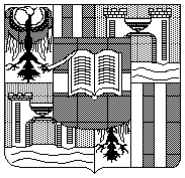

DEPARTMENT OF ECONOMICS
JOHANNES KEPLER UNIVERSITY OF LINZ

Bilateral Exchange Rates and Jobs

by

Eddy BEKKERS[*)]
Joseph FRANCOIS

Working Paper No. 1202
January 2012

Johannes Kepler University of Linz
Department of Economics
Altenberger Strasse 69
A-4040 Linz - Auhof, Austria
www.econ.jku.at

[*)]eddy.bekkers@jku.at
phone +43 (0)70 2468 -8220, -8238 (fax)

Bilateral Exchange Rates and Jobs *

Eddy Bekkers
Johannes Kepler University (Linz)

Joseph Francois
Johannes Kepler University (Linz)
& CEPR (London)

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Keywords: bilateral exchange rates, devaluation, exchange rates and trade, trade and employment

JEL codes: F32, F41

*We would like to thank Richard Baldwin, Peter Egger, Doug Nelson, Clint Shiells, and participants at CEPR workshops and ETSG sessions for helpful comments and suggestions. Address for correspondence: Eddy Bekkers, Johannes Kepler University of Linz, Dept. of Economics, Altenbergerstr 69, 4040 Linz, Austria. email: eddy.bekkers@jku.at

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1 Introduction

Conventional reasoning suggests that a country's output and employment will rise when its currency falls. The chain of logic is relatively straightforward – improved export competitiveness stimulates demand and so drives up output. However, there are also well known countervailing factors to consider. For example, it has been shown that that the increased price of imports as a result of depreciation may also reduce output through adverse supply effects (Edwards , 1986; van Wijnbergen , 1986). Broadly speaking, the literature focuses on generic exchange rate changes (i.e. vis-a-vis the world as a whole). This paper's contribution is a better understanding of bilateral exchange rate changes (or revaluation against a sub-set of partners). At a practical level, our focus on the issue of bilateral revaluation has immediate relevance given the current exchange rate dispute between China and

the US, the earlier exchange rate dispute between Japan and the US, and ongoing calls for inclusion of exchange rate issues within the WTO.

To examine the employment effects of bilateral revaluation, we extend the model of de Melo and Robinson (1986) to include variable labor supply conditions as well as intermediate in inputs in production. We explore this framework both analytically and numerically. The analytics allow us to highlight detailed mechanics linked to particular aspects of technology and the composition of trade. We then use numerics to examine and illustrate more complex issues related to interaction between key elements of the model. The numeric version of the model is calibrated to global macroeconomic data for 2007.

The import and export shares of trade of the exchange rate realigning trade partner are shown to be crucial determinants of the employment effects. In particular, an appreciation of the currency of a trading partner can have negative employment effects when a country's import share from that trading partner is larger than its share of exports going to that trading partner. An appreciation of a trading partner's currency helps a country, because its export sales generate more revenues. It hurts a country, because the price of its inputs go up. This adversely affects employment for two reasons. Imported intermediates become more expensive, reducing the marginal product of labor. And a higher price of imported final goods leads to higher wage demands. In a baseline model with flexible labor markets and balanced trade, a trading partner's currency depreciation is harmful when the import share from that country exceeds the export share to that country.

Further analytical results include proof that a slower wage adjustment and a smaller share of intermediates in the gross production function make it more likely that a trading partner's currency appreciation is beneficial. A

lower rate of pass through on the importer side also increases the probability that a country benefits from the trading partner's appreciation, as it does not suffer so much from increased import prices. Also, it is shown that an improvement in the trade balance as a result of a trading partner's currency appreciation contributes negatively to the change in employment, whereas a deterioration of the trade balance makes a positive contribution. From the numerics, we are able to highlight the importance of underlying labor conditions, and in particular the scope for magnification of employment effects. We also show that parameterization (the structure of technology in allowing substitution) is critical to both the direction and magnitude of effects.

To place this paper in context, there is an early literature arguing that broad-based devaluations can be contractionary. Hirschman (1949), Diaz-Alejandro (1963) and Krugman and Taylor (1978). Edwards (1986) and van Wijnbergen (1986) all emphasize the supply side effects driving in the possible contraction. In the more recent literature, open economy DSGE models are used to study the effect of exchange rate realignments,[1] including Erceg et al. (2006) and Bodenstein et al. (2009). Throughout, the emphasis is on broad-based rather than bilateral realignment. An exception is Fair (2010), who uses a macroeconometric model to estimate the effects of a realignment of the exchange rate of one of the trading partners of the US, China and finds modest effects of a Chinese revaluation. He does not identify trade shares, but focuses instead on inflation effects.

The rest of this paper is organized as follows. We develop the basic model in 2. The basic properties of the model are explored analytically in Section 3, including changes in the trade balance, and the role of variations in passthrough rates. This is followed by numerical analysis, based on Chinese

[1] With exchange rates typically endogenous in these models, shocks to monetary policy can be used to mimic these effects

revaluation vis-a-vis the US in Section 4. From the numerics, we demonstrate that there is not an unambiguous pairing between improved trade balance and increased employment. Rather, this depends on technology and parameter sets, on top of the trade composition effects stressed in Section 3. Finally, we summarize and conclude in Section 5.

2 Basic Model

Consider the '123 model' of de Melo and Robinson (1986).[2][3] A small country produces goods for the domestic market and the exporting market, equation (1) and consumes imports and domestic goods, equation (2):

$$X = G(E, D_s) = \left(\beta_E E^{\frac{\theta+1}{\theta}} + \beta_{D_s} D_s^{\frac{\theta+1}{\theta}}\right)^{\frac{\theta}{\theta+1}} \tag{1}$$

$$Q = F(M, D_d) = \left(\alpha_M M^{\frac{\sigma-1}{\sigma}} + \alpha_{D_d} D_d^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \tag{2}$$

The price indexes corresponding to equations (1) and (2) are given by:

$$p_x = \left(\beta_E^{-\theta} p_e^{\theta+1} + \beta_{D_s}^{-\theta} p_d^{\theta+1}\right)^{\frac{1}{\theta+1}} \tag{3}$$

$$p_q = \left(\alpha_M^{\sigma} p_m^{1-\sigma} + \alpha_{D_d}^{\sigma} p_d^{1-\sigma}\right)^{\frac{1}{1-\sigma}} \tag{4}$$

Optimality along transformation curve and indifference curve imply the following conditions:

$$\frac{E}{D_s} = \left(\frac{\beta_{D_s}}{\beta_E}\frac{p_e}{p_d}\right)^{\theta} \tag{5}$$

$$\frac{M}{D_d} = \left(\frac{\alpha_M}{\alpha_{D_d}}\frac{p_d}{p_m}\right)^{\sigma} \tag{6}$$

[2] See de Melo and Robinson (1986) and Devarajan, et al. (1998) for a detailed description of the model.

[3] Table 1 contains a description of the variables and parameters of the model.

Table 1: List of Variables and Parameters

Variable	**Description**
X	gross output
Q	gross demand
M, E	imports and exports
p_q, p_x	price of demand and output
p_m, p_e	price of imports and exports
$p_{m,i}, p_{e,i}$	home price of imports and exports of country i
R_i	nominal exchange rate between home and country i
$\pi_{m,i}, \pi_{e,i}$	country i price of imports and exports
B	net capital inflow into home, measured in domestic prices
D_d, D_s	demand and supply of non tradable
I	intermediates
L, K	employment and capital
w	(nominal) wage
Parameters	**Description**
θ	elasticity of transformation between domestic goods and exports
σ	elasticity of substitution between domestic goods and imports
η	elasticity of substitution between imports from different countries
ω	elasticity of transformation between exports to different countries
ρ	elasticity of substitition between inputs in production function
φ	labor supply elasticity
β_E, β_{D_s}	shift parameters in supply of exports and domestic goods
α_M, α_{D_d}	shift parameters in demand for imports and domestic goods
γ_i, δ_i	shift parameters in imports from and exports to different trade partners
ϕ_I, ϕ_L, ϕ_K	shift parameters in production function
ξ_q	degree of stickyness of price expectations
$\xi_{p_{m,i}}$	rate of importer pass through

Domestic equilibrium requires equality of supply of and demand for non tradables:

$$D_d - D_s = 0 \tag{7}$$

There are N trade partners. The price index of imports in equation (8) and the price index of exports in equation (9) follow from the Armington assumption:

$$p_m = \left(\sum_{i=1}^{N} \gamma_i^{\eta} p_{m,i}^{1-\eta} \right)^{\frac{1}{1-\eta}} \tag{8}$$

$$p_e = \left(\sum_{i=1}^{N} \delta_i^{-\omega} p_{e,i}^{\omega+1} \right)^{\frac{1}{\omega+1}} \tag{9}$$

Foreign prices $\pi_{m,i}$ and $\pi_{e,i}$ are given reflecting the small country assumption. The foreign prices are related with the domestic trading prices $p_{m,i}$ and $p_{e,i}$ by a bilateral exchange rate R_i with trading partner i:

$$p_{m,i} = R_i \pi_{m,i} \tag{10}$$

$$p_{e,i} = R_i \pi_{e,i} \tag{11}$$

An increase in R_i corresponds with an appreciation of the exchange rate of trading partner i. Capital inflows B are positive when the country's imports exceed its exports:

$$B = p_m M - p_e E \tag{12}$$

To address the effect of exchange rate realignments including both demand and supply side effects, we add a production structure. The country uses intermediates, labor and capital in production giving rise to the following

CES production function:

$$X = \left(\phi_I I^{\frac{\rho-1}{\rho}} + \phi_L L^{\frac{\rho-1}{\rho}} + \phi_K K^{\frac{\rho-1}{\rho}}\right)^{\frac{\rho}{\rho-1}} \tag{13}$$

The amount of capital is fixed. Firms use the same aggregate good Q with corresponding price p_q as intermediate inputs as consumers for final goods consumption implying the following demand for intermediates:

$$I = \left(\phi_I \frac{p_x}{p_q}\right)^{\rho} X \tag{14}$$

The labor market is characterized by a constant elasticity supply curve, equation (15). Labor demand in equation (16) follows from the production function in equation (13):

$$w = p_q^e L^{\frac{1}{\varphi}} \tag{15}$$

$$L = \left(\phi_L \frac{p_x}{w}\right)^{\rho} X \tag{16}$$

To model labor market rigidities, the expected price level p_q^e responds less than proportional to the true price level p_q:

$$\widehat{p_q^e} = \xi_{p_q} \widehat{p_q}$$

Variables with a hat indicate relative changes. Working with (partially) sticky wages as in much of the recent business cycle literature (see Smets and Wouters (2003)) would generate equivalent results. Partial adjustment of the expected price level fits in the macro literature on imperfect information (see Mankiw and Reis (2010)).[4]

[4] Also, we could model unemployment using efficiency wages or search frictions, but the results would be equivalent to our specification, though we do not account explicitly for unemployment.

3 Properties of Basic Model

In this section we derive analytical results on the effects of exchange rate realignments of one of the trading partners, working with the small country assumption. The first subsection addresses the effects under balanced trade, then we come to the effects under a changing trade balance and finally we address the impact of imperfect pass through. In the next section we explore with simulations the impact of working with a large country starting from unbalanced trade.

3.1 Balanced Trade

We can log linearize the model to derive the effect of a change in the exchange rate of country i, R_i. To derive analytical results, we start from trade balance, i.e. $B = 0$. The relative change in the consumption price p_q and output price p_x follow easily from log differentiating equations (3) and (4) and (8)-(11):

$$\widehat{p_q} = \kappa_{TR} s_{m,i} \widehat{R_i} + (1 - \kappa_{TR}) \widehat{p_d} \tag{17}$$

$$\widehat{p_x} = \kappa_{TR} s_{e,i} \widehat{R_i} + (1 - \kappa_{TR}) \widehat{p_d} \tag{18}$$

κ_{TR} is the trade share of output, $\kappa_{TR} = \frac{p_e E}{p_e E + p_d D}$ and $s_{m,i}$ and $s_{e,i}$ are the import and export share of country i, $s_{m,i} = \frac{p_{m,i} M_i}{\sum_{i=1}^{N} p_{m,i} M_i}$ and $s_{e,i} = \frac{p_{e,i} E_i}{\sum_{i=1}^{N} p_{e,i} E_i}$.

To find the change in employment, the production side is log differenti-

ated, i.e. equations (13)-(15), leading to:[5]

$$\widehat{L} = \frac{\rho}{1-\lambda_I-\lambda_L}\left(\widehat{p_x} - (1-\lambda_I)\,\widehat{w} - \lambda_I \widehat{p_q}\right) \tag{19}$$

$$\widehat{w} = \xi_{p_q}\widehat{p_q} + \frac{1}{\varphi}\widehat{L} \tag{20}$$

Substituting equation (20) into (19) and rearranging, one arrives at:

$$\widehat{L} = A_0\left(\widehat{p_x} - \left(\lambda_I + (1-\lambda_I)\,\xi_{p_q}\right)\widehat{p_q}\right); \tag{21}$$

$$A_0 = \frac{\rho\varphi}{\varphi\,(1-\lambda_I-\lambda_L) + \rho\,(1-\lambda_I)} \tag{22}$$

Log differentiating the production and consumption optimality equations (6), (5) and the balance of trade equation (12), assuming that we start from balanced trade, leads to an expression for the relative change in domestic price as a function of the relative exchange rate change (derivation in Appendix A):

$$\widehat{p_d} = A_1\widehat{R_i} + \frac{1}{\theta+\sigma}dB; \tag{23}$$

$$A_1 = \frac{(\theta+1)\,s_{e,i} + (\sigma-1)\,s_{m,i}}{\theta+\sigma} \tag{24}$$

Substituting equations (17)-(23) into equation (21), we find the relative change in employment as a function of the relative exchange rate change:

$$\begin{aligned}\widehat{L} = {} & A_0\kappa_{TR}\left(s_{e,i} - \left(\lambda_I + (1-\lambda_I)\,\xi_{p_q}\right)s_{m,i}\right)\widehat{R_i} \\ & + A_0\,(1-\kappa_{TR})\left(1 - \left(\lambda_I + (1-\lambda_I)\,\xi_{p_q}\right)\right)\left(A_1\widehat{R_i} + \frac{1}{\theta+\sigma}dB\right)\end{aligned} \tag{25}$$

We can state the following result based on this equation:

Proposition 1 *In a small economy with balanced trade and fully adjusting*

[5] derivation in Appendix A

wages, employment expands in response to an appreciation of the currency of one of its trading partners if and only if the share of its exports to the trading partner is larger than the share of imports from the trading partner.

Proposition 1 follows directly from equation (25) setting ξ_{p_q} equal to 1, implying that the expected price level of workers is equal to the actual price level, so fully adjusting wages. A substitution elasticity between domestic and imported goods larger than 1 implies that substitution towards nontradables when import prices rise lead to an increase in the price of nontradables. This condition is likely to be satisfied in rich countries.

The three channels at work can be found in equations (19). First, an increase in the sales price p_x as a result of appreciation of the currency of a trading partner raises value marginal product of labor fostering labor demand. Second, an increase in p_q raises the cost of intermediates used in production. This decreases the marginal product of labor, reflected in the term $-\lambda_I \widehat{p_q}$ in equation (19). Third, the rise in p_q drives up wages in equation (20), which leads to less labor demand, the term $-(1-\lambda_I)\,\widehat{w}$ in equation (19). With fully adjusting wages, the overall effect depends on the trading partners import and export shares, which determine by how much output prices p_x and consumption/input price p_q change.

In proposition 1 we work with fully adjusting wages, representing the effects in the long run. With sticky wages there is a fourth channel present, represented by the second line in equation (25). An appreciation of the exchange rate of the trading partner drives up the import price and decreases the export price. If the substitution elasticity between domestic and imported goods is larger than 1, the domestic price p_d goes up. Therefore, both consumers and producers switch to domestic goods. This leads to increased demand for labor, unless wages are fully flexible. With fully flexible

wages the beneficial demand side effect on employment of the higher price of domestic goods would exactly cancel out against the adverse supply side effect through a higher price of intermediates and higher wage demands, as is clear from equation (25). With rigid wages (sticky price expectations in wage formation) instead the demand side effect of higher domestic price dominates the supply side effect.

Sticky price expectations reflect a soft labor market with high unemployment, where workers do not demand compensation for higher prices. Using equation (25) one can show that for reasonable parameter values the employment effects of apprecation of a trading partner are negative, also under sticky price expectations, when the import share of the trading partner is much larger than the export share. If we take for example $\theta = \frac{5}{3}$, $\sigma = 3$ as in Devarajan, et al. (1998), intermediates share $\lambda_I = 0.7$ and a tradables share of 0.3 we get a negative employment effect from a country's trading partner's appreciation when its import share $s_m = 0.2$ and its export share $s_e = 0.05$. Hence, also when wage demands are modest due to for example high unemployment, employment may still decline when a country's trading partner appreciates. Higher prices of imported intermediates have a direct negative impact on labor demand and this effect may dominate the beneficial effect of higher export prices and the beneficial substitution towards the use of domestic goods.

The effect of wage rigidity following from equation (25) can be summarized as follows:

Proposition 2 *In a small economy with balanced trade and a substitution elasticity between domestic and imported goods larger than* 1*, a higher degree of wage flexibility makes it more likely that an appreciation of the currency of one of its trading partners has a negative effect on employment.*

Larger wage flexibility raises the impact of higher import prices on wages the workers demand, leading to a more negative employment effect. There are two channels, a direct effect through higher import prices and an indirect effect through higher prices of domestic goods when the substitution elasticity between domestic and imported varieties, σ, is larger than 1. Hence, the employment effect is more likely to be negative in the long run, when wages can fully adjust. If we interpret the parameter ξ_{p_q} as following from conditions on the labor market, this proposition points out that it is less likely that an appreciation of the currency of one of the trading partners has a negative impact on employment when the labor market is softer with workers asking less compensation for increased prices.

We can also draw some conclusions on the influence of the intermediates share in output:

Proposition 3 *In a small economy with balanced trade, a substitution elasticity between domestic and imported goods larger than* 1 *and imperfect wage flexibility, an increase in the share of intermediates in output makes it more likely that an appreciation of the currency of one of its trading partners has a negative effect on employment.*

This proposition follows from the fact that a larger import price reduces employment through two channels: it depresses the marginal product of labor and raises wage demands. When wage flexibility is imperfect, the impact through the first channel is stronger. Hence, the larger the intermediates share, the larger the detrimental effect on employment.

3.2 Changing Trade Balance

Until now we have assumed that the country under consideration retains trade balance. Starting from balanced trade, i.e. $B = 0$, we can explore

the implications of a change in the trade balance analytically. In principle we need to extend the model with demand and supply for capital to determine the change in the capital balance. This would require a dynamic model making the model too complicated for the point we want to make. To show the effect of changes in the trade balance on the outcomes of exchange rate realignment, we address two scenarios: one where the Marshall-Lerner condition is not satisfied and one where it is satisfied. These correspond empirically with the short run and long run, respectively. When the Marshall-Lerner condition is not satisfied, $dB/dR_i > 0$, i.e. the trade balance deteriorates. From equation (23) and (25), we see that the employment effect of the deteriorating trade balance is positive. If more capital flows into the country, i.e. $dB > 0$, the demand for labor will increase through an increase in the price of nontradables (cf. equation (23)). When the Marshall-Lerner condition is satisfied, the trade balance improves. This has a negative employment effect, because the demand for labor declines as a result of the declining price of non-tradables, see equations (23) and (25). The effects are only present when wages are not fully adjusting, i.e. $\xi_{p_q} < 1$, as the effect runs through changes in the price of non-tradables and a change in the price of non-tradables only affects employment under inflexible wages.

We can summarize the discussion as follows:

Proposition 4 *In a small economy starting from balanced trade and a substitution elasticity between domestic and imported goods larger than* 1*, a deterioration of the trade balance as a result of an appreciation of the currency of one of its trading partners contributes positively to the change in employment. An improvement of the trade balance generates a negative contribution to the change in employment.*

So, an improving trade balance impinges negatively on employment,

which is a surprising result. The reason is that an improving trade balance goes along with capital outflows, leading to a lower price of nontradables and therefore less demand for labor. Observe that dynamic effects of an improving trade balance like capital outflows leading to less demand for labor are not taken into account.

3.3 Incomplete Pass Through

In the short run, changes in exchange rates might not fully work through into domestic prices. Working with a small country, there can be imperfect pass through on the importer side. The domestic import price $p_{m,i}$ changes less than proportional with the exchange rate R_i, $\widehat{p_{m,i}} = \xi_{p_{m,i}} \widehat{R_i}$. Working through the model, the new expression for the change in employment is now:

$$\begin{aligned} \widehat{L} &= A_0 \kappa_{TR} \left(s_{e,i} - \left(\lambda_I + (1-\lambda_I)\, \xi_{p_q} \right) \xi_{p_{m,i}} s_{m,i} \right) \widehat{R_i} \\ &\quad + A_0 \left(1 - \kappa_{TR}\right) \left(1 - \left(\lambda_I + (1-\lambda_I)\, \xi_{p_q} \right) \right) A_2 \widehat{R_i} \\ A_2 &= \frac{(\theta+1)\, s_{e,i} + (\sigma - 1)\, s_{m,i} \xi_{p_{m,i}}}{\theta + \sigma} \end{aligned} \tag{26}$$

Equation (26) makes clear that the export share and import share of a trading partner, the degree wage of rigidity and the degree of pass through together determine the employment effect of a trading partner's depreciation. More specific we can state the following:

Proposition 5 *In a small economy with balanced trade and a substitution elasticity between domestic and imported goods larger than* 1*, employment expands in response to an appreciation of the currency of one of its trading partners if and only if wages are fully flexible and the share of its exports to the trading partner is larger than the share of imports from the trading partner times the rate of pass through.*

Proposition 6 *In a small economy with balanced trade and a substitution elasticity between domestic and imported goods larger than* 1*, an increase in the rate of pass through of imports makes it more likely that an appreciation of the currency of one of its trading partners has a negative effect on employment.*

As we are considering a small country, the rate of pass through onto sales prices in the export market is by definition zero: firms have no market power in the foreign market and are thus not able to pass part of the lower exchange rate onto their buyers. In the simulations we address the large country case and also come to the possibility of incomplete pass through on the exporter side. Proposition 5 makes clear that the employment effects of an appreciation of a country's trading partner can be positive, irrespective of this trading partner's importance in exports and imports when the rate of pass through on the importer side goes to zero.

Incomplete pass through goes together with markup adjustments and market power. With appreciation of the currency of a trading partner incomplete pass through means that importers with market power lower their markups. Proposition 6 points out that a lower degree of pass through dampens the negative employment effects of appreciation of the currency of a trading partner, because import prices do not rise so much. The importers with market power pay the price for this dampened employment effect, because of the lower markups they charge.

4 Numerics

So far we have worked with a small country, focusing on general equilibrium mechanics within the economy. In this section, we work with a numerical

version of the model, implemented as a multi-country extension of the basic theory and calibrated to macroeconomic data for 2007. We use the model to illustrate numerically the role that parameters play, as outlined above, when we open up the underlying framework to allow for size and third country effects.

Before discussion numerics in detail, we will briefly discuss expected changes in the effect of exchange rate realignment. The first is that, when the country under consideration is large, foreign prices $\pi_{m,i}$ and $\pi_{e,i}$ vary with the volume of the country's imports and exports. The effect of the policy experiment explored in the basic model, an appreciation of the currency of one of the trading partners, can be expected to change as follows. The appreciation raises both the domestic export and import price. This implies more exports and less imports. More exports implies more imports for the trading partner and a move along its import demand function, such that the export price of our country will increase less as a result of the appreciation and the gains on the export side will be smaller. The decrease in imports means a shift along the export supply curve of the trading partner towards lower prices. Our import price will go up less and the losses on the import side will be smaller. So, we can expect that working with a large instead of small country attenuates the effects of an exchange rate realignment.

Additionally, in the basic model we were able to focus strictly on price changes of the realigning trading partner. If the realigning country also appreciates relative to third countries, export and import prices vis-vis other countries will change as well. An appreciation of the realigning trading partner vis-a-vis other countries implies on the export side that our country becomes cheaper in third markets and will pick up market share. Exports and the export price will increase implying larger gains on the export side.

On the import side effects also become larger. Third countries will have to pay more for imports from the appreciating country. This drives up their price of exports through increased prices of intermediates and a shift in demand towards non-tradables. The higher export price of third countries makes imports for our country more expensive with adverse employment effects. Appendix B lists the set of equations for the multicountry model, the underlying data, and the baseline parameter values. All equations are as in the basic model, but we explicitly model all countries, implying that foreign prices are not given.[6] Running simulations requires an explicit expression for how the capital balance changes. We focus on the case where the Marshall-Lerner condition is met (so trade balances improve with a depreciated exchange rate.) These conditions are discussed formally in Appendix B.

We numerically estimate the effects of an appreciation by China on employment in the US, starting from our basic data for 2007. We actually implement both a 20% appreciation against the US (a bilateral revaluation), and 20% appreciation against the world (a multilateral revaluation). This is done while ranging parameters to examine their role, as represented above in the analytical discussion.

We start with Figure 1, where we present employment effects for both the bilateral and multilateral experiments over a range of values for the trade substitution elasticity. Recall that the numeric examples in Figure 1 reflect the assumption that the Marshall-Lerner conditions are met. On the basis of the simulations, we make the following observation.

Observation 1 *In a multi-country setting with large countries, an appreciation of the currency of one of the trading partners can lead to either a decline*

[6] GAMS-based model code is available on request.

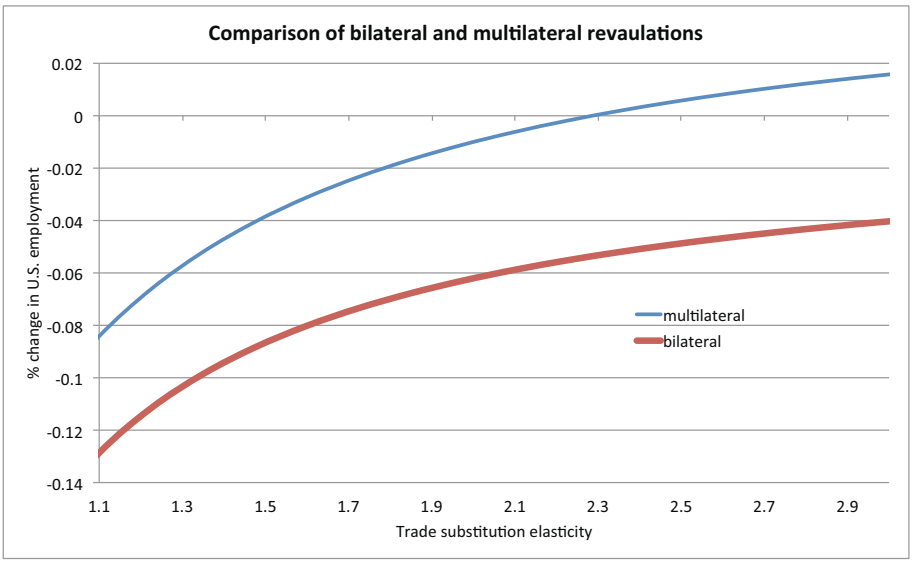

Figure 1: trade substitution and employment effects

or gain in employment, even with an improvement in the trade balance. This depends, in part, on the underlying elasticity of substitution for imports.

What we stress in Observation 1 is that there is not an unambiguous pairing between trade balance improvement and employment gains. Indeed, we can have gains or losses in employment, and this will hinge on the properties of technology, the underlying trade relationship, and preferences. It also depends on labor market conditions. In Figure 2 we present estimated employment effects of revaluation under alternative labor market conditions, leading to the following observation:

Observation 2 *In a multi-country setting with large countries, higher wage flexibility (higher labor supply elasticity) can lead to larger employment effects. However, this can be a magnification of losses or gains.*

The ambiguity stressed in Observation 2 is linked to Observation 1. Given ambiguity in the change in employment levels, this ambiguity can itself be magnified by labor market conditions. Indeed, it is the case that, in an

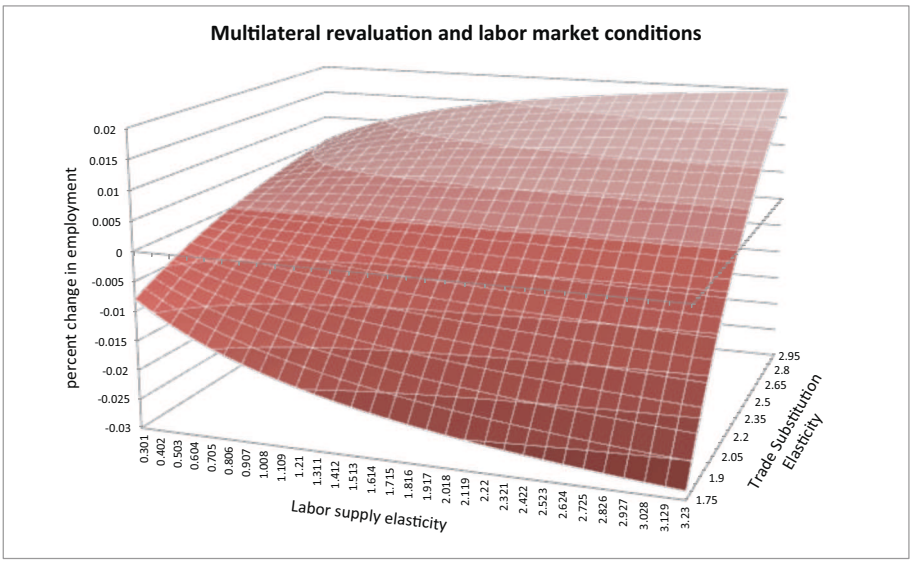

Figure 2: wage flexibility and employment

equilibrium characterized by revaluation generating employment, situations of relatively flat labor supply can yield even greater job gains. They can also yield even greater jobs losses. Note also the importance of trade substitution (the extent to which China's goods can be substituted following revaluation), as stated in the Proposition 3.

Observation 3 *In the numerical model, the easier it is to substitute away from more expensive (revalued) inputs toward other inputs, the greater the job gains or smaller the job losses.*

The relationship stressed in Observation 3 can be seen in Figures 1 and 2 above and Figure 3, which is discussed below.

Finally, both panels of Figure 3 map a range of results for variation in the ease to substitute between value added and inputs. The focus on substitutability in production highlights the extent to which domestic value added can be used in lieu of higher priced imports. Following from Observation 1, Figure 3 again highlights ambiguity, in particular depending on the trade

substitution elasticity. In addition, the numerical results also illustrate that there is ambiguity with respect to the degree of substitution between inputs and value added in equation (13). When we have jobs losses, these are magnified in our numerical examples as we increase this value. However when we have job gains, these are also magnified as we increase the degree of substitution between inputs and value added ρ. On the basis of the simulations,

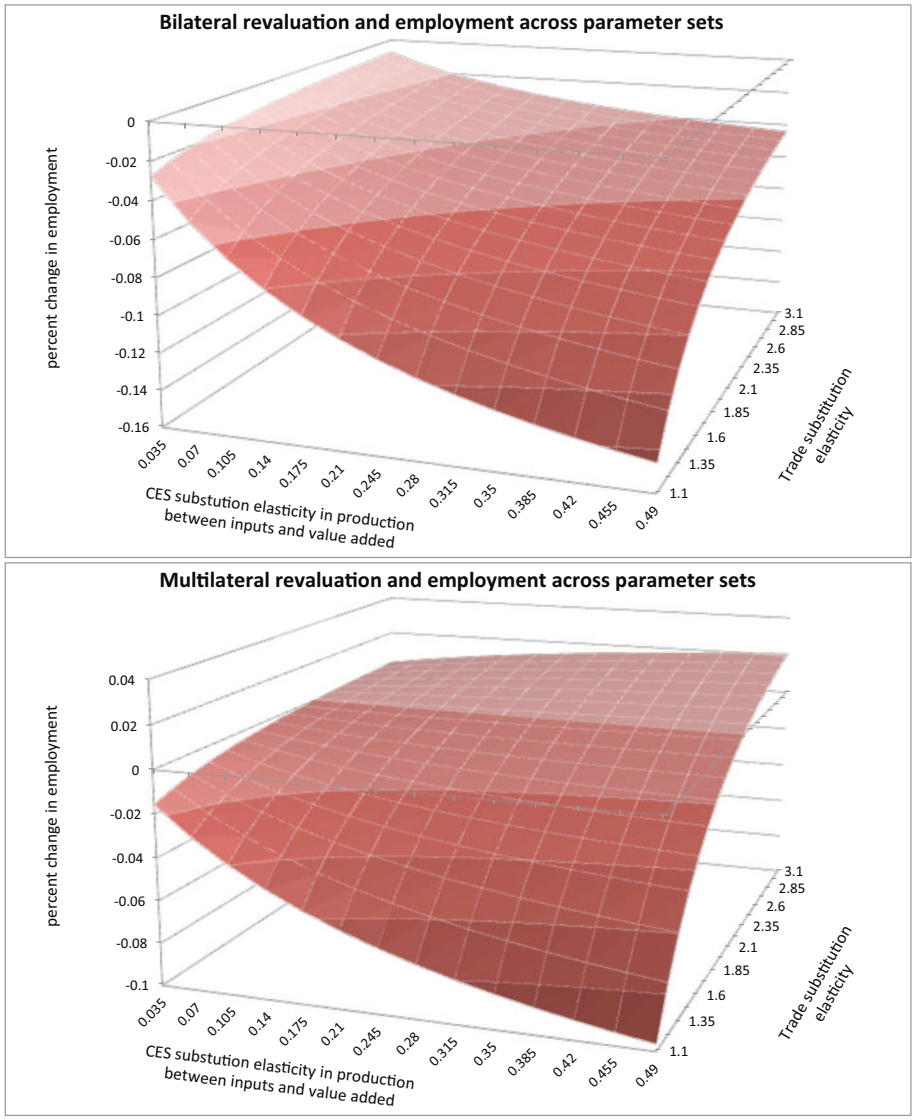

Figure 3: substitution between inputs and value added

we make the following observation.

Observation 4 *In a multi-country setting with large countries, the impact on employment depends on the combination of the degree of substitution in production between inputs and value added, and between sources of inputs (the trade substitution elasticity).*

The mechanics driving this last observation are those drawn out in the analytical discussion above. Increased prices of intermediates can reduce demand for labor in a setting with imperfect substitutability between intermediates and labor (a volume effect), though this is weaked by greater degrees of substitution (an input price effect). On top of this, increased prices of imported consumer goods drive up wage demands, which also reduces demand for labor (a consumer price). From Figure 3, how these work out on net can involve gains or losses in jobs following revaluation by a trading partner.

5 Summary and Closing Remarks

In this paper we have extended the de Melo and Robinson (1986) model of production and trade to include intermediate linkages and variable labor market conditions. We have used this to study the employment effects of bilateral revaluation on employment. A basic contribution to the literature is the focus on bilateral rather than general revaluation, and the emphasis on the composition of imports in this context.

Analytically, we focus individually on factors like technology, the bilateral balance of trade, and the composition of imports. This is complemented by numerical analysis with a calibrated numerical model, used to highlight the interaction of factors examined individually in the analytics. With fully flexible labor markets and full pass-through, employment increases with ap-

preciation of one of the trading partners when the fraction exported to the trading partner is larger than the fraction imported. With sticky wages, a larger fraction of intermediate inputs in production makes it more likely that the negative supply side effects dominate positive demand effects. A smaller degree of stickyness of price expectations in wage formation and a smaller importer pass through make the negative supply side effects smaller. In the numerics, the ability to substitute for higher cost inputs following a trading partner revaluation proves critical to the direction of employment changes. General labor market conditions, in terms of wage sensitivity to increased labor demand, also prove critical to the magnitude of employment effects. Indeed, depending on technology, weaker labor markets may imply magnified job gains or losses following revaluation.

Our focus here has been on direct employment effects of exchange rate realignment linked to relative price changes, rather than the issue of sustainability of current account imbalances. In the current context of both China (vis-a-vis the US) and Germany (vis-a-vis the euro zone), these provide additional channels to argue about macroeconomic effects of real exchange rate misalignment outside the scope of this paper. With respect to the framework explored here, extensions that combine real misalignment with a sub-set of countries (like within the euro) might be particularly fruitful.

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Appendix A Derivations Basic Model

Equation (23)

Start by log differentiating equations (10) and (11) substituting into the log differentiation of equations (8) and (9) to get:

$$\widehat{p_m} = s_{m,i}\widehat{R_i} \tag{A.1}$$

$$\widehat{p_e} = s_{e,i}\widehat{R_i} \tag{A.2}$$

Next, log differentiate equations (6) and (5), using (A.1) and (A.2):

$$s_{m,i}\widehat{M_i} - \widehat{D} = \sigma\left(\widehat{p_d} - s_{m,i}\widehat{R_i}\right) \tag{A.3}$$

$$s_{e,i}\widehat{E_i} - \widehat{D} = \theta\left(s_{e,i}\widehat{R_i} - \widehat{p_d}\right) \tag{A.4}$$

Combining equations (A.3) and (A.4) leads to:

$$\begin{aligned} s_{m,i}\widehat{M_i} - \sigma\left(\widehat{p_d} - s_{m,i}\widehat{R_i}\right) &= s_{e,i}\widehat{E_i} - \theta\left(s_{e,i}\widehat{R_i} - \widehat{p_d}\right) \\ s_{e,i}\widehat{E_i} - s_{m,i}\widehat{M_i} &= \theta\left(s_{e,i}\widehat{R_i} - \widehat{p_d}\right) - \sigma\left(\widehat{p_d} - s_{m,i}\widehat{R_i}\right) \\ s_{e,i}\widehat{E_i} - s_{m,i}\widehat{M_i} &= \left(\theta s_{e,i} + \sigma s_{m,i}\right)\widehat{R_i} - \left(\theta + \sigma\right)\widehat{p_d} \end{aligned} \tag{A.5}$$

Log differentiating the BoP condition, equation (12), assuming that we start from balanced trade, gives:

$$dB = s_{m,i}\left(\widehat{M_i} + \widehat{R_i}\right) - s_{e,i}\left(\widehat{E_i} + \widehat{R_i}\right) \tag{A.6}$$

Substituting equation (A.5) into equation (A.6) implies the equation for the relative change of p_d in the main text, equation (23)

Equation (19)

Log differentiating equations (13)-(15) gives:

$$\widehat{X} = \lambda_L \widehat{L} + \lambda_I \widehat{I} \tag{A.7}$$

$$\widehat{I} = \rho\left(\widehat{p_x} - \widehat{p_q}\right) + \widehat{X} \tag{A.8}$$

$$\widehat{L} = \rho\left(\widehat{p_x} - \widehat{w}\right) + \widehat{X} \tag{A.9}$$

$$\widehat{w} = \xi_{p_q}\widehat{p_q} + \frac{1}{\varphi}\widehat{L} \tag{A.10}$$

Substituting equation (A.7) into equations (A.8) and (A.9) and solving for $\widehat{L}$ generates:

$$\widehat{L} = \rho\frac{1}{1-\lambda_I-\lambda_L}\widehat{p_x} - \rho\frac{1-\lambda_I}{1-\lambda_I-\lambda_L}\widehat{w} - \rho\frac{\lambda_I}{1-\lambda_I-\lambda_L}\widehat{p_q} \tag{A.11}$$

Appendix B The Numerical Model

The numerical model is described by the following set of equations. Variables with a subscript ij indicate flows from country i to country j.

$$X_i = G_i\left(E_i, D_{s,i}\right) = \left(\beta_{E_i} E_i^{\frac{\theta+1}{\theta}} + \beta_{D_{s,i}} D_{s,i}^{\frac{\theta+1}{\theta}}\right)^{\frac{\theta}{\theta+1}} \quad \text{(B.1)}$$

$$Q_i = F_i\left(M_i, D_{d,i}\right) = \left(\alpha_{M_i} M_i^{\frac{\sigma-1}{\sigma}} + \alpha_{D_{d,i}} D_{d,i}^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \quad \text{(B.2)}$$

$$M_{ji} = \left(\frac{p_{m_{ji}}}{\gamma_{ji} p_{m_i}}\right)^{-\eta} M_i \quad \text{(B.3)}$$

$$E_{ij} = \left(\frac{p_{e_{ij}}}{\delta_{ij} p_{e_i}}\right)^{\omega} E_i \quad \text{(B.4)}$$

$$p_{q_i} = \left(\alpha_{M_i}^{\sigma} p_{m_i}^{1-\sigma} + \alpha_{D_{d,i}}^{\sigma} p_{d_i}^{1-\sigma}\right)^{\frac{1}{1-\sigma}} \quad \text{(B.5)}$$

$$p_{x_i} = \left(\beta_{E_i}^{-\theta} p_{e_i}^{\theta+1} + \beta_{D_{s,i}}^{-\theta} p_{d_i}^{\theta+1}\right)^{\frac{1}{\theta+1}} \quad \text{(B.6)}$$

$$p_{m_i} = \left(\sum_{j \neq i}^{N} \gamma_{ji}^{\eta} p_{m_{ji}}^{1-\eta}\right)^{\frac{1}{1-\eta}} \quad \text{(B.7)}$$

$$p_{e_i} = \left(\sum_{j \neq i}^{N} \delta_{ij}^{-\omega} p_{e_{ij}}^{\omega+1}\right)^{\frac{1}{\omega+1}} \quad \text{(B.8)}$$

$$R_{ij} p_{e_{ij}} = p_{m_{ij}} \quad \text{(B.9)}$$

$$E_{ij} = M_{ij} \quad \text{(B.10)}$$

$$\frac{M_i}{D_{d,i}} = \left(\frac{\alpha_{M_i}}{\alpha_{D_{d,i}}} \frac{p_{d_i}}{p_{m_i}}\right)^{\sigma} \quad \text{(B.11)}$$

$$\frac{E_i}{D_{s,i}} = \left(\frac{\beta_{D_{s,i}}}{\beta_{E_i}} \frac{p_{e_i}}{p_{d_i}}\right)^{\theta} \quad \text{(B.12)}$$

$$B_i = p_{m_i} M_i - p_{e_i} E_i \quad \text{(B.13)}$$

$$B_i = \overline{B} \quad \text{(B.14)}$$

$$D_{d_i} - D_{s_i} = 0 \quad \text{(B.15)}$$

$$X_i = \left(\phi_{I_i} I_i^{\frac{\rho-1}{\rho}} + \phi_{L_i} L_i^{\frac{\rho-1}{\rho}} + \phi_{K_i} K_i^{\frac{\rho-1}{\rho}}\right)^{\frac{\rho}{\rho-1}} \tag{B.16}$$

$$I_i = \left(\phi_{I_i} \frac{p_{x_i}}{p_{q_i}}\right)^{\rho} X_i \tag{B.17}$$

$$L_i = \left(\phi_{L_i} \frac{p_{x_i}}{w_i}\right)^{\rho} X_i \tag{B.18}$$

$$w_i = p_{q_i}^e L_i^{\frac{1}{\varphi_i}} \tag{B.19}$$

R_{ij} is the exchange rate between country i and j or more specifically the price of the currency of country i expressed in terms of the currency of country j. So, an increase in R_{ij} reflects an appreciation of the currency of country i relative to the currency of country j.

All the equations are as in the small economy model, we added equations for import demand and export supply per country (B.3) and (B.4) and an equation imposing that the exports of country i to country j are equal to the imports of country j from country i.

We get $15N + 4\,(N-1)\,N$ equations in the same number of unknowns, the following 15 variables per country:

$$X_i, Q_i, M_i, E_i, D_{d_i}, D_{s_i}, p_{x_i}, p_{q_i}, p_{d_i}, p_{e_i}, p_{m_i}, B_i, I_i, L_i, w_i$$

and the $N-1$ variables $M_{ij}, E_{ij}, p_{m_{ij}}, p_{e_{ij}}$ per country.

The model is calibrated to macroeconomic data for 2007, based on data from the IMF's World Economic Outlook database and the GTAPv8 database from the GTAP Project.

Running experiments, we add two sets of equations for sticky prices and wages. Incomplete adjustment of the price expectations in wage formation implies:

$$\widehat{p_{q_i}^e} = \xi_{p_{q_i}} \widehat{p_{q_i}} \tag{B.20}$$

Incomplete pass through implies:

$$\widehat{p_{m_{ij}}} = \xi_{p_{m_{ij}}} \left(\widehat{R_{ij}} + \widehat{p_{e_{ij}}} \right) \tag{B.21}$$

To model changes in the trade balance, we distinguish between the cases where the Marshall Lerner condition is and is not satisfied. We work with the following equation for the changing trade balance:

$$\widehat{B_{ij}} = \mu sign\left(B_{ij}\right) \widehat{R_{ij}} \tag{B.22}$$

$\mu > 0$ and $\mu < 0$ reflect respectively the situations where the Marshall Lerner is and is not satisfied. If the initial capital balance is positive ($B_{ij} > 0$) and $\mu > 0$, an appreciation of the currency of country i relative to country j raises B_{ij}, so increases capital inflows into the country. If the initial capital balance is negative and $\mu > 0$, an appreciation of the currency of country i relative to country j should raise B_{ij} as well and so should decrease B_{ij} in absolute terms. Therefore, we have to add the $sign\left(B_{ij}\right)$ term.

The change in the total trade balance is a function of the sum of the bilateral trade balance changes:

$$\begin{aligned} \widehat{B_i} &= \sum_{j \neq i} \frac{B_{ij}}{B_i} \widehat{B_{ij}} \\ &= \sum_{j \neq i} \frac{B_{ij}}{B_i} \mu sign\left(B_{ij}\right) \widehat{R_{ij}} \end{aligned} \tag{B.23}$$

We need to set values for the following parameters, $\theta, \sigma, \eta, \omega, \rho, \varphi_i$ and the taste parameters $\beta_{E_i}, \alpha_{M_i}, \gamma_{ij}, \delta_{ij}, \phi_I, \phi_L, \phi_K$ and the scale parameters $\overline{A_i}$. The chosen values of the parameters are displayed in 2. To get expressions for the taste parameters we can set all prices at 1 in the baseline scenario and express the taste parameters and scale parameters as a function of the

Table 2: Values of Parameters

parameters in benchmark
$\theta = 10$
$\sigma = 1.25$
$\eta = 1.25$
$\omega = 30$
$\rho = 0.35$
$\varphi = 1.5$
$\mu = 0.05$
$\xi_{p_q} = 1$
$\xi_{p_m} = 0.9$

value shares:[7]

$$
\begin{aligned}
\delta_{ij} &= \left(\frac{E_{ij}p_{e_{ij}}}{E_i p_{e_i}}\right)^{-\frac{1}{\omega}} \left(\frac{p_{e_{ij}}}{p_{e_i}}\right)^{\frac{\omega+1}{\omega}} = \left(\frac{E_{ij}p_{e_{ij}}}{E_i p_{e_i}}\right)^{-\frac{1}{\omega}} \\
\gamma_{ji} &= \left(\frac{M_{ji}p_{m_{ji}}}{M_i p_{m_i}}\right)^{\frac{1}{\eta}} \left(\frac{p_{e_{ij}}}{p_{e_i}}\right)^{\frac{\eta-1}{\eta}} = \left(\frac{M_{ji}p_{m_{ji}}}{M_i p_{m_i}}\right)^{\frac{1}{\eta}} \\
\alpha_{M_i} &= \left(\frac{M_i p_{m_i}}{Q_i p_{q_i}}\right)^{\frac{1}{\sigma}} \\
\alpha_{D_i} &= \left(1 - \frac{M_i p_{m_i}}{Q_i p_{q_i}}\right)^{\frac{1}{\sigma}} \\
\beta_{E_i} &= \left(\frac{E_i p_{e_i}}{X_i p_{x_i}}\right)^{-\frac{1}{\theta}} \\
\beta_{D_i} &= \left(1 - \frac{E_i p_{e_i}}{X_i p_{x_i}}\right)^{-\frac{1}{\theta}} \\
\phi_{I_i} &= \left(\frac{I_i p_{q_i}}{X_i p_{x_i}}\right)^{\frac{1}{\rho}} \\
\phi_{L_i} &= \left(\frac{L_i w_i}{X_i p_{x_i}}\right)^{\frac{1}{\rho}} \\
\phi_{K_i} &= \left(\frac{K_i r_i}{X_i p_{x_i}}\right)^{\frac{1}{\rho}} \\
\overline{A_i} &= \left(\frac{L_i}{\overline{X_i}}\right)^{-\frac{1}{\varphi_i}}
\end{aligned}
$$

[7] If in the baseline prices are not equal to 1, this just means that volumes of the different variables are measured in different units.