not always coincide with the outcome chosen by a social planner. This implies that a coordinated labour market policy may be considered. Whether this leads to more or less real wage flexibility depends on the exact characteristics of the economy.

6 Conclusions

It is often argued that rigid labour markets may constitute an important obstacle for the European Monetary Union to work efficiently. The present paper has provided a rigorous general equilibrium analysis to trace out the effects of real wage rigidities in internationally integrated economies. We have shown how real wage rigidities affect both the expected level of consumption as well as the variance of consumption, which are both important determinants for welfare. Moreover, we have demonstrated how wage rigidities are transmitted between countries through international trade.

Assuming that the wage setting regime is determined by unions each maximizing the welfare of its members, the international transmission of shocks implies that real wages may be rigid in either none, one or both countries. Hence, for certain parametervalues we may end up in an asymmetric equilibrium where wages are flexible in one country and rigid in the other. This is interesting since it challenges the usual wisdom that once labour market reforms are undertaken in a sufficient number of countries in Europe, the rest will automatically follow after.

For different parametervalues all three equilibria can be equivalent to the utilitarian outcome achieved by an internationally coordinated labour market policy. However, the conditions for the joint policy to result in either of the three equilibria are not the same as the conditions for the country-specific unions, implying that a coordinated labour market policy may be welfare improving. It is not clear whether this coordinated policy will lead to more or less rigidity than the decentralized policy.

The paper has considered business cycles driven by real (productivity) shocks. In future research it would be interesting to consider more general shock structures, including the covariance of shocks and different types of shocks. For an example of how shocks that generate similar output patters may call for fundamentally different policy responses, see e.g. Spange (2003). It would also be interesting to build the model into an explicit intertemporal framework to allow for a more detailed modeling of capital markets.

The model is very stylized in the sense that apart from real wage adjustments, there is no way to mitigate the consequences of productivity shocks. Introducing a monetary or fiscal authority pursuing an active stabilization policy might obviously change the qualitatively effects of rigidities, but whether it will change something interesting regarding the spill-over effects is a question that we will leave open for future research. Since differences in the degree of real wage rigidities between countries may prevail in equilibrium, it also becomes interesting to analyse how fiscal and monetary policy should be conducted in the case of asymmetric countries. Asymmetries may have important implications for the gains from policy coordiantion, and it raises questions concerning the countries incentives to engage in coordination.

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Appendix A: welfare

As a measure of welfare we use expected utility given as

$$EU(B, L, \Psi) = \frac{1}{1-\epsilon} E\left(B^{1-\epsilon}\right) - \lambda E\left(L\right) - V$$

From (6) and (5) we have that

$$\lambda E\left(L^{i}\right) = \frac{\theta - 1}{\theta} E\left(B^{-\epsilon} R^{i} L^{i}\right) \quad , = f, r$$

Using that

$$\frac{L^{i}}{B} = \frac{L^{i}Q}{I} = \frac{L^{i}Q\beta}{W^{i}L^{i}} = \frac{\beta Q}{W^{i}} = \left(R^{i}\right)^{-1}\beta \quad , i = f, r$$

the following can be derived

$$\lambda E\left(L^{i}\right) = \frac{\beta\left(\theta - 1\right)}{\theta} E\left(B^{1-\epsilon}\right)$$

so

$$EU = \left(\frac{1}{1-\epsilon} - \frac{\beta\left(\theta-1\right)}{\theta}\right) E\left(B^{1-\epsilon}\right) - V$$

Due to the properties of the log-normal distribution this can be rewritten as

$$EU = \left(\frac{1}{1-\epsilon} - \frac{\beta\left(\theta-1\right)}{\theta}\right) \exp\left\{\left(1-\epsilon\right) Eb + \frac{\left(1-\epsilon\right)^{2}}{2} Var\left(b\right)\right\} - V$$

Appendix B: Derivation of the reduced form

In logs the aggregate supply and demand relations are given as

$$y = \eta_{s}^{i} + \eta_{sz}^{i} z + \eta_{s\tau}^{i}\tau \qquad (15)$$

$$y^{*} = \eta_{s}^{*i} + \eta_{sz}^{*i} z^{*} + \eta_{s\tau}^{*i}\tau \qquad (16)$$

$$\tau = y^{*} - y \qquad (17)$$

Making the following definitions

$$\psi \equiv \left(1 - \beta\left(1-\epsilon\right)\right) \quad ; \quad \psi^{*} \equiv \left(1 - \beta\left(1-\epsilon\right)\right)$$

the coefficients in the domestic supply relation can be written

$$\eta_{s}^{f} = -\beta\psi^{-1}\log\left(\beta^{\frac{1-\beta}{\beta}}\frac{\lambda\theta}{\theta-1}\right) \qquad \eta_{s}^{r} = -\log\beta - \tfrac{\beta}{1-\beta} r^{r}$$

$$\eta_{sz}^{f} = \psi^{-1} \qquad \eta_{sz}^{r} = \left(1-\beta\right)^{-1}$$

$$\eta_{s\tau}^{f} = \psi^{-1}\beta\left(1-\alpha\right)\left(1-\epsilon\right) \qquad \eta_{s\tau}^{r} = \left(1-\beta\right)^{-1}\beta\left(1-\alpha\right)$$

Hence

$$\begin{array}{ll} \eta_{sz}^{f} > 0 & \eta_{sz}^{r} > 0 \\ sign\left(\eta_{s\tau}^{f}\right) = sign\left(1-\epsilon\right) & \eta_{s\tau}^{r} > 0 \end{array}$$

Similarly for the foreign supply relation

$$\begin{array}{ll} \eta_{s}^{*f} = -\beta\psi^{-1}\log\left(\beta^{\frac{1-\beta}{\beta}}\frac{\lambda\theta}{\theta-1}\right) & \eta_{s}^{r} = -\log\beta - \frac{\beta}{1-\beta}r^{r} \\ \eta_{sz}^{*f} = \psi^{-1} & \eta_{sz}^{r} = \left(1-\beta\right)^{-1} \\ \eta_{s\tau}^{*f} = \psi^{-1}\beta\left(1-\alpha\right)\left(\epsilon-1\right) & \eta_{s\tau}^{r} = -\left(1-\beta\right)^{-1}\beta\left(1-\alpha\right) \end{array}$$

so

$$\begin{array}{ll} \eta_{sz}^{*f} > 0 & \eta_{sz}^{*r} > 0 \\ sign\left(\eta_{s\tau}^{*f}\right) = -sign\left(1-\epsilon\right) & \eta_{s\tau}^{*r} < 0 \end{array}$$

To solve the model start by subtracting (16) from (15) and invoke (17) to obtain

$$\tau = E\tau + \phi_{\tau z}z + \phi_{\tau z^*}z^* \tag{18}$$

where

$$E\tau = \frac{-\left(\eta_s - \eta_s^*\right)}{1+\eta_{s\tau}-\eta_{s\tau}^*} \quad ; \quad \phi_{\tau z} \equiv \frac{-\eta_{sz}}{1+\eta_{s\tau}-\eta_{s\tau}^*} \quad ; \quad \phi_{\tau z^*} \equiv \frac{\eta_{sz}^*}{1+\eta_{s\tau}-\eta_{s\tau}^*} \tag{19}$$

Now insert (18) in (15)

$$y = \eta_s + \eta_{s\tau}E\tau + \left(\eta_{sz} + \eta_{s\tau}\phi_{\tau z}\right)z + \eta_{s\tau}\phi_{\tau z^*}z^*$$

Invoke (19) and rearrange to obtain

$$y = Ey + \phi_{yz}y + \phi_{yz^*}z^* \tag{20}$$

where

$$Ey = \frac{\eta_s - \eta_{s\tau}^*\eta_s + \eta_{s\tau}\eta_s^*}{1+\eta_{s\tau}-\eta_{s\tau}^*} \quad ; \quad \phi_{yz} \equiv \frac{\eta_{sz}\left(1-\eta_{s\tau}^*\right)}{1+\eta_{s\tau}-\eta_{s\tau}^*} \quad ; \quad \phi_{yz^*} \equiv \frac{\eta_{s\tau}\eta_{sz}^*}{1+\eta_{s\tau}-\eta_{s\tau}^*}$$

Since

$$1+\eta_{s\tau}-\eta_{s\tau}^* > 0 \quad ; \quad \left(1-\eta_{s\tau}^*\right) > 0$$

holds independently of the chosen wage setting regimes, it follows that

$$\begin{array}{rcl} \phi_{yz}^{ff} & > & 0 \quad ; \quad \phi_{yz}^{rr} > 0 \quad ; \quad \phi_{yz}^{fr} > 0 \quad ; \quad \phi_{yz}^{rf} > 0 \\ sign\left(\phi_{yz^*}^{ff}\right) & = & sign\left(1-\epsilon\right) \quad ; \quad \phi_{yz^*}^{rr} > 0 \quad ; \quad sign\left(\phi_{yz^*}^{fr}\right) = sign\left(1-\epsilon\right) \quad ; \quad \phi_{yz^*}^{rf} > 0 \end{array}$$

Considering the expression for labour supply, we take log of (1)

$$y = -\log\beta + z + \beta l \tag{21}$$

Insert (20) in (21) and rearrange to obtain

$$l = El + \phi_{lz} z + \phi_{lz^*} z^* \tag{22}$$

where

$$\begin{aligned} El &= \frac{1}{\beta}\left[\frac{\eta_s - \eta^*_{s\tau}\eta_s + \eta_{s\tau}\eta^*_s}{1+\eta_{s\tau}-\eta^*_{s\tau}} + \log\beta\right] \\ \phi_{lz} &\equiv \frac{1}{\beta}\left[\frac{\eta_{sz}\left(1-\eta^*_{s\tau}\right)}{1+\eta_{s\tau}-\eta^*_{s\tau}} - 1\right] \quad ; \quad \phi_{lz^*} \equiv \frac{1}{\beta}\left[\frac{\eta_{s\tau}\eta^*_{sz}}{1+\eta_{s\tau}-\eta^*_{s\tau}}\right] \end{aligned}$$

It follows straightforwardly that $sign\left(\phi_{lz^*}\right) = sign\left(\phi_{yz^*}\right)$. To sign ϕ_{lz} we have to go through the four possible cases and insert the expressions for the supply-coefficients. Doing so leads us to conclude that

$$\begin{aligned} \phi^{ff}_{yz} &> 0 \quad ; \quad \phi^{rr}_{yz} > 0 \quad ; \quad \phi^{fr}_{yz} > 0 \quad ; \quad \phi^{rf}_{yz} > 0 \\ sign\left(\phi^{ff}_{lz^*}\right) &= sign\left(1-\epsilon\right) \quad ; \quad \phi^{rr}_{lz^*} > 0 \quad ; \quad sign\left(\phi^{fr}_{lz^*}\right) = sign\left(1-\epsilon\right) \quad ; \quad \phi^{rf}_{lz^*} > 0 \end{aligned}$$

Now take log of (7)

$$b = \left(1-\alpha\right)\tau + y \tag{23}$$

Insert (18) and (20) in (23) to arrive at

$$b = Eb + \phi_{bz} z + \phi_{bz^*} z^*$$

where

$$\begin{aligned} Eb &= \frac{\alpha - \eta^*_{s\tau}}{1+\eta_{s\tau}-\eta^*_{s\tau}}\eta_s + \frac{1-\alpha+\eta_{s\tau}}{1+\eta_{s\tau}-\eta^*_{s\tau}}\eta^*_s \\ \phi_{bz} &\equiv \frac{\left(\alpha-\eta^*_{s\tau}\right)\eta_{sz}}{1+\eta_{s\tau}-\eta^*_{s\tau}} \quad ; \quad \phi_{bz^*} \equiv \frac{\left(1-\alpha+\eta_{s\tau}\right)\eta^*_{sz}}{1+\eta_{s\tau}-\eta^*_{s\tau}} \end{aligned}$$

To sign the shock-coefficients we use that

$$\begin{aligned} \left(\alpha - \eta^{*f}_{s\tau}\right) &> 0 \quad ; \quad \left(\alpha - \eta^{*r}_{s\tau}\right) > 0 \\ \left(1-\alpha+\eta^f_{s\tau}\right) &> 0 \quad ; \quad \left(1-\alpha+\eta^r_{s\tau}\right) > 0 \\ 1+\eta^f_{s\tau}-\eta^{*f}_{s\tau} &> 0 \quad ; \quad 1+\eta^r_{s\tau}-\eta^{*r}_{s\tau} > 0 \\ 1+\eta^f_{s\tau}-\eta^{*r}_{s\tau} &> 0 \quad ; \quad 1+\eta^r_{s\tau}-\eta^{*f}_{s\tau} > 0 \end{aligned}$$

implying that

$$\begin{aligned}\phi_{bz}^{ff} &> 0 \quad ; \quad \phi_{bz}^{rr} > 0 \quad ; \quad \phi_{bz}^{fr} > 0 \quad ; \quad \phi_{bz}^{rf} > 0 \\ \phi_{bz^*}^{ff} &> 0 \quad ; \quad \phi_{bz^*}^{rr} > 0 \quad ; \quad \phi_{bz^*}^{fr} > 0 \quad ; \quad \phi_{bz^*}^{rf} > 0\end{aligned}$$

Now take a closer look at Eb. If wages are flexible both in the domestic and in the foreign country we find that

$$Eb^{ff} = \eta_s^f = -\beta\psi^{-1}\log\left(\beta^{\frac{1-\beta}{\beta}}\frac{\lambda\theta}{\theta-1}\right)$$

If instead wages are rigid in both countries we have that

$$Eb^{rr} = \eta_s^r = -\log\beta - \frac{\beta}{1-\beta}r^r \tag{24}$$

From (5) we derive

$$r^r = \log\left(\frac{\lambda\theta}{\theta-1}\right) + \epsilon Eb + rp \tag{25}$$

Inserting this in (24) and solving for Eb we derive

$$Eb^{rr} = Eb^{ff} + \Xi_{Eb}^{rr} rp$$

where

$$\Xi_{Eb}^{rr} \equiv -\beta\psi^{-1} < 0$$

Now consider the case in which domestic wages are rigid while foreign wages are rigid. Then we have that

$$Eb^{rf} = \frac{\alpha + \eta_{s\tau}^f}{1+\eta_{s\tau}^r+\eta_{s\tau}^f}\eta_s^r + \frac{1-\alpha+\eta_{s\tau}^r}{1+\eta_{s\tau}^r+\eta_{s\tau}^f}\eta_s^f$$

Insert the expressions for the supply coefficients as well as (25), rearrange and obtain

$$Eb^{rf} = Eb^{ff} + \Xi_{Eb}^{rf} rp$$

where

$$\Xi_{Eb}^{rf} \equiv \frac{\beta\left(\beta\left(1-\epsilon\right)\left(1-2\alpha\right)+\alpha\right)}{2\left(1-\epsilon\right)\beta\alpha + \left(1-\epsilon\right)^2\left(1-2\alpha\right)\beta^2 - 1} < 0$$

Finally we solve for Eb^{fr}. We have that

$$Eb^{fr} = \frac{\alpha + \eta_{s\tau}^{r}}{1 + \eta_{s\tau}^{f} + \eta_{s\tau}^{r}} \eta_s^f + \frac{1 - \alpha + \eta_{s\tau}^{f}}{1 + \eta_{s\tau}^{f} + \eta_{s\tau}^{f}} \eta_s^r$$

To compute η_s^r we use the expression for Eb^{rf} in (25), rearrange and obtain

$$Eb^{fr} = Eb^{ff} + \Xi_{Eb}^{fr} rp$$

where

$$\Xi_{Eb}^{fr} \equiv \frac{\beta (1 - \alpha)}{2 (1 - \epsilon) \beta \alpha + (1 - \epsilon)^2 (1 - 2\alpha) \beta^2 - 1} < 0$$

It is straightforward to show that

$$\Xi_{Eb}^{rr} < \Xi_{Eb}^{rf} \leq \Xi_{Eb}^{fr}$$

where the last inequality is weak since for $\alpha = \frac{1}{2}$, $\Xi_{Eb}^{rf} = \Xi_{Eb}^{fr}$.

Appendix C: Interactions between distortions

There are three potential distortions in the model, namely the monopoly distortion, the wage rigidity and the inefficient consumption risk sharing between countries. First we show that the monopoly distortion does not interact with the other distortions. This is easily seen since the monopoly distortion is introduced by the parameter θ, and for $\theta \to \infty$ it vanishes. θ does not enter in any of the adjustment coefficients or in the risk premium. Hence it only enters in the part of Eb that is common for all structures of wage setting. This implies that there cannot be any interaction between the monopoly distortion and the other distortions.

Now, for risk sharing to be perfect, the marginal utility for domestic consumers of one unit of the domestic consumption bundle, relative to its price, must always be equal to the marginal utility for foreign consumers of one unit of the foreign consumption bundle relative to the price of this bundle, that is

$$\begin{aligned} \frac{U'(B)}{Q} &= \frac{U^{*\prime}(B^*)}{Q^*} \Longleftrightarrow \\ \frac{B^{-\epsilon}}{Q} &= \frac{(B^*)^{-\epsilon}}{Q^*} \end{aligned}$$

By use of the budget constraints and the definitions of the price indices and the terms of trade, this condition can be rewritten

$$1 = \left(\frac{P^*}{P}\right)^{(1-2\alpha)(\epsilon-1)}$$

Since the relative price depends on the shocks, this is only satisfied when either $\alpha = \frac{1}{2}$ or $\epsilon = 1$. Except for these cases we have inefficient consumption risk sharing, and we cannot say how this interacts with the distortion due to wage rigidity.

Appendix D: Comparisons of variances

We start out by showing that

$$Var\,(b)^{fr} > Var\,(b)^{ff} \quad ; \quad Var\,(b)^{rr} > Var\,(b)^{rf}$$

In order to do that we will start by showing that $\phi_{bz}^{fr} > \phi_{bz}^{ff} >$ and $\phi_{bz}^{rr} > \phi_{bz}^{rf}$. We have that

$$\phi_{bz} = \frac{\left(\alpha - \eta_{s\tau}^*\right)\eta_{sz}}{1 + \eta_{s\tau} - \eta_{s\tau}^*}$$

Only the coefficient $\eta_{s\tau}^*$ is affected by the foreign wage setting procedure. We find that

$$\frac{\partial \phi_{bz}}{\partial \eta_{s\tau}^*} = -\frac{\left(1 - \alpha + \eta_{s\tau}\right)\eta_{sz}}{\left(1 + \eta_{s\tau} - \eta_{s\tau}^*\right)^2} < 0$$

Since $\eta_{s\tau}^{*f} > \eta_{s\tau}^{*r}$ this implies that

$$\phi_{bz}^{fr} > \phi_{bz}^{ff} > \text{ and } \phi_{bz}^{rr} > \phi_{bz}^{rf}$$

We now show that $\phi_{bz^*}^{rr} > \phi_{bz^*}^{rf}$

$$\begin{aligned}
\phi_{bz^*}^{rr} &> \phi_{bz^*}^{rf} \Longleftrightarrow \\
\frac{\left(1 - \alpha + \eta_{s\tau}^{r}\right)\eta_{sz}^{*r}}{1 + \eta_{s\tau}^{r} - \eta_{s\tau}^{*r}} &> \frac{\left(1 - \alpha + \eta_{s\tau}^{r}\right)\eta_{sz}^{*f}}{1 + \eta_{s\tau}^{r} - \eta_{s\tau}^{*f}} \Longleftrightarrow \\
\left(1 + \eta_{s\tau}^{r} - \eta_{s\tau}^{*f}\right)\eta_{sz}^{*r} &> \eta_{sz}^{*f}\left(1 + \eta_{s\tau}^{r} - \eta_{s\tau}^{*r}\right) \Longleftrightarrow \\
\left(1 - (1-\beta)^{-1}\beta(\alpha - 1) + \psi^{-1}\beta(1-\alpha)(1-\epsilon)\right)(1-\beta)^{-1} &> \\
\psi^{-1}\left(1 - (1-\beta)^{-1}\beta(\alpha-1) + (1-\beta)^{-1}\beta(1-\alpha)\right) &\Longleftrightarrow \\
-(1-\beta)(1-\epsilon)\alpha + 1 - \alpha &> (1-\beta)(1-2\alpha)
\end{aligned}$$

which is always satisfied. Next we show that $\phi_{bz^*}^{fr} > \phi_{bz^*}^{ff}$

$$\begin{aligned}
\phi_{bz^*}^{fr} &> \phi_{bz^*}^{ff} \iff \\
\frac{\left(1-\alpha+\eta_{s\tau}^{f}\right)\eta_{sz}^{*r}}{1+\eta_{s\tau}^{f}-\eta_{s\tau}^{*r}} &> \frac{\left(1-\alpha+\eta_{s\tau}^{f}\right)\eta_{sz}^{*f}}{1+\eta_{s\tau}^{f}-\eta_{s\tau}^{*f}} \iff \\
\left(1+\eta_{s\tau}^{f}-\eta_{s\tau}^{*f}\right)\eta_{sz}^{*r} &> \eta_{sz}^{*f}\left(1+\eta_{s\tau}^{f}-\eta_{s\tau}^{*r}\right) \iff \\
\left(1-\psi^{-1}\beta(\alpha-1)(1-\epsilon)+\psi^{-1}\beta(1-\alpha)(1-\epsilon)\right)(1-\beta)^{-1} &> \\
\left(1-\psi^{-1}\beta(\alpha-1)(1-\epsilon)+(1-\beta)^{-1}\beta(1-\alpha)\right)\psi^{-1} &\iff \\
\alpha+(1-\epsilon)(\beta-\alpha-2\alpha\beta) &> \beta(1-\epsilon)^{2}(1-2\alpha)
\end{aligned}$$

which is satisfied for all admissable parametervalues. Since

$$Var(b) = \left[(\phi_{bz})^2 + (\phi_{bz^*})^2\right]\sigma_z^2$$

we conclude that

$$Var(b)^{fr} > Var(b)^{ff} \quad ; \quad Var(b)^{rr} > Var(b)^{rf} \tag{26}$$

We now show that

$$Var(b)^{rf} > Var(b)^{ff} \quad ; \quad Var(b)^{rr} > Var(b)^{fr}$$

Since we have already shown (26), it is sufficient to show that

$$Var(b)^{rf} > Var(b)^{fr} \tag{27}$$

To do so we show that $\phi_{bz}^{rf} > \phi_{bz}^{fr}$ and $\phi_{bz^*}^{rf} = \phi_{bz^*}^{fr}$. We have

$$\begin{aligned}
\phi_{bz}^{rf} &> \phi_{bz}^{fr} \iff \\
\frac{\left(\alpha-\eta_{s\tau}^{*f}\right)\eta_{sz}^{r}}{1+\eta_{s\tau}^{r}-\eta_{s\tau}^{*f}} &> \frac{\left(\alpha-\eta_{s\tau}^{*r}\right)\eta_{sz}^{f}}{1+\eta_{s\tau}^{f}-\eta_{s\tau}^{*r}} \iff \\
\frac{\left(\alpha+\eta_{s\tau}^{f}\right)\eta_{sz}^{r}}{1+\eta_{s\tau}^{r}+\eta_{s\tau}^{f}} &> \frac{\left(\alpha+\eta_{s\tau}^{r}\right)\eta_{sz}^{f}}{1+\eta_{s\tau}^{f}+\eta_{s\tau}^{r}} \iff \\
\left(\alpha+\eta_{s\tau}^{f}\right)\eta_{sz}^{r} &> \left(\alpha+\eta_{s\tau}^{r}\right)\eta_{sz}^{f}
\end{aligned}$$

By inserting values for η_{sz}^{f}, η_{sz}^{r}, $\eta_{s\tau}^{f}$ and $\eta_{s\tau}^{r}$ lots of terms cancel out and the inequality reduces to $\epsilon > 0$, which we have assumed throughout. Next we have that

$$\begin{aligned}
\phi^{rf}_{bz^*} &= \phi^{fr}_{bz^*} \Longleftrightarrow \\
\frac{(1-\alpha+\eta^r_{s\tau})\,\eta^{*f}_{sz}}{1+\eta^r_{s\tau}-\eta^{*f}_{s\tau}} &= \frac{\left(1-\alpha+\eta^f_{s\tau}\right)\eta^{*r}_{sz}}{1+\eta^f_{s\tau}-\eta^{*r}_{s\tau}} \Longleftrightarrow \\
(1-\alpha+\eta^r_{s\tau})\,\eta^{*f}_{sz} &= \left(1-\alpha+\eta^f_{s\tau}\right)\eta^{*r}_{sz}
\end{aligned}$$

Inserting the expressions for $\eta^f_{s\tau}$, $\eta^r_{s\tau}$, η^{*f}_{sz}, and η^{*r}_{sz} we find that this equality is satisfied. Hence we have shown (27), implying that

$$Var\,(b)^{rf} > Var\,(b)^{ff} \quad ; \quad Var\,(b)^{rr} > Var\,(b)^{fr}$$

Finally we show that

$$\left|var\left(b^{ff}\right)-var\left(b^{rf}\right)\right| < \left|var\left(b^{fr}\right)-var\left(b^{rr}\right)\right|$$

To show that we show the following

$$\begin{aligned}
\left(\phi^{rr}_{bz}\right)^2-\left(\phi^{fr}_{bz}\right)^2 &> \left(\phi^{rf}_{bz}\right)^2-\left(\phi^{ff}_{bz}\right)^2 \\
\left(\phi^{rr}_{bz^*}\right)^2-\left(\phi^{fr}_{bz^*}\right)^2 &> \left(\phi^{rf}_{bz^*}\right)^2-\left(\phi^{ff}_{bz^*}\right)^2
\end{aligned}$$

Since

$$\phi^{fr}_{bz} > \phi^{ff}_{bz} \text{ and } \phi^{fr}_{bz^*} > \phi^{ff}_{bz^*}$$

it is sufficient to show the following

$$\begin{aligned}
\phi^{rr}_{bz}-\phi^{fr}_{bz} &> \phi^{rf}_{bz}-\phi^{ff}_{bz} \\
\phi^{rr}_{bz^*}-\phi^{fr}_{bz^*} &> \phi^{rf}_{bz^*}-\phi^{ff}_{bz^*}
\end{aligned}$$

We have that

$$\begin{aligned}
\phi^{rr}_{bz}-\phi^{fr}_{bz}-\left(\phi^{rf}_{bz}-\phi^{ff}_{bz}\right) &> 0 \Longleftrightarrow \\
\frac{(\alpha+\eta^r_{s\tau})\,\eta^r_{sz}}{1+2\eta^r_{s\tau}}-\frac{(\alpha+\eta^r_{s\tau})\,\eta^f_{sz}+\left(\alpha+\eta^f_{s\tau}\right)\eta^r_{sz}}{1+\eta^f_{s\tau}+\eta^r_{s\tau}}+\frac{\left(\alpha+\eta^f_{s\tau}\right)\eta^f_{sz}}{1+2\eta^f_{s\tau}} &> 0
\end{aligned}$$

Now define

$$\begin{aligned}
&\underline{A}=(\alpha+\eta^r_{s\tau}) && \overline{A}=\left(\alpha+\eta^f_{s\tau}\right) \\
&\underline{B}=\eta^f_{sz} && \overline{B}=\eta^r_{sz} \\
&\underline{N}=2\underline{A}+(1-2\alpha) && \overline{N}=2\overline{A}+(1-2\alpha)
\end{aligned}$$

and rewrite the condition accordingly

$$\frac{\overline{AB}}{2\overline{A}+(1-2\alpha)}-\frac{\overline{A}\underline{B}+\underline{A}\overline{B}}{2\overline{A}+2\underline{A}+2(1-2\alpha)}+\frac{\underline{AB}}{2\underline{A}+(1-2\alpha)}>0 \qquad (28)$$

We have that

$$\overline{AB}+\underline{AB}\geq\overline{A}\underline{B}+\underline{A}\overline{B}$$

The condition (28) is most likely not to be satisfied if $\overline{AB}+\underline{AB}=\overline{A}\underline{B}+\underline{A}\overline{B}$ so we insert this scenario and define

$$\underline{T}=\underline{AB} \quad ; \quad \overline{T}=\overline{AB}$$

Then (28) becomes

$$\overline{T}\underline{NN}+\underline{T}\overline{NN}>0$$

which is satisfied. Hence we conclude that

$$\left(\phi_{bz}^{rr}\right)^2-\left(\phi_{bz}^{fr}\right)^2>\left(\phi_{bz}^{rf}\right)^2-\left(\phi_{bz}^{ff}\right)^2$$

Similarly we show that

$$\begin{aligned}\phi_{bz^*}^{rr}-\phi_{bz^*}^{fr}-\left(\phi_{bz^*}^{rf}-\phi_{bz^*}^{ff}\right) &> 0\Longleftrightarrow\\ \frac{(1-\alpha+\eta_{s\tau}^r)\,\eta_{sz}^r}{1+2\eta_{s\tau}^r}-\frac{(1-\alpha+\eta_{s\tau}^r)\,\eta_{sz}^f+\left(1-\alpha+\eta_{s\tau}^f\right)\eta_{sz}^r}{1+\eta_{s\tau}^f+\eta_{s\tau}^r}+\frac{\left(1-\alpha+\eta_{s\tau}^f\right)\eta_{sz}^f}{1+2\eta_{s\tau}^f} &> 0\end{aligned}$$

Now define

$$\begin{aligned}\underline{A}&=(1-\alpha+\eta_{s\tau}^r) & \overline{A}&=\left(1-\alpha+\eta_{s\tau}^f\right)\\ \underline{B}&=\eta_{sz}^f & \overline{B}&=\eta_{sz}^r\\ \underline{N}&=2\underline{A}+(1-2\alpha) & \overline{N}&=2\overline{A}+(1-2\alpha)\end{aligned}$$

Then go through the same steps as before and conclude that

$$\left(\phi_{bz^*}^{rr}\right)^2-\left(\phi_{bz^*}^{fr}\right)^2>\left(\phi_{bz^*}^{rf}\right)^2-\left(\phi_{bz^*}^{ff}\right)^2$$

It has now been shown that

$$\left|var\left(b^{ff}\right)-var\left(b^{rf}\right)\right|<\left|var\left(b^{fr}\right)-var\left(b^{rr}\right)\right|$$

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