Trade Costs and the Open Macroeconomy

Dennis Novy

No 778

WARWICK ECONOMIC RESEARCH PAPERS

DEPARTMENT OF ECONOMICS

THE UNIVERSITY OF WARWICK

Trade Costs and the Open Macroeconomy*

Dennis Novy†
University of Warwick

14 November 2006

Abstract

Trade costs are known to be a major obstacle to international economic integration. Following the approach of New Open Economy Macroeconomics, this paper explores the effects of international trade costs in a micro-founded general equilibrium model that also allows for pricing to market. Trade costs are shown to create an endogenous home bias in consumption and reduce cross-country consumption correlations. In addition, trade costs magnify exchange rate volatility in response to monetary shocks and typically turn a monetary expansion into a beggar-thy-neighbor policy. It is striking that trade costs generally lead to these results both under producer and local currency pricing.

JEL classification: F12, F31, F41
Keywords: Trade Costs, New Open Economy Macroeconomics, Pricing to Market, Exchange Rates, Consumption Correlations

*I am grateful to Giancarlo Corsetti, Petra Geraats and Neil Rankin for helpful comments.
†Department of Economics, University of Warwick, Coventry CV4 7AL, United Kingdom. Tel. +44-2476-150046, Fax +44-2476-523032. d.novy@warwick.ac.uk and http://www2.warwick.ac.uk/fac/soc/economics/staff/faculty/novy/

1 Introduction

Trade costs have long been known as a major obstacle to international economic integration. In a recent survey, James Anderson and Eric van Wincoop (2004) show that empirical trade costs are large even when formal barriers to trade do not exist. They argue that the tariff equivalent of representative international trade costs is around 74%. This paper puts trade costs in the spotlight by integrating them into a rigorous micro-founded general equilibrium model. The central focus of the paper is to explore their theoretical effects on cross-country consumption correlations, exchange rate volatility and welfare.

Following the approach of New Open Economy Macroeconomics, the paper demonstrates that even moderate international trade costs can substantially tone down the cross-country correlation of consumption. Trade costs are therefore likely to play an important role in explaining the consumption correlations puzzle. In addition, trade costs magnify exchange rate volatility in the face of monetary shocks, and for realistic parameter values they convert a monetary expansion into a beggar-thy-neighbor policy for welfare. An overarching result of the paper is that all these effects generally arise under both producer and local currency pricing. The findings therefore have the potential to apply to a wide range of modeling frameworks because they do not crucially depend on the degree of pricing to market.

Intuitively, by raising the price of imported goods trade costs render domestic goods more attractive to consumers. As a consequence, spending is predominantly kept within the domestic country and consumption is tilted towards domestic goods, creating an endogenous home bias in consumption. This *containment effect* of trade costs tends to isolate two countries from each other and makes them behave more like closed economies. Shocks hitting one country therefore have a reduced bearing on the other, weakening current account movements and the international correlations of consumption and output. As a result of the containment effect, trade costs also prevent a domestic monetary expansion from sufficiently stimulating demand for foreign goods. For a wide range of realistic parameter values they therefore lead to negative welfare spillovers.

The effect of trade costs is generally biggest when the two countries are of equal size. Intuitively, in that case the volume of trade flows is largest and trade costs are most detrimental. Interestingly, the impact of trade costs is nonlinear such that small magnitudes are sufficient to create a sizeable effect.

The model of my paper falls into the tradition of the New Open Economy Macroeconomics literature that has evolved from Maurice Obstfeld and Kenneth Rogoff's (1995) seminal contribution. It represents a micro-founded two-country general equilibrium framework with monopolistic competition and one-period price stickiness. The key contribution of my paper is to combine this set-up with iceberg trade costs as the central modeling device. As a consequence of trade costs, many conclusions from Obstfeld and Rogoff's (1995) paper no longer hold, for example consumption is no longer highly correlated across countries and a monetary expansion no longer leads to positive welfare spillovers.

In addition, I adopt the pricing-to-market extension by Caroline Betts and Michael Devereux

(2000) to allow for local currency pricing. Betts and Devereux (2000) show that local currency pricing reduces consumption correlations and leads to negative welfare spillovers. My paper generalizes this finding by demonstrating that local currency pricing is not necessary to obtain these results. In fact, trade costs generally reduce consumption correlations and lead to negative welfare spillovers for any degree of pricing to market. Moreover, as discussed by Andrew Atkeson and Ariel Burstein (2006), trade costs are a plausible cause of market segmentation and thus provide a good motivation for local currency pricing and deviations from the law of one price.

Paul Krugman (1980) is the first author to introduce iceberg trade costs into a monopolistic competition framework but he focuses on trade and increasing returns and does not model money nor the exchange rate. John Fender and Chong Yip (2000) consider a unilateral tariff but not symmetric trade costs. Ravn and Mazzenga (2004) evaluate the effect of transportation costs in a real business cycle approach. Apart from the flexible-price environment their paper is different by assuming a home bias in preferences. The latter assumption is also made by Francis Warnock (2003), whereas in my paper preferences are deliberately not biased. Unbiased preferences are supported by micro-evidence from Carolyn Evans (2001) and in combination with trade costs, they give rise to an *endogenous* home bias in consumption.

My model is closely related in spirit to the paper by Obstfeld and Rogoff (2000). They have given trade costs new impetus by pointing out their potential to elucidate major puzzles of international macroeconomics like the consumption correlations puzzle. But Obstfeld and Rogoff (2000) only use a small open endowment economy model, as do Paul Bergin and Reuven Glick (2006) who introduce heterogeneous iceberg trade costs and endogenous tradability. Allan Brunner and Kanda Naknoi (2003) integrate trade costs into a more rigorous two-country general equilibrium model with production, assuming full pass-through of the exchange rate. Generalizing this framework even further, my paper allows for less than full pass-through, shows that trade costs reduce consumption correlations across countries and also conducts a welfare analysis. Furthermore, it demonstrates that the effects of trade costs are typically most pronounced when two countries are of equal size. Intuitively, when two countries are equally big, the overall reliance on trade is largest and the impact of trade costs is felt most strongly.

The inclusion of trade costs yields results that are in some respects similar to the ones obtained by David Backus and Gregor Smith (1993) and Harald Hau (2000) in their models with nontradable goods. Hau (2000) also finds that consumption becomes less correlated across countries and that both nominal and real exchange rates are more volatile in the presence of monetary shocks. But my paper obtains these results with tradable goods only. The abstraction from nontradable goods is motivated by empirical evidence by Charles Engel (1999) and V. V. Chari, Patrick Kehoe and Ellen McGrattan (2002), showing that the relative price of nontradable goods accounts for virtually none of U.S. and European real exchange rate movements. Instead, the real exchange rate appears to be driven almost exclusively by the relative price of tradable goods.

The paper is structured as follows. Section 2 introduces trade costs into a New Open Economy Macroeconomics model with sticky prices. Section 3 describes its flexible-price equilibrium, establishing the endogenous home bias in consumption. Section 4 discusses the effects of monetary shocks under sticky prices with particular focus on the volatility of real and nominal exchange rates. It also presents simulation results, showing that moderate values of trade costs can lead to substantial reductions in cross-country consumption correlations. In Section 5 I conduct a welfare analysis with the result that a monetary expansion is typically a beggar-thy-neighbor policy in the presence of trade costs. Section 6 concludes.

2 A Model with Trade Costs

The model follows the New Open Economy Macroeconomics literature and is based on the pricing-to-market setting in Betts and Devereux (2000). As a new ingredient there exist exogenous 'iceberg' trade costs τ, where τ represents the fraction of goods that melts away during the trading process with $0 \leq \tau < 1$. If $\tau = 0$ we have the special case of frictionless trade that is customary in the literature. In the extreme case of $\tau \to 1$, trade between the two countries breaks down and they become closed economies.

Households choose among a continuum $[0, 1]$ of differentiated, nondurable and tradable goods which are produced by monopolistic firms. The sizes of the Home and Foreign countries are n and $1-n$ with $0 < n < 1$. As in Betts and Devereux (2000), it is assumed that s with $0 \leq s \leq 1$ is the fraction of firms in each country that engage in pricing to market (PTM) and that can price-discriminate across the two countries because households cannot arbitrage away potential cross-country price differences. If $s = 0$ all firms set prices in producer currency, if $s = 1$ all firms set prices in local currency.

2.1 Households

Households derive utility from consumption C_t and also from real money balances M_t/P_t due to a transactionary motive but they dislike work h_t. In Home country notation utility is given by

$$U_t = \sum_{v=t}^{\infty} \beta^{v-t} \left(\ln C_v + \frac{\gamma}{1-\epsilon} \left(\frac{M_v}{P_v} \right)^{1-\epsilon} + \eta \ln (1 - h_v) \right) \tag{1}$$

with the composite consumption index defined as

$$C_t \equiv \left(\int_0^1 c_{it}^{\left(\frac{\rho-1}{\rho}\right)} \, \mathrm{d}\, i \right)^{\frac{\rho}{\rho-1}} \tag{2}$$

where ρ is the elasticity of substitution with $\rho > 1$, c_{it} is consumption of good i at time t, β is the subjective discount factor with $0 < \beta < 1$, M_t is the money supply and h_t represents labor. The parameters β, γ, ϵ, η and ρ are positive and identical across countries. All above variables C_t and h_t etc. are Home per-capita variables. Since all households within one country are identical by construction, the corresponding Home aggregate quantities are nC_t and nh_t etc. Note that unlike in Warnock (2003) there is no home bias in preferences.

The Home consumption-based price index is defined as the minimum expenditure subject to $C_t = 1$ and can be derived as[1]

$$P_t = \left[\int_0^n {p_{it}}^{1-\rho} \,\mathrm{d}\, i + \int_n^{n+(1-n)s} \left(\frac{1}{1-\tau} p^*_{it} \right)^{1-\rho} \mathrm{d}\, i + \int_{n+(1-n)s}^1 \left(\frac{1}{1-\tau} e_t q^*_{it} \right)^{1-\rho} \mathrm{d}\, i \right]^{\frac{1}{1-\rho}} \tag{3}$$

The Foreign price index is given by

$$P^*_t = \left[\int_0^{ns} \left(\frac{1}{1-\tau} q_{it} \right)^{1-\rho} \mathrm{d}\, i + \int_{ns}^{n} \left(\frac{1}{1-\tau} \frac{1}{e_t} p_{it} \right)^{1-\rho} \mathrm{d}\, i + \int_n^1 {q^*_{it}}^{1-\rho} \,\mathrm{d}\, i \right]^{\frac{1}{1-\rho}} \tag{4}$$

where prices p represent Home currency goods prices and prices q represent Foreign currency goods prices. In general, asterisks indicate Foreign country variables but in the context of goods prices an asterisk means that a price is *set* by a Foreign firm. Thus, all p^*_{it} are set by Foreign firms in Home currency and all q^*_{it} are set by Foreign firms in Foreign currency.

The goods in the range $[0, n]$ are produced by Home firms and the goods in the range $[n, 1]$ are produced by Foreign firms. In the Home price index (3), Foreign firms price to market for the goods in the range $[n, n + (1 - n)s]$, i.e. they set the corresponding prices p^*_{it} in Home currency. The range $[n + (1 - n)s, 1]$ represents the goods produced by Foreign firms that do not price to market and therefore set prices q^*_{it} in Foreign currency. These are converted into Home currency through multiplying by the nominal exchange rate e_t, which is defined as the Home price of Foreign currency.

Note that the factor $\frac{1}{1-\tau}$ is included in the range $[n, 1]$ of Home index (3) as well as in the range $[0, n]$ of Foreign index (4). The reason is that all prices p_{it}, p^*_{it}, q_{it}, q^*_{it} are f.o.b. (free on board) unit prices that are charged at the factory gate. If a Foreign good is shipped to the Home country, only the fraction $(1 - \tau)$ arrives. The Home consumer must therefore buy $\frac{1}{1-\tau}$ units in the Foreign country so that one full unit arrives in the Home country. Hence, from a Home consumer's perspective $\frac{1}{1-\tau} p^*_{it}$ is the c.i.f. (cost, insurance and freight) unit price of a Foreign pricing-to-market good, and $\frac{1}{1-\tau} e_t q^*_{it}$ is the c.i.f. unit price of a Foreign non-pricing-to-market good. One can think of this f.o.b./c.i.f. relationship as firms' charging an additional markup for shipping the purchased goods over to the destination country.[2]

Asset markets are complete domestically such that each household owns an equal share of an initial stock of domestic currency and an equal share of all domestic firms. There is no bond denominated in Foreign currency but there is free and costless trade in a Home currency nominal discount bond. F_t represents the Home holdings of the bond maturing in period $t + 1$ and d_t is its price. The Home budget constraint at time t in per-capita terms is thus given by

$$P_t C_t + M_t + d_t F_t = W_t h_t + \pi_t + M_{t-1} + Z_t + F_{t-1} \tag{5}$$

[1] The derivations of this section are outlined in Appendix A.

[2] However, the fraction τ of goods gets lost in the trading process so that firms do not receive the additional markup. See Section 4.4 for a rebate of trade costs.

where W_t is the nominal wage rate, π_t are Home firms' profits and Z_t are nominal lump-sum transfers from the Home government.

The Home consumption demand function can be derived as

$$c_{it} = \left(\frac{\xi_{it}}{P_t}\right)^{-\rho} C_t \tag{6}$$

where

$$\xi_{it} = \begin{cases} p_{it} & \text{for} \quad 0 \leq i \leq n \\ \frac{1}{1-\tau} p_{it}^* & \text{for} \quad n \leq i \leq n + (1-n)s \\ \frac{1}{1-\tau} e_t q_{it}^* & \text{for} \quad n + (1-n)s \leq i \leq 1 \end{cases} \tag{7}$$

analogous to the three terms in price index (3).

2.2 Government

Let the composite government consumption index G_t be defined like the private one in (2). Government demand is then analogous to private demand. The Home government budget constraint is

$$P_t G_t + Z_t = M_t - M_{t-1} \tag{8}$$

If the Home government generates revenue from printing money, it can either consume goods or give out nominal lump-sum transfers to its citizens, in which case $Z_t > 0$. The same holds for the Foreign government budget constraint.

2.3 Firms

Each firm faces the same linear production technology

$$y_t = h_t \tag{9}$$

where y_t denotes Home per-capita output and h_t is Home per-capita labor input. Note that the i subscript is dropped as all firms face the same production technology. Home output can be divided into output destined for the domestic country, denoted by x_t, and output destined for the Foreign country, denoted by z_t

$$y_t = x_t + z_t \tag{10}$$

Labor markets in each country are perfectly competitive so that the internationally immobile workers are wage-takers. The Home per-capita profit function for any $s \in [0, 1]$ is then given by

$$\pi_t = s(p_t x_t + e_t q_t z_t) + (1 - s)(p_t x_t + p_t z_t) - W_t y_t \tag{11}$$

Note that (11) is expressed in f.o.b. terms and that z_t is the amount of Home output that is *shipped* to Foreign. Due to trade costs only the fraction $(1 - \tau)$ of z_t arrives and is *consumed* in Foreign. The first term on the right-hand side of (11) reflects the revenue of firms that engage in pricing to market and charge the Foreign currency price q_t to Foreign consumers. The second term is the revenue from non-pricing-to-market firms, which always charge the Home currency price p_t. The last term of (11) constitutes the costs of production.

As the demand elasticities are equal in both countries, it follows

$$p_t = e_t q_t \tag{12}$$

$$q_t^* = p_t^* / e_t \tag{13}$$

Conditions (12) and (13) imply that in f.o.b. terms there is no price discrimination across countries under flexible prices. Firms receive the same revenue per unit, no matter whether they sell their products to Home or Foreign consumers. Appendix A shows that profit maximization leads to the standard price markups for Home firms

$$p_t = \frac{\rho}{\rho - 1} W_t \tag{14}$$

and for Foreign firms

$$q_t^* = \frac{\rho}{\rho - 1} W_t^* \tag{15}$$

3 The Flexible-Price Equilibrium

The question of interest in this section is how trade costs affect the flexible-price equilibrium compared to a perfect, frictionless world. As usual in the New Open Economy Macroeconomics literature, it is assumed that firms set prices after the exchange rate and wages are known and that initially there are neither bond holdings, government consumption nor lump-sum transfers so that $F = F^* = G = G^* = Z = Z^* = 0$. The time index t is dropped to denote initial equilibrium values.

3.1 An Endogenous Home Bias in Consumption

By comparing individual goods prices in (7) one can easily see that trade costs drive up the price of imported goods and thus render domestic goods more attractive. As a result, consumers spend a bigger fraction of their income on domestic goods. This buffering feature of trade costs will be referred to as the *containment effect* of trade costs, meaning that spending tends to be retained within the domestic country. Trade costs therefore lead to an *endogenous home bias* in consumption in each country.[3]

The home bias arises although the preference specification in (2) is symmetric such that consumers equally desire all goods, regardless of where they are produced. Of course, abandoning the symmetry by introducing an exogenous home bias in preferences, for example as in Warnock (2003), would be an alternative way of explaining the home bias. However, Carolyn Evans (2001)

[3] Consumers also spend a bigger fraction of income on domestic goods if one assumes nontradable goods, see Hau (2000).

finds empirically that the only significant reason for the tendency of consumers to purchase domestic goods are locational factors arising due to geographic distance and legal regulations - but not consumer preferences.[4] Her findings are therefore consistent with the preference specification in (2) and the model's iceberg trade costs but not with Warnock's (2003) assumption of home bias in preferences.

3.2 A Numerical Example

As shown in Appendix B, equilibrium labor supply is not affected by trade costs because of the logarithmic utility specification in (1). However, trade costs reduce consumption, real profits and real wages and hence, they make individuals worse off.[5] Figure 1 illustrates this reduction with a numerical example that will be used again in subsequent sections. In order to remain close to the existing literature, the parameter values are the same as in Betts and Devereux (2000) who give a detailed empirical motivation for their chosen magnitudes. As the price markup in (14) and (15) is $\rho/(\rho-1)$, a value of $\rho = 11$ is chosen to match an empirical markup of approximately 10%. ϵ is unity in order to be in line with empirical estimates of consumption elasticities of money demand ($1/\epsilon$ in the model) that are close to one. β is chosen to be 0.94, implying a real interest rate of about 6%, roughly the average long-run real return on stocks. η is chosen as 10/11. Unless indicated otherwise, the two countries are of equal size ($n = 0.5$) and trade costs are set to be $\tau = 0.25$ as in Obstfeld and Rogoff (2000), which is a moderate value compared to $\tau = 0.43$ reported by Anderson and van Wincoop (2004) in their survey of empirical trade costs.[6]

Figure 1 demonstrates two characteristic features of trade costs with a numerical example for consumption. First, trade costs reduce consumption in a nonlinear fashion. For the moderate value of $\tau = 0.25$ consumption almost attains the magnitude it would have in a closed economy (i.e. in the case of $\tau \to 1$). Second, trade costs have a more detrimental impact on small countries, as can be seen in the case of $n = 0.25$. Intuitively, since all the goods produced in the world are equally desired by consumers, smaller countries are more open economies and therefore more strongly exposed to trade costs. This latter point is also illustrated by Figure 2 which compares Home consumption C relative to Foreign consumption C^*. For $n = 0.5$ both countries are of equal size and therefore equally affected by trade costs such that C/C^* is stable. But in the case of $n = 0.25$ when the Home country is smaller, relative Home consumption

[4] Evans (2001) compares prices and quantities of imported goods produced by American firms for domestic sale with those of the same goods produced by foreign affiliates of these American firms for local sale. Her data set encompasses seven industries, ranging from transportation equipment to food products, across nine OECD countries over the period 1985-1994. She finds that the ad-valorem tariff equivalent of producing domestically and shipping abroad ranges between 51 and 105 percent across industries, which considerably reduces the attractiveness of the foreign goods for domestic consumers. Establishing and selling from an affiliate, however, does not lead to any negative effect on sales of these foreign products when compared to sales of domestic goods. In other words, French consumers do not intrinsically prefer French to American beer, only if it is cheaper.

[5] Formally, $\partial U/\partial\tau < 0$ and $\partial U^*/\partial\tau < 0$. For given money supply trade costs also decrease equilibrium real money balances.

[6] Anderson and van Wincoop (2004) argue that the representative tariff equivalent of international trade costs is around 74%. The tariff equivalent of iceberg trade costs is given by $1/(1-\tau) - 1$, implying $\tau = 0.43$.

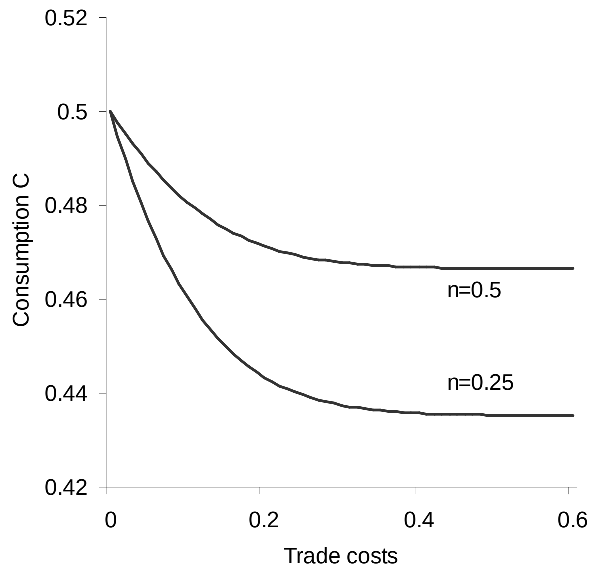

Figure 1: Trade costs reduce consumption in a nonlinear way.

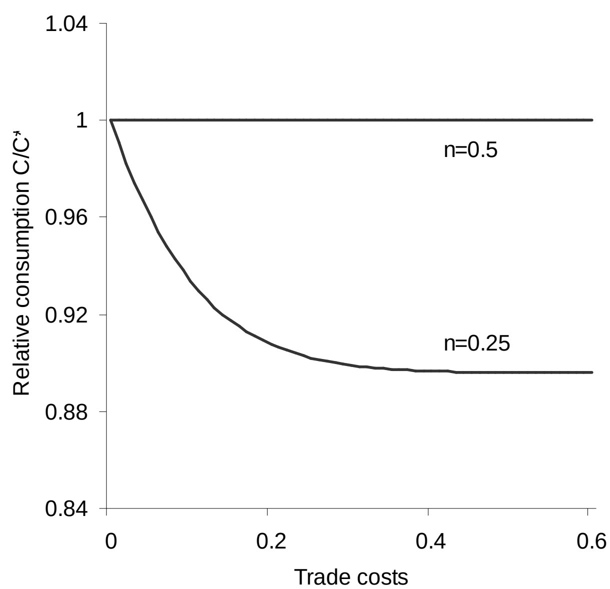

Figure 2: If the Home country is smaller than the Foreign country ($n = 0.25$), its relative consumption is reduced by trade costs.

drops. Both Hau (2000) and Warnock (2003) assume symmetric country size so that this effect cannot occur.

In the same vein, if the countries are not of equal size, absolute PPP will no longer hold in equilibrium because the two countries are asymmetrically affected by trade costs. That is, the equilibrium real exchange rate $\psi \equiv eP^*/P$ will be below 1 if the Home country is smaller and vice versa (see Appendix B). In contrast, in a model without trade costs the law of one price on the individual goods level inevitably leads to absolute PPP irrespective of country size.

4 Sticky Prices and Shocks

This section examines how key economic variables respond to shocks when trade costs impede the international exchange of goods and when prices are sticky for one period. The discussion concentrates on the real and nominal exchange rates, consumption, output and the current account. Full analytical derivations are given in Appendix C.

As a Keynesian feature of the model, it is now assumed that all prices (p_t, p_t^*, q_t, q_t^*) are preset every period and that firms choose prices to be optimal in the absence of shocks. They therefore preset the prices of the initial flexible-price equilibrium. For a sufficiently small shock in period t, firms have an incentive to produce the post-shock market demand since they are monopolistic competitors and still make profits. As there is no capital in the model, prices and all other variables reach their new long-run equilibrium in $t+1$, just one period after the shock hits the economy. Log-linear approximations are taken around the pre-shock flexible-price equilibrium of Section 3. For any variable X let $\widehat{X}_{t+k} \equiv (X_{t+k} - X)/X$ be the percentage deviation from the initial equilibrium at time $t+k$ for $k = 0, 1$ caused by either a monetary shock or a government spending shock. The following discussion concentrates on monetary shocks and an analysis of government spending shocks is provided in Appendix C.3.

4.1 Price Indices and the Real Exchange Rate

The short-run responses of the price indices to an exchange rate movement in period t can be obtained by log-linearizing (3) and (4). Under full pricing to market ($s = 1$) the price indices are not affected by nominal exchange rate movements since all prices are fixed in local currency irrespective of trade costs ($\widehat{P}_t = \widehat{P}_t^* = 0$). A nominal exchange rate depreciation therefore directly translates into a real exchange rate depreciation ($\widehat{\psi}_t = \widehat{e}_t$).

But if at least some prices are sticky in producer currency ($0 \leq s < 1$), exchange rate movements do feed into the price indices such that a depreciation of the Home currency will increase the Home price level and decrease the Foreign price level. In this context trade costs weaken the effect that exchange rate movements have on price indices.[7] Intuitively, trade costs act like buffers that shift consumption towards domestic goods through their containment effect and thus decrease the weight of imported goods and exchange rates in the price index. In

[7] Formally, $\left|\partial\widehat{P}_t/\partial\widehat{e}_t\right|/\partial\tau < 0$ and $\left|\partial\widehat{P}_t^*/\partial\widehat{e}_t\right|/\partial\tau < 0$.

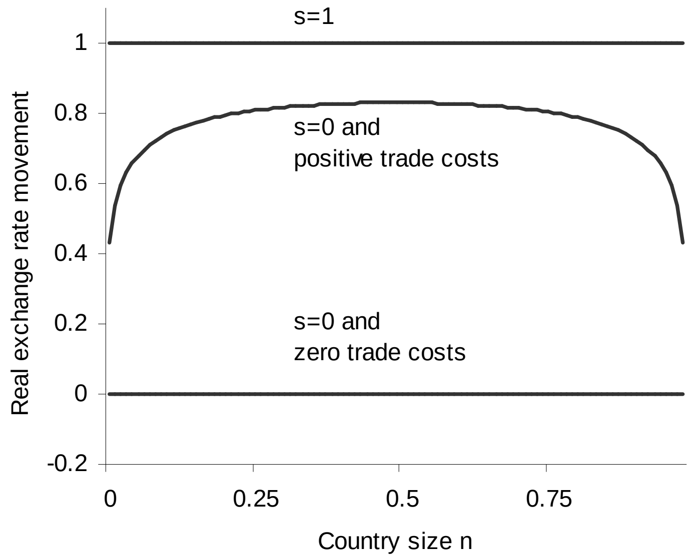

Figure 3: Trade costs increase the real exchange rate movement under producer currency pricing ($s = 0$) but not under local currency pricing ($s = 1$).

the limit as the countries become closed economies ($\tau \to 1$), the price indices are completely insulated from exchange rate movements.

This weakening effect of trade costs has consequences for the real exchange rate movement which can be expressed as

$$\widehat{\psi}_t = \widehat{e}_t + \widehat{P}_t^* - \widehat{P}_t = (s + \chi(1-s))\,\widehat{e}_t \tag{16}$$

where χ is a function of trade costs and exogenous parameters only. χ has the property that $\chi = 0$ for $\tau = 0$ and that it monotonically increases in τ such that $0 < \chi < 1$ for $0 < \tau < 1$.[8] Let us analyze the case of producer currency pricing ($s = 0$) and a depreciation ($\widehat{e}_t > 0$). In the absence of trade costs ($\tau = \chi = 0$) the price index movements are exactly offset by the nominal exchange rate so that the real exchange rate does not move at all ($\widehat{\psi}_t = 0$). But in the presence of trade costs the price index movements are weakened and the real exchange rate is no longer fixed ($\widehat{\psi}_t > 0$). The real exchange rate movement is stronger for higher trade costs with $\widehat{\psi}_t = \widehat{e}_t$ in the limit as $\tau \to 1$.[9]

Real exchange rate movements under producer currency pricing therefore approach the ones under local currency pricing for increasing trade costs. Figure 3 illustrates this behavior with

[8] See Appendix C for details.

[9] Formally, for $0 \le s < 1$, $\left|\partial\widehat{\psi}_t/\partial\widehat{e}_t\right|/\partial\tau > 0$ and $\lim_{\tau\to1}\left|\partial\widehat{\psi}_t/\partial\widehat{e}_t\right| = 1$ since $\lim_{\tau\to1}\chi = 1$. This finding also implies that for some degree of producer currency pricing and a given series of nominal exchange rate movements, trade costs render the real exchange rate more volatile (see Section 4.3 for simulation results).

the numerical example from Section 3.2. Figure 3 and all subsequent figures are drawn for one-percent shocks. Note that the impact of trade costs is greatest for the symmetric case of $n = 0.5$. Intuitively, when the two countries are of equal size, the volume of trade flows is biggest and trade costs are most detrimental. As shown in Appendix C, the expression for nominal exchange rate overshooting ($\widehat{e}_t - \widehat{e}_{t+1}$) is proportional to the real exchange rate movement (16). In the presence of trade costs overshooting therefore even occurs under producer currency pricing and overshooting is biggest when the two countries are of equal size.

4.2 The Nominal Exchange Rate, Consumption, Output and the Current Account

One can express the nominal exchange rate movement in period t in terms of exogenous shocks and parameters as

$$\widehat{e}_t = \frac{a_1(\widehat{M}_t - \widehat{M}_t^*) + a_2\left(\frac{\mathrm{d}\,G_t}{C} - \frac{\mathrm{d}\,G_t^*}{C^*}\right) + a_3\left(\frac{\mathrm{d}\,G_{t+1}}{C} - \frac{\mathrm{d}\,G_{t+1}^*}{C^*}\right)}{a_4(1-s) + a_5 s} \tag{17}$$

where

$$\begin{aligned}
a_1 &= \left(1 + \frac{\sigma\beta}{1-\beta} - \chi\left(1 + \frac{\sigma\beta}{\rho(1-\beta)}\right)\right)\epsilon > 0 \\
a_2 &= 1 - \chi > 0 \\
a_3 &= \frac{\beta}{1-\beta}\left(1 - \chi\frac{\sigma}{\rho}\right) > a_2 > 0 \\
a_4 &= (\rho - 1)\left(1 - \chi^2\right) + \left(1 - \chi\frac{(\epsilon-1)(1-\beta)}{\epsilon(1-\beta)+\beta}\right) a_1 > 0 \\
a_5 &= \frac{1}{\epsilon(1-\beta)+\beta} a_1 > 0 \\
\sigma &\equiv \frac{\rho - 1 + \rho\eta}{\rho - 1 + \eta} > 1
\end{aligned}$$

with $1 < \sigma < \rho$. $\chi \geq 0$ depends on trade costs τ and country size n (see Appendix C). Since a_1, a_2, a_3, a_4 and a_5 are all greater than zero, positive Home shocks unambiguously lead to a depreciation of the Home currency ($\widehat{e}_t > 0$). It is assumed throughout the analysis that monetary shocks are permanent ($\widehat{M}_t = \widehat{M}_{t+1}$ and $\widehat{M}_t^* = \widehat{M}_{t+1}^*$). Government spending shocks are defined with respect to private consumption C and C^* ($\mathrm{d}\,G/C$ and $\mathrm{d}\,G^*/C^*$), as there is no government consumption in the initial equilibrium. A detailed discussion of government spending shocks can be found in Appendix C.3.

Table 1 summarizes the responses of other key variables to a positive Home monetary shock. The results can be understood with the help of two 'switching' effects. Under local currency pricing ($s = 1$) relative prices and thus relative demand are fixed, but measured in domestic currency Home firms generate higher revenue because of the exchange rate depreciation. This will be referred to as the *income-switching effect*. As a result of the containment effect this

Table 1 A monetary shock and the impact of trade costs ($\widehat{M} > 0$)

	Full PTM ($s = 1$)		No PTM ($s = 0$)	
	Direction	Impact of τ	Direction	Impact of τ
Short run				
$\widehat{e}_t$	+	=	+	$>$
$\widehat{P}_t$	0	=	+	$<$
$\widehat{P}_t^*$	0	=	–	$<$
$\widehat{C}_t$	+	=	+	$>$
$\widehat{C}_t^*$	0	=	+	$<$
$\widehat{h}_t$	+	$>$	+	$<$
$\widehat{h}_t^*$	+	$<$	–	$<$
Current account				
$\mathrm{d}\,F_t$	0	=	+	$<$
Long run				
$\widehat{C}_{t+1}$	0	=	+	$<$
$\widehat{C}_{t+1}^*$	0	=	–	$<$
$\widehat{h}_{t+1}$	0	=	–	$<$
$\widehat{h}_{t+1}^*$	0	=	+	$<$

+ up, 0 unchanged, – down, $>$ reinforced, = neutral, $<$ attenuated.

additional income is predominantly spent on domestic goods, leading to a higher increase in Home output and a lower increase in Foreign output ($\widehat{h}_t > \widehat{h}_t^*$). But in the absence of trade costs the additional income would be spent evenly across the two countries ($\widehat{h}_t = \widehat{h}_t^*$). Apart from output trade costs do not affect the reaction of other variables to the monetary shock. In particular, as can be seen from (17) the nominal exchange rate does not behave differently because the ratio a_1/a_5 is independent of trade costs.

In contrast, when a monetary shock hits the economy under producer currency pricing ($s = 0$), price indices are no longer fixed and the familiar *expenditure-switching effect* comes into play. The price indices thus take on some of the adjustment process. But as trade costs hamper the movement of price indices and therefore erode the expenditure-switching effect, the nominal exchange rate must depreciate more strongly than it would without trade costs.[10] Figure 4 illustrates with the numerical example of Section 3.2 that when trade costs increase, the exchange rate movement approaches the one under local currency pricing. In that case it is most pronounced because there is no expenditure-switching effect at all. Again, the impact of trade costs is biggest when the two countries are of equal size.

The erosion of the expenditure-switching effect also manifests itself in the output reactions. As Table 1 points out, trade costs dampen the increase in demand for Home goods and they dampen the decrease in demand for Foreign goods. More generally, trade costs obstruct the

[10] Formally, $\partial\left(a_1/a_4\right)/\partial\tau > 0$ is required. This is generally the case unless trade costs are very low (roughly below 2%) and unless one country is overwhelmingly big (roughly over 98% of world size).

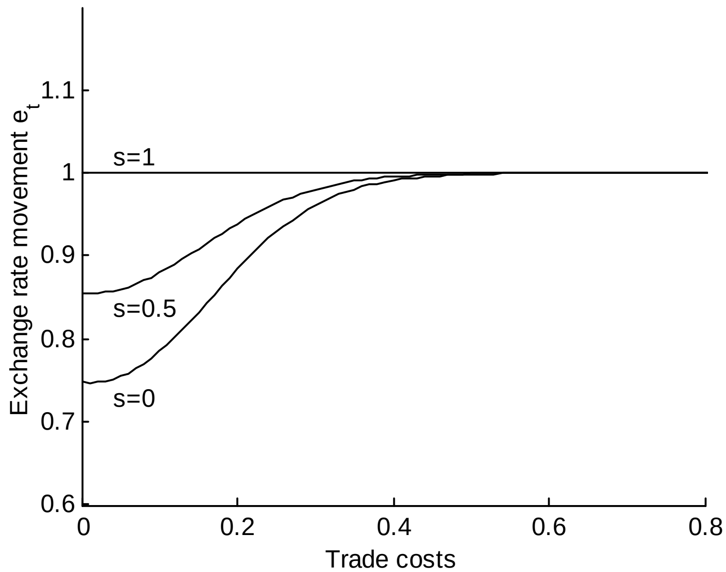

Figure 4: In response to a monetary shock trade costs lead to a more pronounced exchange rate movement for all degrees of pricing to market s except for local currency pricing ($s = 1$).

positive spillover of the monetary stimulus such that Home consumption increases by more than Foreign consumption. The current account response is therefore also dampened, toning down the long-run responses of consumption and output.[11] Those reactions are similar to the behavior of variables in the presence of nontradable goods (Hau, 2000) and home bias in preferences (Warnock, 2003).

4.3 Simulation Results

Two conclusions follow from the results that have been discussed so far. First, trade costs make both nominal and real exchange rates more volatile. Second, trade costs reduce international consumption correlations and increase output correlations for most degrees of pricing to market. These two conclusions are illustrated by simulation results in Figures 5-7. Each simulated observation is constructed from 100 replications over a draw of 100 periods for uncorrelated shocks to M_t and M_t^*. The underlying parameter values are the same as in Betts and Devereux (2000) and the numerical example of Section 3.2.[12] Note that the trade cost value is chosen as $\tau = 0.25$ as in Obstfeld and Rogoff (2000), which is moderate compared to Anderson and van Wincoop's (2004) empirical estimate of $\tau = 0.43$.[6] The simulation results can therefore be regarded as a conservative benchmark for the effects of trade costs.

Nominal and Real Exchange Rate Volatility

Figure 5 plots the volatility of the nominal and real exchange rates against the degree of pricing

[11] Devereux (2000) provides a detailed discussion of the impact on the current account.

[12] $\rho = 11$, $\epsilon = 1$, $\beta = 0.94$, $\eta = 10/11$, $n = 0.5$.

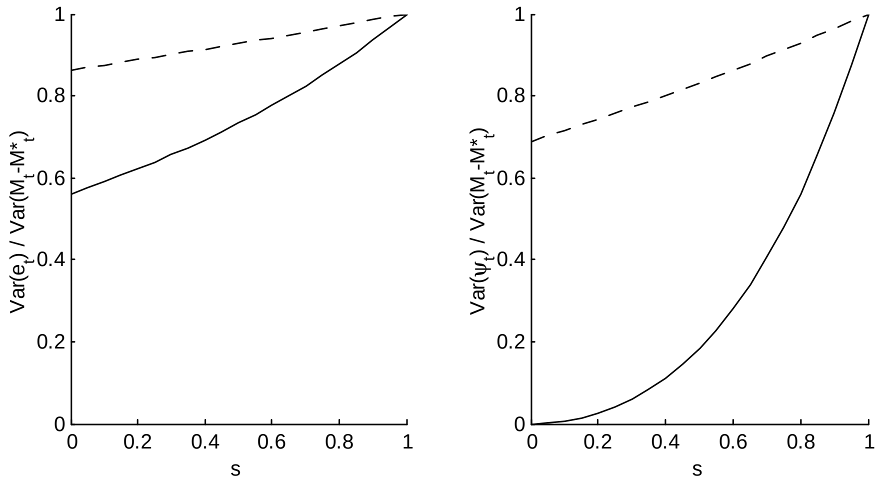

Figure 5: Trade costs render the nominal (left) and real (right) exchange rates more volatile for all degrees of pricing to market s except for local currency pricing ($s = 1$) [$\tau = 0$ for solid lines, $\tau = 0.25$ for dashed lines].

to market s. Volatility is measured as the relative variance of exchange rate movements and monetary shocks, $Var(\widehat{e}_t)/Var(\widehat{M}_t - \widehat{M}_t^*)$ and $Var(\widehat{\psi}_t)/Var(\widehat{M}_t - \widehat{M}_t^*)$. For $s = 0$ the volatility of the nominal exchange rate goes up by over 50 percent (from 0.56 to 0.86) and the real exchange rate is no longer fixed. Thus, especially for low degrees of pricing to market trade costs can significantly increase the volatility of exchange rates.

International Consumption and Output Correlations

Empirically, output is more strongly correlated across countries than consumption.[13] However, the literature on international business cycles has struggled to explain this phenomenon known as the "consumption correlations puzzle" (for a discussion see Obstfeld and Rogoff, 2000). Figure 6 visualizes the international correlations of consumption growth and output growth, $Corr(\widehat{C}_t, \widehat{C}_t^*)$ and $Corr(\widehat{h}_t, \widehat{h}_t^*)$, that arise in the presence of trade costs. Unless $s = 1$ trade costs enormously reduce consumption correlations. For producer currency pricing ($s = 0$) they reduce it by over 80 percent (from 0.88 to 0.11). Unless s is big, trade costs increase output correlations. For $s = 0$ they are pushed up by about 20 percent (from -0.97 to -0.77). Trade costs thus move consumption and output correlations into the right direction. It is striking that the effect of trade costs is again nonlinear such that even small magnitudes of trade costs can have a big impact. This nonlinearity is demonstrated in Figure 7 for consumption correlations under producer currency pricing.

As in Betts and Devereux (2000), the simulation results in Figures 5-7 are based on an elasticity of substitution of $\rho = 11$. Obstfeld and Rogoff (2000) use a lower value of 6, and

[13]For example, using quarterly data for the U.S., the UK, France, Italy and Germany from 1973-1994 Chari, Kehoe and McGrattan (2002, Table 6) report cross-country correlations of 0.60 for output and 0.38 for consumption.

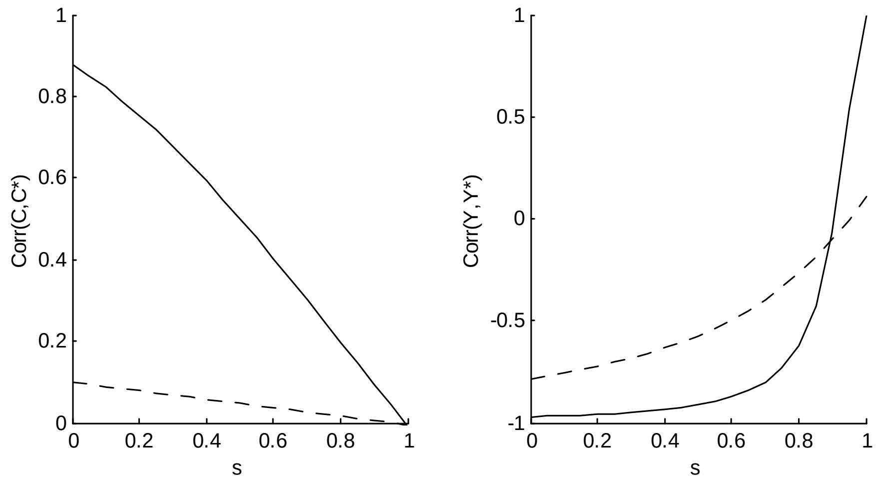

Figure 6: Trade costs reduce international consumption correlations (left), and for most degrees of pricing to market s they increase output correlations (right) [$\tau = 0$ for solid lines, $\tau = 0.25$ for dashed lines].

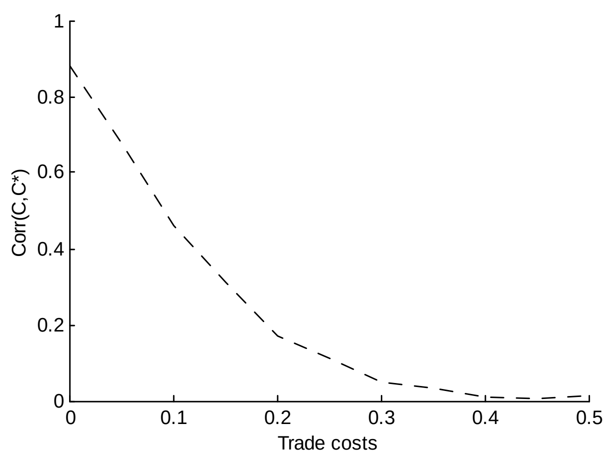

Figure 7: Trade costs reduce consumption correlations in a nonlinear way [plotted for producer currency pricing ($s = 0$)].

Anderson and van Wincoop (2004) suggest that empirical estimates of ρ range from 5 to 10. But for lower values of ρ the changes in consumption and output correlations are still sizeable, albeit not as dramatic. For $\rho = 6$ and $s = 0$ the consumption correlation is still reduced by about 60 percent (from 0.96 to 0.39) and the output correlation is increased by about 7.5 percent (from -0.93 to -0.86).

Backus, Kehoe and Kydland (1992) cannot generate low cross-country consumption correlations even if they introduce transportation costs as a trading friction into their real business cycle model (also see Ravn and Mazzenga, 2004). Instead, sticky prices in combination with demand shocks seem to be key ingredients to generate more realistic cross-country correlations. Indeed, Chari, Kehoe and McGrattan (2002) use sticky prices in combination with monetary shocks and local currency pricing ($s = 1$) to bring down consumption correlations, and by introducing investment and capital they also yield more realistic output correlations. My paper demonstrates that in the presence of trade costs local currency pricing is not required to obtain more realistic international correlations because trade costs reduce consumption correlations even for low degrees of pricing to market. It therefore seems promising for future work to integrate trade costs into a sticky-price model that allows for capital accumulation.

4.4 Rebating Trade Costs

So far iceberg trade costs have been treated as a black hole in the model. Although a certain dead-weight loss is conceivable in the form of red tape and language barriers, some sectors in the economy are likely to absorb trade costs, for instance transportation companies. In this vein a recent strand of literature has incorporated a distribution sector into trade models, for instance Burstein, Neves and Rebelo (2003).[14]

As Appendix D shows, all the results that have been discussed in previous sections are qualitatively the same when trade costs are rebated. It is assumed that by holding a monopoly on the shipping of goods into the domestic country, governments are able to recuperate trade costs and then rebate them to consumers in a lump-sum fashion, a set-up which is comparable to an import tariff and a lump-sum transfer of the tariff revenue. Intuitively, the results are robust to a rebate because the relative price of imported over domestically produced goods is not affected. The containment effect of trade costs therefore still applies.

5 Trade Costs and Welfare

How do trade costs affect the welfare properties of monetary and government spending shocks? To address this issue, we adopt Obstfeld and Rogoff's (1995) methodology and decompose the utility function (1) into $U_t = U_t^R + U_t^M$ where U_t^R consists of the consumption and labor terms and U_t^M of real money balances. As Obstfeld and Rogoff (1995) argue, unless real money balances are assigned an implausibly large weight γ in (1), U_t^R dominates the overall welfare

[14] Bacchetta and van Wincoop (2003) discuss the role of a distribution sector for exchange rate pass-through.

Table 2 The impact of trade costs on welfare

	Full PTM ($s = 1$)		No PTM ($s = 0$)	
	Direction	Impact of τ	Direction	Impact of τ
$\widehat{M} > 0$				
$\mathrm{d}\,U_t^R$	$+$	$<$	$+$	$>$
$\mathrm{d}\,U_t^{*R}$	$-$	$<$	$+$ becomes $-$	

$+$ up, $-$ down, $>$ reinforced, $<$ attenuated.

effect of a shock and U_t^M can be neglected. Taking log-linear approximation and noting that $C_{t+1} = C_{t+1+k}$ as well as $h_{t+1} = h_{t+1+k}$ for $k = 1, 2...$ yields

$$\mathrm{d}\,U_t^R = \widehat{C}_t - \left(\frac{\rho - 1}{\rho}\right)\widehat{h}_t + \frac{\beta}{(1-\beta)}\left[\widehat{C}_{t+1} - \left(\frac{\rho - 1}{\rho}\right)\widehat{h}_{t+1}\right] \tag{18}$$

The notation for the Foreign country is analogous. Table 2 summarizes the welfare effects $\mathrm{d}\,U_t^R$ and $\mathrm{d}\,U_t^{*R}$.

The welfare effect of a monetary shock under local currency pricing ($s = 1$) is particularly easy to analyze because in that case, the long run is not affected (cf. Table 1). Foreign citizens are worse off ($\mathrm{d}\,U_t^{*R} < 0$) because they have to work harder in the short run, whereas Home citizens are better off ($\mathrm{d}\,U_t^R > 0$). Since trade costs tone down the labor supply response to the shock, they also tone down the welfare response and thus, as shown in Figure 8, the welfare gap between Home and Foreign citizens shrinks.

Under producer currency pricing ($s = 0$), however, trade costs lead to a qualitative change in the welfare response. The containment effect ensures that the positive stimulus of a Home monetary expansion can be for the most part retained in the domestic economy. For sufficiently large trade costs, a monetary expansion therefore becomes a beggar-thy-neighbor policy. Figure 9 illustrates the welfare response under producer currency pricing. Only in the limit when the two countries become closed economies ($\tau \to 1$) are Foreign citizens not affected by a Home shock.

To summarize, in the presence of trade costs a monetary expansion typically triggers a negative welfare spillover regardless of the degree of pricing to market, a finding which is also pointed out by Warnock (2003) for a home bias in preferences and which could also arise with nontradable goods. For intermediate degrees of pricing to market ($0 < s < 1$) welfare gains can therefore be expected from the international coordination of monetary policy (see Corsetti and Pesenti, 2005). The finding of a negative welfare spillover stands in sharp contrast to Obstfeld and Rogoff's (1995) result that in a frictionless world with producer currency pricing, monetary shocks entail positive and symmetric international welfare spillovers.

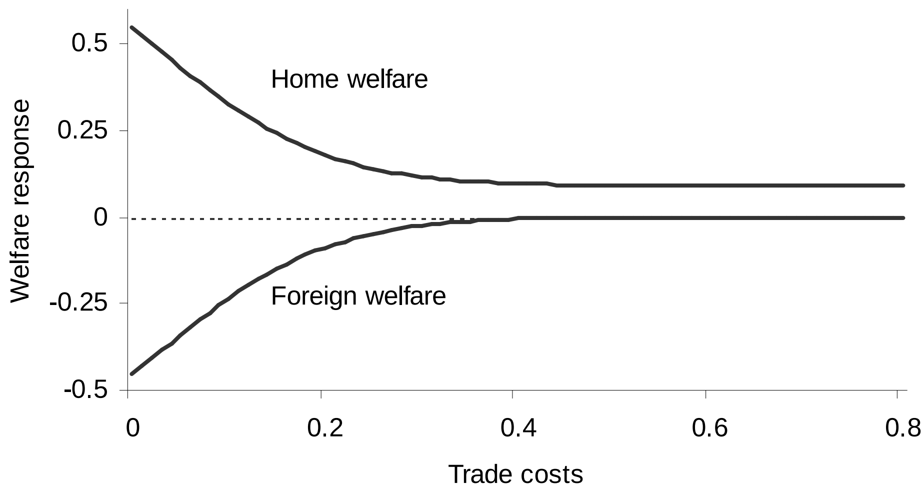

Figure 8: Under local currency pricing ($s = 1$) trade costs reduce the welfare gap between Home and Foreign citizens.

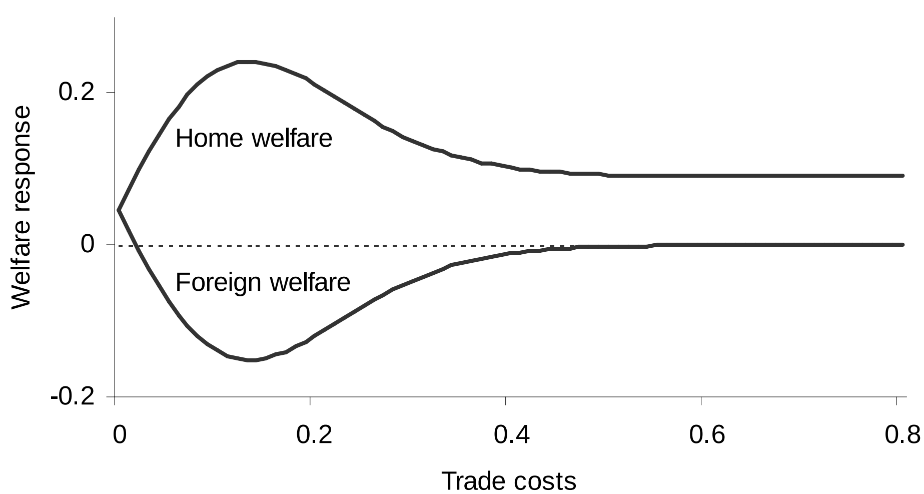

Figure 9: Under producer currency pricing ($s = 0$) sufficiently large trade costs convert a monetary expansion into a beggar-thy-neighbor policy.

6 Conclusion

The central focus of this paper is to investigate the theoretical implications of international trade costs for major macroeconomic variables. This is achieved by integrating iceberg trade costs into a micro-founded two-country general equilibrium model based on the New Open Economy Macroeconomics literature. The inclusion of trade costs is motivated by Anderson and van Wincoop (2004)'s recent survey in which they show that empirical trade costs are widespread and large with a tariff equivalent of representative international trade costs of around 74%.

Trade costs generally have a substantial impact on the behavior of the model's variables. The overall impact of trade costs is always biggest if the two countries are of equal size. In that case total trade flows are largest and trade costs are most harmful. By increasing the price of foreign goods, trade costs tilt consumption towards domestic goods and create an endogenous home bias in consumption. By impeding trade flows they tend to isolate two countries from each other and therefore reduce the international transmission of shocks, leading to smaller current account movements as well as lower international consumption and output correlations. Simulation results confirm that even moderate amounts of trade costs can significantly reduce international consumption correlations. It therefore seems promising for the solution of the consumption correlations puzzle to take international trade costs into account.

Trade costs also have a major impact on exchange rate movements. In the presence of monetary shocks nominal exchange rates have to move more strongly in order to restore equilibrium in money markets. Exchange rate volatility therefore goes up. Furthermore, for a wide range of realistic parameter values trade costs convert a monetary expansion into a beggar-thy-neighbor policy. For this reason welfare gains can be expected from the international coordination of monetary policy. This finding stands in contrast to the Obstfeld and Rogoff (1995) Redux model in which a monetary expansion creates positive welfare spillovers.

Finally, the model is also combined with pricing to market in order to allow for both producer and local currency pricing. A general insight from this set-up is that trade costs typically lead to the same qualitative effects under both producer and local currency pricing. The findings therefore have the potential to apply to a wide range of modeling frameworks because they do not crucially depend on the degree of pricing to market.

References

Anderson, J., van Wincoop, E., 2004. Trade Costs. *Journal of Economic Literature* 42, pp. 691-751.

Atkeson, A., Burstein, A., 2006. Pricing to Market, Trade Costs, and International Relative Prices. Mimeo, University of California at Los Angeles.

Bacchetta, P., van Wincoop, E., 2003. Why Do Consumer Prices React Less Than Import Prices to Exchange Rates? *Journal of the European Economic Association* 1, pp. 662-670.

Backus, D., Kehoe, P., Kydland, F., 1992. International Real Business Cycles. *Journal of Political Economy* 100, pp. 745-775.

Backus, D., Smith, G., 1993. Consumption and Real Exchange Rates in Dynamic Economies with Non-Traded Goods. *Journal of International Economics* 35, pp. 297-316.

Bergin, P., Glick, R., 2006. Endogenous Tradability and Macroeconomic Implications. Mimeo, University of California at Davis.

Betts, C., Devereux, M., 2000. Exchange Rate Dynamics in a Model of Pricing to Market. *Journal of International Economics* 50, pp. 215-244.

Brunner, A., Naknoi, K., 2003. Trade Costs, Market Integration, and Macroeconomic Volatility. *IMF Working Paper* No. 54 (March).

Burstein, A., Neves, J., Rebelo, S., 2003. Distribution Costs and Real Exchange Rate Dynamics During Exchange-Rate-Based Stabilizations. *Journal of Monetary Economics* 50, pp. 1189-1214.

Chari, V., Kehoe, P., McGrattan, E., 2002. Can Sticky Price Models Generate Volatile and Persistent Real Exchange Rates? *Review of Economic Studies* 69, pp. 533-563.

Corsetti, G., Pesenti, P., 2005. International Dimensions of Optimal Monetary Policy. *Journal of Monetary Economics* 52, pp. 281-305.

Devereux, M., 2000. How Does a Devaluation Affect the Current Account? *Journal of International Money and Finance* 19, pp. 833-851.

Engel, C., 1999. Accounting for U.S. Real Exchange Rate Changes. *Journal of Political Economy* 107, pp. 507-538.

Evans, C., 2001. Home Bias in Trade: Location or Foreign-ness? *Federal Reserve Bank of New York Staff Report* No. 128.

Fender, J., Yip, C., 2000. Tariffs and Exchange Rate Dynamics Redux. *Journal of International Money and Finance* 19, pp. 633-655.

Hau, H., 2000. Exchange Rate Determination: The Role of Factor Price Rigidities and Nontradeables. *Journal of International Economics* 50, pp. 421-447.

Krugman, P., 1980. Scale Economies, Product Differentiation, and the Pattern of Trade. *American Economic Review* 70, pp. 950-959.

Obstfeld, M., Rogoff, K., 1995. Exchange Rate Dynamics Redux. *Journal of Political Economy* 103, pp. 624-660.

Obstfeld, M., Rogoff, K., 2000. The Six Major Puzzles in International Macroeconomics: Is There a Common Cause? In: *NBER Macroeconomics Annual* 15.

Ravn, M., Mazzenga, E., 2004. International Business Cycles: The Quantitative Role of Transportation Costs. *Journal of International Money and Finance* 23, pp. 645-671.

Warnock, F., 2003. Exchange Rate Dynamics and the Welfare Effects of Monetary Policy in a Two-Country Model with Home-Product Bias. *Journal of International Money and Finance* 22, pp. 343-363.

A Households and Firms

Appendix A outlines the derivations of the expressions in Section 2. Demand function (6) is derived by maximizing C_t in (2) subject to the expenditure given by

$$K_t = \int_0^n p_{it} c_{it} \,\mathrm{d}\, i + \int_n^{n+(1-n)s} \frac{1}{1-\tau} p_{it}^* c_{it} \,\mathrm{d}\, i + \int_{n+(1-n)s}^1 \frac{1}{1-\tau} e_t q_{it}^* c_{it} \,\mathrm{d}\, i$$

This also results in price index (3). Maximizing utility (1) subject to the two-period intertemporal budget constraint constructed from (5)

$$\begin{array}{c} P_{t+1}C_{t+1} + M_{t+1} + d_{t+1}F_{t+1} = W_{t+1}h_{t+1} + \pi_{t+1} + \frac{d_t - 1}{d_t} M_t + Z_{t+1} \\ + \frac{1}{d_t} \left[W_t h_t + \pi_t + M_{t-1} + Z_t + F_{t-1} - P_t C_t \right] \end{array}$$

yields the optimality condition for labor supply

$$\frac{\eta}{1 - h_t} = \frac{W_t}{P_t C_t} \tag{19}$$

and the money demand function

$$\frac{M_t}{P_t} = \left(\frac{\gamma C_t}{1 - d_t} \right)^{\frac{1}{\epsilon}} \tag{20}$$

as well as the intertemporal consumption stream

$$d_t P_{t+1} C_{t+1} = \beta P_t C_t \tag{21}$$

The corresponding equations for the Foreign country are analogous.

Let us now turn to profit maximization. For the firms' price markups note that with the nominal anchor (12) the profit function (11) simplifies to

$$\pi_t = (p_t - W_t)(x_t + z_t)$$

From (6) insert the demand functions

$$x_t = \left(\frac{p_t}{P_t} \right)^{-\rho} n C_t \tag{22}$$

$$z_t = \frac{1}{(1-\tau)} \left(\frac{\frac{1}{(1-\tau)} \frac{p_t}{e_t}}{P_t^*} \right)^{-\rho} (1-n) C_t^* \tag{23}$$

Then maximize with respect to p_t to yield (14). (15) can be analogously computed for the Foreign country.

In order to derive the relative wage $W_t/(e_t W_t^*)$ consistent with (12)-(15) initially impose that $W_t/(e_t W_t^*) = \alpha$. Then plug this into the price indices (3) and (4), also using the markups

(14) and (15). This results in the real wages

$$\frac{W}{P} = \frac{\rho-1}{\rho}\theta^{\frac{1}{\rho-1}} \tag{24}$$

$$\frac{W^*}{P^*} = \frac{\rho-1}{\rho}\theta^{*\frac{1}{\rho-1}} \tag{25}$$

where

$$\theta = \left[n+(1-n)(1-\tau)^{\rho-1}\left(\frac{\theta}{\theta^*}\right)^{\frac{\rho-1}{2\rho-1}}\right] > n \tag{26}$$

$$\theta^* = \left[(1-n)+n(1-\tau)^{\rho-1}\left(\frac{\theta^*}{\theta}\right)^{\frac{\rho-1}{2\rho-1}}\right] > (1-n) \tag{27}$$

Then insert (22) and (23) into (10), again using $W_t/(e_tW_t^*) = \alpha$ and the real wages (24) and (25). Some algebra verifies that $W_t/(e_tW_t^*) = \alpha$ holds with $\alpha = (\theta/\theta^*)^{\frac{1}{2\rho-1}}$. θ and θ^* consist of exogenous parameters only. θ and θ^* cannot be solved analytically but by repeated substitution they always converge to one unique value for all admissible parameters. For $\tau = 0$ it follows $\theta = \theta^* = 1$, and for $0 < \tau < 1$ it follows $n < \theta < 1$ and $(1-n) < \theta^* < 1$.

B The Flexible-Price Equilibrium

Appendix B gives the derivations and analytical results of Section 3. In equilibrium the per-capita supply of labor and thus per-capita output is the same in both countries

$$h = h^* = y = y^* = \frac{\rho-1}{\rho-1+\rho\eta} \tag{28}$$

(28) can be derived by combining (5), (9), (10), (11), (14) and (19), noting that in the initial equilibrium $M_{t-1} = M_t$ and $Z = Z^* = F = F^* = G = G^* = 0$. The equilibrium real wages are given in (24) and (25). Plugging (11) and (24) into (28) yields Home real profits

$$\frac{\pi}{P} = \frac{h}{\rho}\theta^{\frac{1}{\rho-1}} \tag{29}$$

Foreign real profits can be derived similarly as

$$\frac{\pi^*}{P^*} = \frac{h^*}{\rho}\theta^{*\frac{1}{\rho-1}} \tag{30}$$

By inserting (24) and (28) into (19) Home consumption can be derived as

$$C = h\theta^{\frac{1}{\rho-1}} \tag{31}$$

Similarly, Foreign consumption follows as

$$C^* = h^* \theta^{*\frac{1}{\rho-1}} \tag{32}$$

The nominal exchange rate is obtained by plugging (24) and (25) into $W_t/(e_t W_t^*) = \alpha$ with with $\alpha = (\theta/\theta^*)^{\frac{1}{2\rho-1}}$ from Appendix A and then using (20) and its Foreign equivalent

$$e = \frac{M}{M^*} \left(\frac{C^*}{C}\right)^{\frac{1}{\epsilon}} \left(\frac{\theta}{\theta^*}\right)^{\frac{\rho}{(2\rho-1)(\rho-1)}} \tag{33}$$

The real exchange rate can be straightforwardly expressed as

$$\psi \equiv \frac{eP^*}{P} = \left(\frac{\theta}{\theta^*}\right)^{\frac{\rho}{(2\rho-1)(\rho-1)}} \tag{34}$$

Note that real wages in (24) and (25), real profits in (29) and (30) and consumption in (31) and (32) are reduced by trade costs since $\partial\theta/\partial\tau < 0$ and $\partial\theta^*/\partial\tau < 0$ (also see Figure 1). Relative quantities can be expressed as

$$\frac{C}{C^*} = \frac{\pi/P}{\pi^*/P^*} = \frac{W/P}{W^*/P^*} = \left(\frac{\theta}{\theta^*}\right)^{\frac{1}{\rho-1}} \tag{35}$$

If $\tau > 0$, for $n = 1 - n = 0.5$ it follows $\theta = \theta^*$ from (26) and (27), whereas for $n > 1 - n$ it follows $\theta > \theta^*$ and vice versa. Thus, in the presence of trade costs a smaller country faces lower consumption, a lower real wage and lower real profits (see Figure 2).

C Sticky Prices and Shocks

Appendix C outlines the derivations of the expressions in Sections 4.1 and 4.2.

C.1 Price Indices and the Real Exchange Rate

The short-run movements of the price indices are given by

$$\widehat{P}_t = (1-s)\left(1 - \frac{n}{\theta}\right)\widehat{e}_t \tag{36}$$

$$\widehat{P}_t^* = -(1-s)\left(1 - \frac{(1-n)}{\theta^*}\right)\widehat{e}_t \tag{37}$$

For a given nominal depreciation of the Home currency the behavior of the price indices can be summarized as

$$\begin{array}{ll} \widehat{P}_t = \widehat{P}_t^* = \widehat{P}_{t,\tau=0} = \widehat{P}_{t,\tau=0}^* = 0 & \text{if } s = 1 \\ -\widehat{e}_t < \widehat{P}_{t,\tau=0}^* < \widehat{P}_t^* < 0 < \widehat{P}_t < \widehat{P}_{t,\tau=0} < \widehat{e}_t & \text{if } 0 \leq s < 1 \end{array}$$

The parameter χ in (16) is defined as

$$\chi \equiv \frac{n}{\theta} + \frac{(1-n)}{\theta^*} - 1$$

with $\chi = 0$ for $\tau = 0$ and $0 < \chi < 1$ for $0 < \tau < 1$. The nominal exchange rate overshooting equation can be expressed as

$$\widehat{e}_t - \widehat{e}_{t+1} = \left(\frac{\epsilon - 1}{\epsilon + \beta/(1-\beta)}\right)(s + \chi(1-s))\widehat{e}_t \tag{38}$$

The usual necessary condition for overshooting is $\epsilon > 1$, i.e. that the consumption elasticity of money demand $(1/\epsilon)$ is smaller than one.

C.2 The Nominal Exchange Rate, Consumption, Output and the Current Account

The derivation of the exchange rate movement (17) is sketched first. Noting that $F_{t-1} = 0$ by assumption, combine (5), (8) and (11) to get the overall Home budget constraint

$$P_t C_t + P_t G_t + d_t F_t = p_t x_t + s e_t q_t z_t^{PTM} + (1-s) p_t z_t^{NPTM} \tag{39}$$

where

$$x_t = \left(\frac{p_t}{P_t}\right)^{-\rho} n(C_t + G_t) \tag{40}$$

$$z_t^{PTM} = \frac{1}{(1-\tau)} \left(\frac{\left(\frac{1}{1-\tau}\right) q_t}{P_t^*}\right)^{-\rho} (1-n)(C_t^* + G_t^*) \tag{41}$$

$$z_t^{NPTM} = \frac{1}{(1-\tau)} \left(\frac{\left(\frac{1}{1-\tau}\right) \frac{p_t}{e_t}}{P_t^*}\right)^{-\rho} (1-n)(C_t^* + G_t^*) \tag{42}$$

represent goods market clearing conditions. Analogously, for the Foreign country

$$P_t^* C_t^* + P_t^* G_t^* + \frac{d_t}{e_t} F_t^* = q_t^* x_t^* + s \frac{p_t^*}{e_t} z_t^{*PTM} + (1-s) q_t^* z_t^{*NPTM} \tag{43}$$

where F_t^* represents Foreign holdings of the bond maturing in period $t+1$ and

$$x_t^* = \left(\frac{q_t^*}{P_t^*}\right)^{-\rho} (1-n)(C_t^* + G_t^*) \tag{44}$$

$$z_t^{*PTM} = \frac{1}{(1-\tau)} \left(\frac{\left(\frac{1}{1-\tau}\right) p_t^*}{P_t}\right)^{-\rho} n(C_t + G_t) \tag{45}$$

$$z_t^{*NPTM} = \frac{1}{(1-\tau)} \left(\frac{\left(\frac{1}{1-\tau}\right) e_t q_t^*}{P_t} \right)^{-\rho} n(C_t + G_t) \tag{46}$$

Take log-linear approximations and combine these equations. Note that by using (40)-(42), (44)-(46), $z^{PTM} = z^{NPTM} = z$ and $z^{*PTM} = z^{*NPTM} = z^*$ as well as (34) and (35) one finds that in the initial equilibrium $x/y = \frac{n}{\theta}$, $z/y = 1 - \frac{n}{\theta}$, $x^*/y^* = \frac{1-n}{\theta^*}$, $z^*/y^* = 1 - \frac{1-n}{\theta^*}$. Subtract the approximation of (43) from the approximation of (39), using $\mathrm{d}\,F_t^* = -\frac{n}{1-n}\,\mathrm{d}\,F_t$, $d = \beta$, $CP = py = \alpha e C^* P^* = \alpha e q^* y^*$ where $\alpha = (\theta/\theta^*)^{\frac{1}{2\rho-1}}$ from above. Also use (36) and (37). The resulting equation is

$$\widehat{e}_t = \frac{(1-\chi)\left(\widehat{C}_t - \widehat{C}_t^* + \frac{\mathrm{d}\,G_t}{C} - \frac{\mathrm{d}\,G_t^*}{C^*}\right) + \frac{(1-n+\alpha n)\beta\,\mathrm{d}\,F_t}{(1-n)PC}}{(1-\chi)(\rho - 1 + \chi\rho)(1-s) + (1-\chi)\,s} \tag{47}$$

Approximations of long-run market clearing and optimality conditions are required in order to express the current term $\mathrm{d}\,F_t$ in (47) as dependent on exogenous variables. The following equations need to be log-linearized and combined

$$P_{t+1}C_{t+1} + P_{t+1}G_{t+1} + d_{t+1}F_{t+1} = p_{t+1}y_{t+1} + F_t \tag{48}$$

$$P_{t+1}^* C_{t+1}^* + P_{t+1}^* G_{t+1}^* + \frac{d_{t+1}}{e_{t+1}} F_{t+1}^* = q_{t+1}^* y_{t+1}^* + \frac{F_t^*}{e_t} \tag{49}$$

$$x_{t+1} = \left(\frac{p_{t+1}}{P_{t+1}}\right)^{-\rho} n(C_{t+1} + G_{t+1}) \tag{50}$$

$$z_{t+1} = \frac{1}{(1-\tau)} \left(\frac{\left(\frac{1}{1-\tau}\right) \frac{p_{t+1}}{e_{t+1}}}{P_{t+1}^*} \right)^{-\rho} (1-n)(C_{t+1}^* + G_{t+1}^*) \tag{51}$$

$$\frac{1}{1-h_{t+1}} = \frac{\rho-1}{\rho\eta} \frac{p_{t+1}}{P_{t+1}C_{t+1}} \tag{52}$$

$$x_{t+1}^* = \left(\frac{q_{t+1}^*}{P_{t+1}^*}\right)^{-\rho} (1-n)(C_{t+1}^* + G_{t+1}^*) \tag{53}$$

$$z_{t+1}^* = \frac{1}{(1-\tau)} \left(\frac{\left(\frac{1}{1-\tau}\right) e_{t+1} q_{t+1}^*}{P_{t+1}} \right)^{-\rho} n(C_{t+1} + G_{t+1}) \tag{54}$$

$$\frac{1}{1-h_{t+1}^*} = \frac{\rho-1}{\rho\eta} \frac{q_{t+1}^*}{P_{t+1}^* C_{t+1}^*} \tag{55}$$

Note that (12) and (13) also hold at time $t+1$. Also note that $\mathrm{d}\,F_t = \mathrm{d}\,F_{t+1}$ and $\mathrm{d}\,F_t^* = \mathrm{d}\,F_{t+1}^*$. (52) and (55) are the households' optimal labor supply decisions combined with the long-run versions of markups (14) and (15). As a result one yields

$$\begin{aligned} \tfrac{(1-n+\alpha n)\beta \,\mathrm{d}\, F_t}{(1-n)PC} &= \tfrac{\sigma\beta}{\rho(1-\beta)}\left(\rho-\chi\right)\left(\widehat{C}_{t+1}-\widehat{C}^*_{t+1}\right) \\ &+\tfrac{\beta}{\rho(1-\beta)}\left(\rho-\chi\sigma\right)\left(\tfrac{\mathrm{d}\, G_{t+1}}{C}-\tfrac{\mathrm{d}\, G^*_{t+1}}{C^*}\right) \end{aligned} \tag{56}$$

Now make use of the intertemporal Euler equation (21) and its Foreign equivalent in order to derive

$$\left(\widehat{C}_{t+1}-\widehat{C}^*_{t+1}\right)=\left(\widehat{C}_t-\widehat{C}^*_t\right)-\left(\chi(1-s)+s\right)\widehat{e}_t \tag{57}$$

noting $d^*_t = d_t\,(e_{t+1}/e_t)$ and $\widehat{P}_{t+1}-\widehat{P}^*_{t+1}=\widehat{e}_{t+1}$ from (34) and also using (36) and (37). Combine this result with the money market clearing condition (20) and its Foreign equivalent to yield

$$(1-s)(1-\chi)\widehat{e}_t=\left(\widehat{M_t}-\widehat{M^*_t}\right)-\frac{1}{\epsilon}\left(\widehat{C}_t-\widehat{C}^*_t\right)-\frac{\beta}{\epsilon(1-\beta)}\left(\widehat{e}_t-\widehat{e}_{t+1}\right) \tag{58}$$

From (33) note that

$$\widehat{e}_{t+1}=\left(\widehat{M}_{t+1}-\widehat{M}^*_{t+1}\right)-\frac{1}{\epsilon}\left(\widehat{C}_{t+1}-\widehat{C}^*_{t+1}\right) \tag{59}$$

and recall the assumption of permanent monetary shocks ($\widehat{M_t}=\widehat{M}_{t+1}$ and $\widehat{M^*_t}=\widehat{M}^*_{t+1}$). Combine (47) and (56)-(59) to obtain (17). Then combining (17), (47), (56) and (57) yields the overshooting equation (38).

In contrast to (56) $\widehat{C}_{t+1}$ and $\widehat{C}^*_{t+1}$ as the long-run consumption movements can also be expressed separately with the help of the log-linear approximations of (48)-(55) as

$$\begin{aligned} \widehat{C}_{t+1} &= \tfrac{\rho}{(\rho-1)(\rho-\chi)}\Big[\Big\{\rho-\tfrac{1-n}{\theta^*}-\left(\tfrac{n}{1-n}\right)\alpha(1-\tfrac{n}{\theta})\Big\}\tfrac{1}{\sigma}\tfrac{(1-\beta)\,\mathrm{d}\, F_t}{PC} \\ &+\Big\{-\chi\tfrac{1}{\rho}+\tfrac{n}{\theta}+\tfrac{1}{\sigma}\tfrac{1-n}{\theta^*}-\tfrac{\rho}{\sigma}\Big\}\tfrac{\mathrm{d}\, G_{t+1}}{C}+\left\{(1-\tfrac{n}{\theta})(1-\tfrac{1}{\sigma})\right\}\tfrac{\mathrm{d}\, G^*_{t+1}}{C^*}\Big] \end{aligned} \tag{60}$$

$$\begin{aligned} \widehat{C}^*_{t+1} &= \tfrac{\rho}{(\rho-1)(\rho-\chi)}\Big[\Big\{-\left(\tfrac{n}{1-n}\right)\alpha(\rho-\tfrac{n}{\theta})+(1-\tfrac{1-n}{\theta^*})\Big\}\tfrac{1}{\sigma}\tfrac{(1-\beta)\,\mathrm{d}\, F_t}{PC} \\ &+\left\{(1-\tfrac{1-n}{\theta^*})(1-\tfrac{1}{\sigma})\right\}\tfrac{\mathrm{d}\, G_{t+1}}{C}+\Big\{-\chi\tfrac{1}{\rho}+\tfrac{1-n}{\theta^*}+\tfrac{1}{\sigma}\tfrac{n}{\theta}-\tfrac{\rho}{\sigma}\Big\}\tfrac{\mathrm{d}\, G^*_{t+1}}{C^*}\Big] \end{aligned} \tag{61}$$

The current account term $\mathrm{d}\, F_t$ showing up in (56), (60) and (61) can be expressed as dependent on exogenous variables by using (56)-(59)

$$\begin{aligned} \tfrac{(1-n+\alpha n)(1-\beta)\,\mathrm{d}\, F_t}{(1-n)PC} &= \tfrac{1}{\sigma+\frac{(1-\beta)}{\beta}\left(\frac{\rho-\chi\rho)}{\rho-\chi)}\right)}\Big[\sigma(1-s)(\rho-1)(1-\chi^2)\widehat{e}_t \\ &-\sigma(1-\chi)\left(\tfrac{\mathrm{d}\, G_t}{C}-\tfrac{\mathrm{d}\, G^*_t}{C^*}\right)+(1-\chi)\left(\tfrac{\rho-\chi\sigma}{\rho-\chi}\right)\left(\tfrac{\mathrm{d}\, G_{t+1}}{C}-\tfrac{\mathrm{d}\, G^*_{t+1}}{C^*}\right)\Big] \end{aligned} \tag{62}$$

where $\widehat{e}_t$ is given in (17).

The long-run output movements also follow from the log-linearizations of (48)-(55) as

$$\begin{aligned} \widehat{h}_{t+1} &= \left(\frac{\rho\eta}{\rho-1+\rho\eta}\right)\left(-\frac{(1-\beta)\,\mathrm{d}\, F_t}{PC}+\frac{\mathrm{d}\, G_{t+1}}{C}\right) \\ \widehat{h}^*_{t+1} &= \left(\frac{\rho\eta}{\rho-1+\rho\eta}\right)\left(\left(\frac{n}{1-n}\right)\frac{(1-\beta)\alpha\,\mathrm{d}\, F_t}{PC}+\frac{\mathrm{d}\, G^*_{t+1}}{C^*}\right) \end{aligned}$$

The short-run consumption movements can be derived by log-linearizing and combining (20) and its Foreign equivalent, both for periods t and $t+1$, as well as (21) and its Foreign equivalent, resulting in

$$\widehat{C}_t^w = \beta\left[\left(1+\frac{\epsilon(1-\beta)}{\beta}\right)\widehat{M}_t^w - \left(1+\frac{\epsilon(1-\beta)}{\beta}\right)\widehat{P}_t^w + \left(\frac{\epsilon-1}{\epsilon}\right)\widehat{C}_{t+1}^w\right]$$

where $\widehat{X}_{t+k}^w \equiv n\widehat{X}_{t+k} + (1-n)\widehat{X}_{t+k}^*$ for $k=0,1$. $\widehat{P}_t^w$ can be replaced by exogenous variables via (17), (36) and (37). Then $\widehat{C}_t$ and $\widehat{C}_t^*$ can be computed as

$$\begin{aligned}\widehat{C}_t &= \widehat{C}_t^w + (1-n)(\widehat{C}_t - \widehat{C}_t^*)\\ \widehat{C}_t^* &= \widehat{C}_t^w - n(\widehat{C}_t - \widehat{C}_t^*)\end{aligned}$$

where $(\widehat{C}_t - \widehat{C}_t^*)$ follows from combining (17), (56), (57) and (62). In the presence of monetary shocks only the consumption movements are given by

$$\widehat{C}_t = \widehat{C}_t^w + (1-n)A_1\widehat{e}_t \tag{63}$$

$$\widehat{C}_t^* = \widehat{C}_t^w - nA_1\widehat{e}_t \tag{64}$$

where

$$A_1 = \left((1-s)\frac{(\rho-1)+\chi\left(1+\frac{\sigma}{r}\right)-\chi^2\left(\rho+\frac{\sigma}{r\rho}\right)}{1+\frac{\sigma}{r}-\chi\left(1+\frac{\sigma}{r\rho}\right)} + s\right)$$

In the special case of $s=1$ and a Home monetary shock the consumption movements follow as

$$\widehat{C}_t = (\epsilon(1-\beta)+\beta)\,\widehat{M}_t > \widehat{C}_t^* = 0$$

In the presence of government spending shocks only they are given by

$$\begin{aligned}\widehat{C}_t = \widehat{C}_t^w + (1-n)\left(\frac{1}{1+\frac{\sigma}{r}-\chi\left(1+\frac{\sigma}{r\rho}\right)}\right)\Big\{\Big((1-s)\left[(\rho-1)+\chi\left(1+\tfrac{\sigma}{r}\right)-\chi^2\left(\rho+\tfrac{\sigma}{r\rho}\right)\right]\\ +s\left[1+\tfrac{\sigma}{r}-\chi\left(1+\tfrac{\sigma}{r\rho}\right)\right]\Big)\widehat{e}_t - (1-\chi)\left(\tfrac{\mathrm{d}\,G_t}{C}-\tfrac{\mathrm{d}\,G_t^*}{C^*}\right) - \tfrac{1}{r}\left(1-\chi\tfrac{\sigma}{\rho}\right)\left(\tfrac{\mathrm{d}\,G_{t+1}}{C}-\tfrac{\mathrm{d}\,G_{t+1}^*}{C^*}\right)\Big\}\end{aligned} \tag{65}$$

$$\begin{aligned}\widehat{C}_t^* = \widehat{C}_t^w - n\left(\frac{1}{1+\frac{\sigma}{r}-\chi\left(1+\frac{\sigma}{r\rho}\right)}\right)\Big\{\Big((1-s)\left[(\rho-1)+\chi\left(1+\tfrac{\sigma}{r}\right)-\chi^2\left(\rho+\tfrac{\sigma}{r\rho}\right)\right]\\ +s\left[1+\tfrac{\sigma}{r}-\chi\left(1+\tfrac{\sigma}{r\rho}\right)\right]\Big)\widehat{e}_t - (1-\chi)\left(\tfrac{\mathrm{d}\,G_t}{C}-\tfrac{\mathrm{d}\,G_t^*}{C^*}\right) - \tfrac{1}{r}\left(1-\chi\tfrac{\sigma}{\rho}\right)\left(\tfrac{\mathrm{d}\,G_{t+1}}{C}-\tfrac{\mathrm{d}\,G_{t+1}^*}{C^*}\right)\Big\}\end{aligned} \tag{66}$$

Finally, the short-run output movements $\widehat{h}_t$ and $\widehat{h}_t^*$ can be derived as follows. Note that

$$\begin{aligned}h_t &= x_t + sz_t^{PTM} + (1-s)z_t^{NPTM}\\ h_t^* &= x_t^* + sz_t^{*PTM} + (1-s)z_t^{*NPTM}\end{aligned}$$

Log-linearize these two equations using (40)-(42) and (44)-(46). The results are

$$\widehat{h}_t = \tfrac{n}{\theta}\left(\rho\widehat{P}_t + \widehat{C}_t + \tfrac{\mathrm{d}\,G_t}{C}\right) + (1-\tfrac{n}{\theta})\left(\rho\widehat{P}_t^* + \widehat{C}_t^* + \tfrac{\mathrm{d}\,G_t^*}{C^*}\right)$$
$$+(1-s)\rho(1-\tfrac{n}{\theta})\widehat{e}_t$$
$$\widehat{h}_t^* = \tfrac{1-n}{\theta^*}\left(\rho\widehat{P}_t^* + \widehat{C}_t^* + \tfrac{\mathrm{d}\,G_t^*}{C^*}\right) + (1-\tfrac{1-n}{\theta^*})\left(\rho\widehat{P}_t + \widehat{C}_t + \tfrac{\mathrm{d}\,G_t}{C}\right)$$
$$-(1-s)\rho(1-\tfrac{1-n}{\theta^*})\widehat{e}_t$$

where $\widehat{P}_t$, $\widehat{P}_t^*$, $\widehat{C}_t$, $\widehat{C}_t^*$ and $\widehat{e}_t$ are given in (36), (37), (63)-(66) and (17). In the special case of $s = 1$ and a Home monetary shock the output movements follow as

$$\widehat{h}_t = (\epsilon(1-\beta)+\beta)\,\frac{n}{\theta}\widehat{M}_t > 0$$
$$\widehat{h}_t^* = (\epsilon(1-\beta)+\beta)\left(1-\frac{(1-n)}{\theta^*}\right)\widehat{M}_t > 0$$

In the special case of $s = 1$ and a Home temporary government spending shock they follow as

$$\widehat{h}_t = \frac{n}{\theta}\frac{\mathrm{d}\,G_t}{C} > 0$$
$$\widehat{h}_t^* = \left(1-\frac{(1-n)}{\theta^*}\right)\frac{\mathrm{d}\,G_t}{C} > 0$$

Note that if $0 < \tau < 1$, then $n/\theta > (1-(1-n)/\theta^*)$ so that $\widehat{h}_t > \widehat{h}_t^*$ in both cases. If $\tau = 0$, then $\theta = \theta^* = 1$ so that $\widehat{h}_t = \widehat{h}_t^*$.

C.3 Government spending shocks

Let us turn to Home government spending shocks. There are two types - a temporary shock ($\mathrm{d}\,G_t/C > 0$ and $\mathrm{d}\,G_{t+1}/C = 0$) and a permanent shock ($\mathrm{d}\,G_t/C = \mathrm{d}\,G_{t+1}/C > 0$).[15] If the government unexpectedly increases its spending without simultaneously printing money, it receives lump-sum transfers from its citizens ($Z_t < 0$) to finance its expenditures. An exchange rate depreciation helps Home citizens to generate this lump-sum transfer because it creates additional income.[16] A permanent government spending shock generally leads to a bigger exchange rate depreciation than a temporary one because the government maintains its level of spending for all future periods.[17] Tables 3 and 4 summarize the effects of the two types of shocks.

The difference to a monetary shock is that a government spending shock does not only set off an exchange rate movement, which entails an income-switching effect in the case of full pricing to market and an expenditure-switching effect in case of producer currency pricing, but it is also a *direct source of additional spending*. The following results generally depend on parameter values but hold for a broad range of realistic magnitudes including the ones chosen in Section

[15] In order to analyze anticipated government spending shocks ($\mathrm{d}\,G_{t+1}/C > 0$ and $\mathrm{d}\,G_t/C = 0$), a set-up in which individuals form expectations would be more appropriate.

[16] $a_2 > 0$ and $a_3 > 0$ in equation (17).

[17] $a_2 + a_3 > a_2 > 0$ in equation (17).

Table 3 A temporary government spending shock and the impact of trade costs ($\mathrm{d}\,G_t > 0, \mathrm{d}\,G_{t+1} = 0$)

	Full PTM ($s = 1$)		No PTM ($s = 0$)	
	Direction	Impact of τ	Direction	Impact of τ
Short run				
$\widehat{e}_t$	+	<	+	<
$\widehat{P}_t$	0	=	+	<
$\widehat{P}_t^*$	0	=	−	<
$\widehat{C}_t$	0	=	−	<
$\widehat{C}_t^*$	0	=	+	<
$\widehat{h}_t$	+	>	+	>
$\widehat{h}_t^*$	+	<	+	<
Current account				
$\mathrm{d}\,F_t$	−	<	−	<
Long run				
$\widehat{C}_{t+1}$	−	<	−	<
$\widehat{C}_{t+1}^*$	+	<	+	<
$\widehat{h}_{t+1}$	+	<	+	<
$\widehat{h}_{t+1}^*$	−	<	−	<

+ up, 0 unchanged, − down, > reinforced, = neutral, < attenuated.
Holds for realistic parameter values (see Section 3.2).

Table 4 A permanent government spending shock and the impact of trade costs ($\mathrm{d}\,G_t = \mathrm{d}\,G_{t+1} > 0$)

	Full PTM ($s = 1$)		No PTM ($s = 0$)	
	Direction	Impact of τ	Direction	Impact of τ
Short run				
$\widehat{e}_t$	+	<	+	>
$\widehat{P}_t$	0	=	+	<
$\widehat{P}_t^*$	0	=	−	<
$\widehat{C}_t$	0	=	−	<
$\widehat{C}_t^*$	0	=	+	<
$\widehat{h}_t$	+	>	+	<
$\widehat{h}_t^*$	+	<	−	<
Current account				
$\mathrm{d}\,F_t$	−	<	+	<
Long run				
$\widehat{C}_{t+1}$	−	<	−	>
$\widehat{C}_{t+1}^*$	+	<	−	<
$\widehat{h}_{t+1}$	+	<	+	>
$\widehat{h}_{t+1}^*$	−	<	+	<

+ up, 0 unchanged, − down, > reinforced, = neutral, < attenuated.
Holds for realistic parameter values (see Section 3.2).

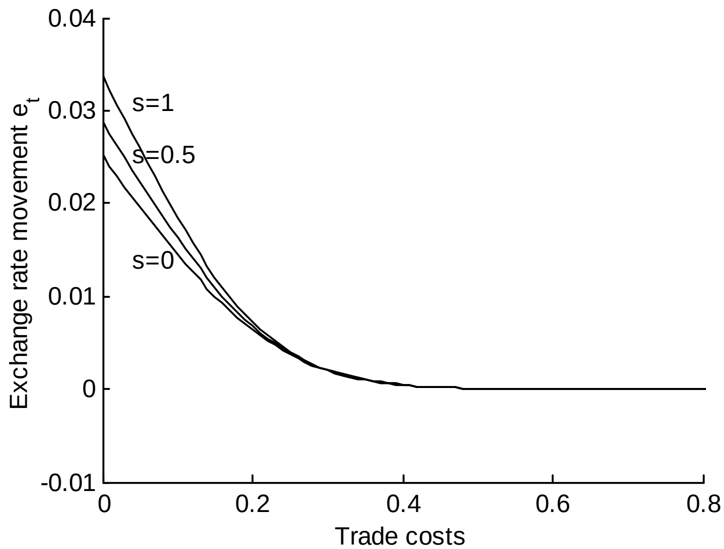

Figure 10: Trade costs lead to a less pronounced exchange rate movement in response to a temporary government spending shock.

3.2.[18]

As described in the context of monetary shocks, under local currency pricing ($s = 1$) the impact of the mere income-switching effect on the exchange rate is not affected by trade costs. But as a new element, additional spending comes into play with government spending shocks. Since the containment effect ensures that a bigger fraction of the government spending is kept in the domestic country, Home citizens are less pressured to generate additional income in order to finance their government's spending. Hence, in total, under local currency pricing the ensuing exchange rate movement is less pronounced both with temporary and permanent government spending shocks.[19] Figures 10 and 11 illustrate the exchange rate movements for $s = 1$ and varying trade cost values.

As before with monetary shocks, under local currency pricing the containment effect leads to a stronger increase in Home production ($\widehat{h}_t > \widehat{h}_t^*$). But now Home citizens incur a current account deficit ($\mathrm{d}\,F_t < 0$) because they borrow in order to smooth their consumption whilst financing their government's spending. Again, trade costs tone down the current account deficit and all long-run movements, as summarized in Tables 3 and 4.

We already know from the analysis of monetary shocks that under producer currency pricing ($s = 0$) trade costs erode the expenditure-switching effect so that the exchange rate depreciation is stronger. In combination with the additional spending coming from the government, which weakens the exchange rate depreciation, an ambiguity arises in terms of the total effect. With a

[18] $\rho = 11$, $\eta = 10/11$, $\beta = 0.94$, $\epsilon = 1$. Country size and trade costs are set as $n = 0.5$ and $\tau = 0.25$ unless indicated otherwise.

[19] Formally, $\partial\left(a_2/a_5\right)/\partial\tau < 0$ always holds. For permanent shocks $\partial\left(a_2/a_5\right)/\partial\tau + \partial\left(a_3/a_5\right)/\partial\tau < 0$ is required. For $\epsilon \geq 1$, $\partial\left(a_3/a_5\right)/\partial\tau < 0$ holds if $\rho - \sigma < (\sigma - 1)\sigma\beta/\left(1 - \beta\right)$, which clearly obtains for realistic parameter values.

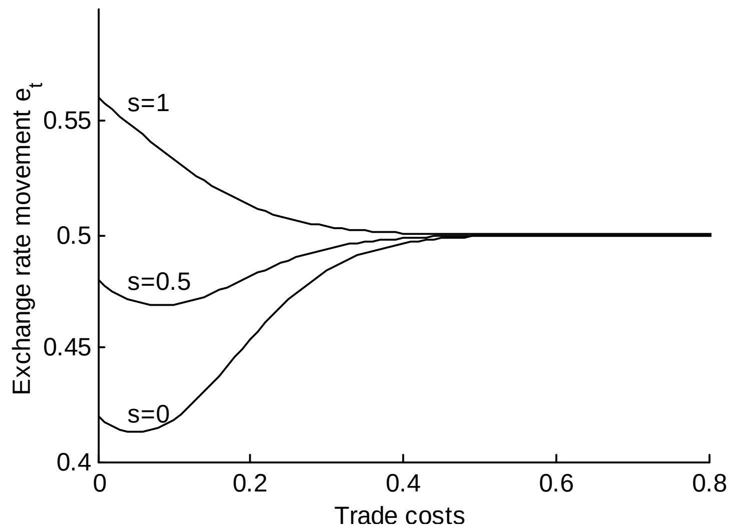

Figure 11: In response to a permanent government spending shock, trade costs lead to a less pronounced exchange rate movement for local currency pricing ($s = 1$) but to a more pronounced movement for low degrees of pricing to market ($s = 0$ and $s = 0.5$ in this example).

temporary government spending shock the influence of the additional spending dominates so that the required exchange rate movement is weaker. With a permanent government spending shock, however, the expenditure-switching effect turns out to dominate so that in total, the required exchange rate movement is stronger than without trade costs. Figures 10 and 11 illustrate the exchange rate movements for $s = 0$ and varying trade cost values.[20]

Under producer currency pricing the exchange rate depreciation leads to a positive spillover for Foreign consumption but of course, domestic private consumption is crowded out by government spending such that $\widehat{C}_t < 0 < \widehat{C}_t^*$. As Tables 3 and 4 indicate, trade costs soften these consumption movements. With a temporary government spending shock the additional spending dominates the expenditure-switching effect and hence, output increases in both countries and the containment effect channels the bigger proportion of government spending towards the domestic country.

With a permanent government spending shock the expenditure-switching effect dominates and the output movements go into opposite directions. The dominating influence of the expenditure-switching effect also leads to a current account surplus ($\mathrm{d}\,F_t > 0$) so that Foreign citizens must decrease their long-run consumption ($\widehat{C}_{t+1}^* < 0$) and increase their long-run production ($\widehat{h}_{t+1}^* > 0$). All these movements are weakened by trade costs.

To summarize the results presented in Tables 3 and 4, trade costs decrease the volatility of the nominal exchange rate in response to government spending shocks, except for the special

[20] Formally, $\partial\left(a_2/a_4\right)/\partial\tau < 0$ holds for realistic parameter values. Then $\partial\left(a_3/a_4\right)/\partial\tau > 0$ is required for permanent government spending shocks to entail a stronger exchange rate movement. Unless one country is overwhelmingly big (roughly over 98% of world size), this is generally the case. For small τ this might not necessarily go through, as can be seen from the non-monotonicity with $s = 0$ and $s = 0.5$ in Figure 11.

case of a permanent shock in combination with a low degree of pricing to market (i.e. small s). Through equation (16) the lower volatility also translates to the real exchange rate. Trade costs tone down the international correlation of consumption, except for short-run consumption under local currency pricing in which case trade costs have no impact. Trade costs always tone down the international correlation of output as well as the adjustment of the current account. As with monetary shocks, the impact of trade costs is generally biggest when the two countries are of equal size.

Regardless of the degree of pricing to market, Home citizens always suffer a welfare loss from Home government spending shocks simply because government spending does not enter the utility function, but Foreign citizens always gain. As the containment effect ensures that the government spending is predominantly kept in the domestic country, trade costs narrow to welfare gap between Home and Foreign citizens. As with monetary shocks, Foreign welfare is not affected at all for the limit of $\tau \to 1$.

D Rebating Trade Costs

The solution method for the rebating extension is exactly the same as the one described in Appendix C. Therefore, only some hints and results are given here.

Governments are able to recuperate a share of the trade costs associated with the shipping of goods into the domestic country. This revenue is then rebated to consumers in a lump-sum fashion. Analogous to (10) the amount of the Foreign country's real output being shipped abroad is denoted by z_t^* so that the real quantity of iceberg trade costs incurred by the Home country is τz_t^*. Let δ denote the share of the iceberg trade costs that the government is able to recuperate. The Home government budget constraint (8) now becomes

$$P_t G_t + Z_t = M_t - M_{t-1} + \delta\tau(s p_t^* + (1-s)e_t q_t^*) z_t^* \tag{67}$$

With $\delta = 1$ the government can recuperate all trade costs, with $\delta = 0$ the model collapses to the one of the preceding sections. For simplicity $n = 1 - n = 0.5$ is assumed.

Output and consumption in the initial equilibrium are

$$h = h^* = y = y^* = \frac{\rho - 1}{\rho - 1 + \rho\eta(1 + \delta\tau\frac{1}{2}(1-\chi))}$$

$$C = C^* = (1 + \delta\tau\frac{1}{2}(1-\chi))h\left(\frac{1}{1+\chi}\right)^{\frac{1}{\rho-1}}$$

Thus, compared to a world with no rebating labor supply is lower whilst consumption is higher.

The expressions for the price indices in (36) and (37) as well as the real exchange rate in (16) are not affected by the rebate. The coefficients of the nominal exchange rate equation (17) change only slightly and now become

$$
\begin{aligned}
\widetilde{a}_1 &= a_1 + \left(\delta\tau\frac{1}{2}(1-\chi)\left(\frac{\widetilde{\sigma}\beta}{1-\beta} - \chi\frac{\widetilde{\sigma}\beta}{\rho(1-\beta)}\right)\right)\epsilon > 0 \\
\widetilde{a}_2 &= a_2 > 0 \\
\widetilde{a}_3 &= a_3 + \frac{\beta}{1-\beta}\delta\tau\frac{1}{2}(1-\chi)\left(1-\chi\frac{\sigma}{\rho}\right) > a_2 > 0 \\
\widetilde{a}_4 &= (\rho-1)\left(1-\chi^2\right) + \left(1-\chi\frac{(\epsilon-1)(1-\beta)}{\epsilon(1-\beta)+\beta}\right)\widetilde{a}_1 > 0 \\
\widetilde{a}_5 &= \frac{1}{\epsilon(1-\beta)+\beta}\widetilde{a}_1 > 0
\end{aligned}
$$

where

$$
\widetilde{\sigma} \equiv \frac{\rho - 1 + \rho\eta(1+\delta\tau\frac{1}{2}(1-\chi))}{\rho - 1 + \eta(1+\delta\tau\frac{1}{2}(1-\chi))}
$$

and where all σ's in a_1 and a_3 are replaced by $\widetilde{\sigma}$. Note that the equivalent expressions of (52) and (55) are now

$$
\frac{1}{1-h_{t+1}} = \frac{\rho-1}{\rho\eta(1+\delta\tau\frac{1}{2}(1-\chi))}\frac{p_{t+1}}{P_{t+1}C_{t+1}}
$$

and

$$
\frac{1}{1-h^*_{t+1}} = \frac{\rho-1}{\rho\eta(1+\delta\tau\frac{1}{2}(1-\chi))}\frac{q^*_{t+1}}{P^*_{t+1}C^*_{t+1}}
$$