Ben Bernanke in Doha:
The effect of monetary policy on optimal tariffs

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Abstract

Trade liberalization can imply slow and long adjustment processes. Taking account of these adjustment processes can change the evaluation of trade policy, especially when policy makers care more about the next couple of years than the infinite future. In this paper I analyze Nash-equilibrium tariffs in a two-country model taking account of adjustment processes with special emphasis on the effects of nominal price rigidity and monetary policy. I show that nominal price rigidity induces policy makers with a short planning horizon to set lower tariffs because it enhances the short run boom following a cut in tariffs. Monetary policy that aggressively fights deviations from its inflation target leads to even lower tariffs.

Key words: Nash-equilibrium tariffs; dynamic trade model; monetary policy

JEL classification: E52, F11, F12, F13

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1 Introduction

The effect of monetary policy on trade policy has so far been largely ignored in the literature (with Cacciatore and Ghironi (2014) being a notable exception). This is mainly due to the tendency of trade economists to use static models, thus ignoring adjustment processes and ruling out effects of monetary policy by construction. This is in contrast with the perspective of most politicians who, driven by the political cycle, are more concerned about the next couple of years than about the infinite future (the new steady state). Thinking about short run adjustment, nominal price rigidity and monetary policy suddenly become relevant, since it is well know that monetary policy has an influence on short run adjustments (see, e.g., Gali (2008) for an overview of the empirical evidence on nominal price rigidity and monetary non-neutrality). In this paper I take the adjustment process seriously, take account of the slow adjustment of prices, and analyze the implications that monetary policy can gain in this context. I show that monetary policy can have a substantial effect on the level of tariffs set by politicians.

To analyze this question I use a dynamic model with nominal price rigidity, as well as endogenous firm entry, firm heterogeneity, and selection into export markets in the spirit of Melitz (2003), by far the most popular model in the trade literature today.[1] The model I use is a variant of Cacciatore and Ghironi (2014) (CG henceforth), extended by income-generating tariffs. I use the model to simulate the dynamic adjustment after a unilateral cut in tariffs. As is standard in the trade literature, I model the setting of tariffs as a non-cooperative game between two countries and calculate Nash-equilibrium tariffs. I show how Nash-equilibrium tariffs depend on the planning horizon of the policy maker that sets the tariff and the conduct of monetary policy.

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[1]Felbermayr, Jung, and Larch (2012) have shown that including firm heterogeneity is crucial when analyzing optimal tariffs because the restriction to homogenous goods shuts off an important channel.

I show that a unilateral cut in tariffs leads to a short run boom in consumption.[2] There are two main reasons for this result. On the one hand, imported varieties become cheaper and thus more of them can be consumed. On the other hand, the lower tariff leads to stronger competition, implying a smaller number of firms. In the transition period this leads to a considerable reduction in investments in new firms. Since a lower number of workers is bound by the construction of new firms, more are available to produce consumption goods.

So far this perfectly resembles the results in Larch and Lechthaler (2013) (LL henceforth), who also look at the optimal setting of tariffs in a dynamic context. The novelty of this paper with respect to LL is the introduction of rigid prices, modelled as Rotemberg price adjustment costs, and the relevance of monetary policy that this implies. Rigid prices imply an even larger short-run boom in consumption because the drop in production for the domestic market is less extreme and because monetary policy, modelled as a standard Taylor rule, lowers the real interest rate to counteract the deflation caused by lower import prices. In the medium run, though, consumption is lower under rigid prices.[3] This pattern implies that a policy maker with a very short planning horizon would set lower tariffs under rigid prices, but a policy maker with an intermediate or long planning horizon would set lower tariffs under rigid prices.[4]

The main interest of this paper is the question of how monetary policy affects the optimal setting of tariffs. To this end I assume that monetary policy in one country is governed by a standard Taylor rule, while monetary policy in the other country is governed by a more aggressive reaction to deviations from the inflation

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[2]Qualitatively this result is similar to the consumption overshooting in Bergin and Lin (2012) and the productivity overshooting in Chaney (2005). Empirical evidence distinguishing the short- and long-run effects of trade liberalization is very scarce. Indirect evidence is provided by Bergin and Lin (2012) who show that the increase at the extensive margin is larger in the short-run than in the long-run.

[3]For the steady state, of course, price rigidity does not matter, because in the long run all prices are flexible.

[4]By a policy maker with a short planning horizon I mean a policy maker who only cares about what happens in the next x periods with x being a small number.

target. I show that the aggressiveness of monetary policy has a huge impact on the setting of tariffs.

Aggressive monetary policy means that the deflation caused by the drop in tariffs is counteracted by a strong drop in the nominal interest rate. As a consequence the short run boom in consumption gets even stronger in the country with aggressive monetary policy, but it gets smaller in the country with normal monetary policy. Consequently we see large deviations in the optimal tariffs of both countries. The economy with aggressive monetary policy sets much lower tariffs than the country with normal monetary policy. This can even lead to a break-down of the monotonically negative relationship, found in LL and confirmed here under normal monetary policy, between the policy setter's planning horizon and the chosen tariff. In the economy with normal monetary policy tariffs might initially drop with increases in the policy setter's planning horizon.

This paper relates to a large and growing literature about the optimal setting of tariffs, a question which has a long tradition in international trade. However, virtually all of this analysis is done in the context of static models (Krugman (1991), Bond and Syropoulos (1996), Bagwell and Staiger (1999), Yi (2000), Ornelas (2005), Demidova and Rodríguez-Clare (2009), Felbermayr, Jung, and Larch (2012)), comparing one steady state with the other, thus ignoring adjustment dynamics which lie at the heart of this analysis. One notable exception is LL, which also uses a dynamic model (in the spirit of Ghironi and Melitz (2005)) to address the question of optimal tariffs and to analyze the relevance of the policy makers planning horizon. However, their paper assumes flexible prices, while rigid prices are certainly important when thinking about short run adjustment processes. The assumption of flexible prices also rules out the analysis of the interaction between monetary policy and trade policy which lies at the heart of this analysis. Cacciatore and Ghironi (2014) also look at the relationship between monetary policy and trade policy but from a different perspective. They analyze how monetary policy should react to an exogenous drop in non-tariff trade bar-

riers, while analyze the implications of monetary policy for the optimal setting of income-generating tariffs.

The rest of the paper proceeds as follows. In the next section I present the model. In section 3 I discuss the parameterization of the model. In section 4 I calculate the Nash-equilibrium tariffs of the static model. In section 5 I describe the dynamic adjustment of the model economy after a unilateral drop in tariffs. In section 6 I describe the setting of Nash-equilibrium tariffs and how they depend on the planning horizon of the policy maker that sets the tariffs. In section 7 I discuss the effects of monetary policy's aggressiveness. Section 8 concludes.

2   A dynamic trade model with tariffs and nominal price rigidity

The model I use is a variant of the model presented in CG, which puts the Melitz-framework with endogenous firm entry, firm heterogeneity and selection into export markets into a dynamic setting with price rigidity. Apart from the success of the Melitz model to replicate important stylized facts,[5] Felbermayr, Jung, and Larch (2012) have shown that including firm heterogeneity is crucial when analyzing optimal tariffs because the restriction to homogenous goods shuts off an important channel.

To keep the model simple I assume that labor markets are perfectly competitive, while CG use search and matching unemployment. In turn I introduce non-resource-consuming, income-generating import tariffs into the model to ana-

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[5]The popularity of the Melitz model stems from the combination of being able to capture important stylized facts, like the fact that only very productive firms export, that exporters are bigger and employ more workers than domestic firms, and that small firms with low productivity are driven out of the market, while it remains still very tractable. See the empirical studies by Dunne, Roberts and Samuelson (1989); Davis and Haltiwanger (1992); Bernard and Jensen (1995, 1999, 2004); Roberts and Tybout (1997); Clerides, Lach and Tybout (1998); and Bartelsman and Doms (2000) for evidence concerning the stylized facts. Recent literature on international business cycles highlights the importance of intra-industry trade and selection into export markets for business cycle synchronization (e.g., Ghironi and Melitz (2005).

lyze their optimal setting. I keep the description of the model deliberately short, for more details the interested reader is referred to CG. The technical Appendix provides an overview over all the equations.

The main deviation from Ghironi and Melitz (2005), the first paper to put the Melitz model into a dynamic setting, is the introduction of rigid prices. To make this tractable, production is structured in two different layers. The aggregate consumption good is a CES-aggregate of a constant number of varieties. Each variety is produced by a single firm, so that the number of firms is also exogenously given and constant. Firms sell their products under monopolistic competition. Changing the price from one period to the other is associated with quadratic price adjustment costs ala Rotemberg.

The variety produced by a single firm is itself a CES-aggregate of intermediate inputs. Each intermediate input is produced by a different plant, owned by the firm. Plants are destroyed each period with an exogenous and constant probability. To create new plants firms need to pay a sunk investment cost. After paying the sunk investment cost, the firm takes a draw from a random distribution that determines the productivity of the plant for the rest of its existence. Due to a fixed cost of exporting, only the most efficient plants export their products.

Thus, in contrast to Melitz (2003) endogenous entry and selection into export markets takes not place at the firm level but at the plant level. The two-layered production process allows to separate the problem of price setting under price adjustment costs from heterogeneous productivity and plant entry, which allows for a tractable solution of the model.

The economy consists of two countries, Home and Foreign. In the following I will describe the equations for Home. Equivalent equations hold for Foreign.

2.1 Households

The representative household at Home inelastically supplies one unit of labor, L, consumes the the aggregate consumption good $C = \left[\int_0^1 C_i^{(\phi-1)/\phi} \right]^{\phi/(1-\phi)}$, and invests in domestic and foreign bonds, a_t and $a_{*,t}$. It earns income from labor, w, from interest payments, i and i^*, from the profits of firms that are distributed in a lump-sum manner, T^f, and from the tariffs that the governments earns and distributes to the households in a lump-sum manner, t. To pin down the steady state and assure stationary responses to temporary shocks I assume that households have to pay a bond adjustment cost η, which is reimbursed to the households (see, e.g., Schmitt-Grohe and Uribe (2003)).

Maximizing the intertemporal utility function $E_0 \sum_{t=0}^{\infty} \beta^t \frac{C_t^{1-\sigma}}{1-\sigma}$, yields two consumption Euler equations (one for domestic bonds, one for foreign bonds), a demand equation for each domestically produced variety, and a demand equation for each imported variety:

$$C_t^{-\sigma}(1 + \eta a_t) = E_t C_{t+1}^{-\sigma} \beta \frac{1 + i_t}{1 + \pi_{C,t+1}} \tag{1}$$

$$C_t^{-\sigma}(1 - \eta a_t^*) = E_t C_{t+1}^{-\sigma} \beta \frac{1 + i_t^*}{1 + \pi_{C,t+1}^*} \frac{Q_{t+1}}{Q_t} \tag{2}$$

$$C_{di,t} = C_t \left(\frac{P_{di,t}}{P_t} \right)^{-\phi} \tag{3}$$

$$C_{xi,t} = C_t \left(\frac{P_{xi,t}^*}{P_t} \right)^{-\phi} \tag{4}$$

where P_d is the price of domestically produced varieties, P_x^* the price of imported varieties, and P the price index.

2.2 Firms

There is a continuum of firms on the unit interval, each selling a variety, Y_i, subject to the demand functions specified above. The demand of a variety, Y_i,

can differ from the private consumption of the variety, C_i, because it includes the cost of adjusting prices (see further below). Each variety is produced using a CES production function aggregating intermediate inputs, y. The intermediate inputs are produced by M plants owned by the firm, which operate at different productivity. To build a new plant the firm needs to pay the sunk investment cost, $f_e w$, where w is the real wage. Then the productivity z of the plant is drawn from a random distribution $G(z)$ with minimum z_{min}. The productivity of the plant will stay the same until it is destroyed by an exogenous shock that occurs with probability δ each period.

Each firm sells at the domestic market and at the export market. In the case of exporting, the intermediate inputs are exported and then assembled using the CES production function. Exporting an intermediate input entails three kinds of costs: a fixed exporting cost, $f_x \geq 0$, a proportional iceberg trade cost, $\tau^* \geq 1$ and a proportional, income-generating tariff, $t^* \geq 1$.[6] The fixed cost of exporting gives rise to selection into export markets, i.e., only a subset of the plants is productive enough (with $z > z_x$) to generate positive profits from exporting. Thus, in contrast to Melitz (2003) there is no selection into export markets at the firm level (every firm exports), but there is selection into export markets at the plant level. Due to selection into export markets the composition of the exported variety, $Y_x = \left[\int_{z_x}^{\infty} y_x(z)^{(\theta-1)/\theta} M dG(z) \right]^{\theta/(1-\theta)}$, will differ from the the composition of the domestically sold variety, $Y_d = \left[\int_{z_{min}}^{\infty} y_d(z)^{(\theta-1)/\theta} M dG(z) \right]^{\theta/(1-\theta)}$.

Due to the two layers of production, the problem of the firm can be separated into two steps. In the first step the firms chooses investments in new plants, M_e, and the export cutoff, z_x, to minimize the cost of production. In the second step the firm chooses the price of its variety to maximize its profits. Because the decision to build a plant affects not only the present period but also future periods the decision is intertemporal. Thus the firm minimizes the total present

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[6]The main difference between the iceberg trade cost and the tariff is that the latter generates an income for the importing country's government.

discounted cost given by:

$$E_t \sum_{s=t} \beta_{t,w} \left[\frac{P^y_{di,s}}{P_s} Y_{di,s} + \frac{P^y_{xi,s}}{P_s} \tau^* Y_{xi,s} + M_{ei,s} f_e w_s + X_{i,s} M_{i,s} f_x w_s \right] \qquad (5)$$

where P^y_{di}/P is the real cost of the domestically sold variety, P^y_{xi}/P is the real cost of the exported variety, and X is the share of exporting plants. Note that the iceberg trade costs raise the marginal costs of exporting, while tariffs don't. Iceberg trade costs imply that $\tau^* > 1$ units need to be produced so that one unit can be consumed in the foreign country. In contrast, tariffs do not drive a wedge between consumption and production, but instead drive a wedge between the price paid by the consumer and the price received by the producer. Therefore, they show up in the revenue equations of the firm but not in the cost equations.

Minimizing the cost of production implies the following two first order conditions:

$$\frac{P^y_{xi,t}}{P_t} \frac{1}{X_{i,t}} \tau^* Y_{xi,t} \left(\frac{kp + (1-\theta)}{(1-\theta) kp} \right) + M_{i,t} f_x w_t = 0 \qquad (6)$$

$$f_e w_t = (1-\delta) \beta_{t,t+1} * \qquad (7)$$
$$\left[\frac{1}{\theta - 1} \left(\frac{P^y_{di,t+1}}{P_{t+1}} \frac{Y_{di,t+1}}{M_{i,t+1}} + \frac{P^y_{xi,t+1}}{P_{t+1}} X_{i,t+1} \tau^* \frac{Y_{xi,t+1}}{X_{i,t+1} M_{i,t+1}} \right) + f_e w_{t+1} - X_{i,t+1} f_x w_{t+1} \right]$$

where the first equation defines the threshold-productivity for exporting and the second equation optimal investment in new firms.

In setting the optimal prices for the domestic and foreign markets, the firm needs to take account of the cost of adjusting prices. This makes the pricing decision also an intertemporal decision. I assume producer currency pricing, i.e., the firm sets the price for the export market in terms of the domestic currency, P^h_x, and lets the price in the foreign currency be $P_x = P^h_x \tau^* t^* / S$, where S is the nominal exchange rate. The price adjustment cost has to be paid for changes in P^h_x, and for changes in P_d, the price for the domestic market, and is measured in

terms of the final consumption good. Thus, the firm's profits are given by

$$
E_t \sum_{s=t}^{\infty} \Delta_{t,s} \left[\frac{P_{di,s}}{P_s} Y_{di,s} - \frac{P_{di,s}^y}{P_s} Y_{di,s} - \frac{\nu}{2} \left(\frac{P_{di,s}}{P_{di,s-1}} - 1 \right)^2 \frac{P_{di,s}}{P_s} Y_{di,s} \right] + \tag{8}
$$

$$
E_t \sum_{s=t}^{\infty} \Delta_{t,s} \left[\frac{P_{xi,s} S_t}{P_s t_{i,s}^*} Y_{xi,s} - \frac{P_{xi,s}^y}{P_s} \tau^* Y_{xi,s} - \frac{\nu}{2} \left(\frac{P_{xi,s}^h}{P_{xi,s-1}^h} - 1 \right)^2 \frac{P_{xi,s} S_t}{P_s t_{i,s}} Y_{xi,s} \right]
$$

Firm's profits are maximized by setting the price as a markup over marginal cost (remember that $P_{xi,t}^h/P_t$ and $P_{xi,s}^y/P_s$ is the marginal cost of domestically sold and exported varieties, resp.)

$$
\frac{P_{di,t}}{P_t} = \phi / \left[\begin{array}{l} (\phi - 1) \left(1 - \frac{\nu}{2} \pi_{di,t}^2 \right) + \nu \pi_{di,t} \left(\pi_{di,t} + 1 \right) - \\ \nu E_t \Delta_{t,t+1} \pi_{di,t+1} \left(\pi_{di,t+1} + 1 \right)^2 \frac{1}{\pi_{t+1}^C + 1} \frac{Y_{di,t+1}}{Y_{di,t}} \end{array} \right] \frac{P_{di,s}^y}{P_s} \tag{9}
$$

$$
\frac{P_{xi,t}^h}{P_t} = \phi / \left[\begin{array}{l} (\phi - 1) \left(1 - \frac{\nu}{2} \left(\pi_{xi,t} - 1 \right)^2 \right) + \nu \left(\pi_{xi,t} - 1 \right) \pi_{xi,t} - \\ \nu E_t \Delta_{t,t+1} \left(\pi_{xi,t+1} - 1 \right) \pi_{xi,t+1}^2 \frac{1}{\pi_{t+1}^C} \frac{Y_{xi,t+1}}{Y_{xi,t}} \end{array} \right] \frac{P_{xi,s}^y}{P_s} \tag{10}
$$

where $\pi_{d,t} = P_{d,t}/P_{d,t-1} - 1$ is the inflation rate of domestically sold varieties and $\pi_{x,t} = P_{x,t}^h/P_{x,t-1}^h - 1$ is the inflation rate of exported varieties.

Note that in the absence of price changes (as in a steady state), the markup reduces to the common $\phi/(1 - \phi)$. Outside of the steady state the firm needs to weigh the benefits of changing the price against the cost of changing the price. Since the price chosen today affects the price adjustment cost tomorrow this is an intertemporal decision that takes account of future expectations.

2.3 Aggregation

Home's aggregate demand for the final consumption good consists of private consumption and the expenses on price adjustment costs

$$
Y_t = C_t - \frac{\nu}{2} \pi_{d,t}^2 \frac{P_{d,t}}{P_t} Y_{d,t} - \frac{\nu}{2} \pi_{x,t}^2 \frac{P_{x,t} S_t}{P_t t_t^*} Y_{x,t} \tag{11}
$$

The total labor endowment is split over the production for the domestic market, the production for the export market, investment in new firms and the fixed cost of exporting

$$L_t = M_t \frac{\tilde{y}_{d,t}}{Z_t \tilde{z}_d} + M_t X_t \frac{\tilde{y}_{x,t}}{Z_t \tilde{z}_{x,t}} \tau^* + M_{e,t} f_e + M_t X_t f_x \qquad (12)$$

Aggregating the budget constraints for domestic and foreign households and imposing the equilibrium conditions under international bond trading, $a_t = a_t^* = a_{*,t} = a_{*,t}^* = 0$ yields the equation for Home net foreign asset accumulation

$$a_t + Q_t a_t^* = \frac{1 + i_{t-1}}{1 + \pi_t} a_{t-1} + Q_t \frac{1 + i_{t-1}^*}{1 + \pi_t^*} a_{t-1}^* + \frac{1}{t_t^*} Q_t M_t X_t \tilde{\rho}_{x,t} \tilde{y}_{x,t} - \frac{1}{t_t} M_t^* X_t^* \tilde{\rho}_{x,t}^* \tilde{y}_{x,t}^* \qquad (13)$$

where $1/t_t^* Q_t M_t X_t \tilde{\rho}_{x,t} \tilde{y}_{x,t}$ are exports and $1/t_t M_t^* X_t^* \tilde{\rho}_{x,t}^* \tilde{y}_{x,t}^*$ are imports.

2.4 Monetary policy

Monetary policy follows a standard Taylor rule of the form

$$1 + i_t = (1 + i_{t-1})^{\alpha_i} \left((1 + i) (1 + \tilde{\pi}_{C,t})^{\alpha_\pi} \tilde{y}^{\alpha_y} \right)^{1-\alpha_i} \qquad (14)$$

where $\tilde{\pi}_{C,t}$ is the data-consistent inflation rate and $\tilde{y}$ is the data-consistent output gap, the gap between GDP in the model economy and GDP in a counterfactual economy with flexible prices.[7] Monetary policy reacts to increases in the inflation rate above the target of zero, and to positive output gaps by raising the nominal interest rate. However, monetary policy tries to avoid large jumps in the nominal interest rate and therefore smoothes out the adjustment. That's why the past interest rate also shows up in the Taylor rule.

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[7]The difference between the variables in the model and data-consistent variables arises from the problem that variables measured in the data typically do not take account of changes in the number of varieties. To transform a model variable into a data-consistent variable it is multiplied by $(M_t + M_t^* X_t^*)^{\frac{1}{\theta-1}}$. For a more detailed discussion see, e.g., Ghironi and Melitz (2005).

3 Parameterization

My aim is to highlight the importance of monetary policy for calculating Nash-equilibrium tariffs. For doing so I parameterize the model and simulate it for alternative assumptions concerning the conduct of monetary policy.[8] The main reference point of my analysis is LL. Therefore, I use the same parameterization as there whenever possible.[9]

I assume that productivity z is distributed Pareto with lower bound $z_{\min}$ and shape parameter $k > \theta - 1 : G(z) = 1 - (z_{\min}/z)^k$. The assumption of a Pareto distribution for productivity induces a size distribution of firms that is also Pareto which fits firm-level data quite well (see Axtell (2001)).

k indexes the dispersion of productivity draws: dispersion decreases as k increases, and the firm productivity levels are increasingly concentrated toward their lower bound $z_{\min}$. Letting $v \equiv \{k/[k-(\theta-1)]\}^{1/(\theta-1)}$, the average productivities $\tilde{z}_D$ and $\tilde{z}_x$ are given by $\tilde{z}_D = v z_{\min}$ and $\tilde{z}_x = v z_x$. The share of Home's exporting firms is then $X = 1 - G(z_x) = (v z_{\min}/\tilde{z}_x)^k$.

θ is set equal to 3.8 following Bernard, Eaton, Jensen, and Kortum (2003). They also report that the standard deviation of log U.S. plant sales is 1.67. As in the given model this standard deviation is equal to $1/(k-\theta+1)$, the choice of $\theta = 3.8$ implies that $k = 3.4$. Following CG I set the elasticity of substitution across varieties, ϕ, equal to θ.

Every period represents a quarter and therefore β is set equal to 0.99. The inverse of the intertemporal elasticity of substitution from consumption γ is set to 2, which is a standard choice for business cycle models (see, e.g., Krause and Lubik (2007) or Faia (2009)). δ, the exogenous firm exit shock, is set equal to 0.025, which matches the U.S. empirical level of 10 percent job destruction per

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[8]For all the simulations I use the deterministic solution method of Dynare for Matlab, see Juillard (1996).

[9]The parameterization in LL follows closely the one proposed in Ghironi and Melitz (2005) and is similar in spirit to the more recent publications of Atkeson and Burstein (2010), Bilbiie, Ghironi, and Melitz (2012), or Bergin and Lin (2012).

year (see Ghironi and Melitz (2005)). Consistently with Obstfeld and Rogoff (2001) I set the iceberg trade cost τ equal to 1.2.

The fixed cost of exporting f_x is set to 10.9 percent of the per-period, amortized flow value of entry costs, $[1-\beta(1-\delta)]/[\beta(1-\delta)]f_E$, such that the proportion of exporting plants matches the 21 percent reported in Bernard, Eaton, Jensen, and Kortum (2003). I set the scale parameter for the bond adjustment costs to $\eta = 0.5$, larger than value in LL or Ghironi and Melitz (2005). This is necessary to generate determinacy even when the tariffs of both countries are very different. Luckily, it is still low enough so that the presence of bond adjustment costs does not affect the optimal level of tariffs.[10]

Entry costs f_E are set to 1 without loss of generality, as changing f_E while maintaining the ratio f_x/f_E does not affect any of the impulse responses (see Ghironi and Melitz (2005)). For similar reasons, I normalize $z_{\min}$ to 1. Labor endowments are also normalized to 1, i.e., $L = 1$ and $L^* = 1$. Following Cacciatore and Ghironi (2014) the cost of adjusting prices is set to $\nu = 80$. Following Clarida, Gali, and Gertler (2000) the coefficients in the Taylor rule are set to $\alpha_\pi = 1.62$, $\alpha_y = 0.34$, and $\alpha_i = 0.71$.

4 Nash equilibrium tariffs in the static model

In the following sections I will first illustrate the dynamic adjustment of the model economy after a unilateral cut in the tariff and then discuss the implications of price rigidity and monetary policy for the optimal tariff. But before starting the discussion of the dynamic adjustment let me determine the equilibrium of the static model, i.e., a model that ignores the dynamic adjustment process and assumes that the economy jumps immediately to the new steady state. This tariff will serve as a reference point and represents the standard approach in the trade

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[10]In the Appendix I compare the dynamic adjustment in the model with flexible prices under $\eta = 0.0025$ and $\eta = 0.5$. The results do not differ, which is due to generally low trade imbalances.

literature.

Charging a tariff on imports has two important effects. On the one hand, it raises revenue which is, of course welfare improving. On the other hand, it raises the price of imports which hurts domestic consumers. However, under monopolistic competition the tariff will not lead to a one-to-one increase in the price, i.e., part of the cost is borne by the foreign producers. Put differently, by charging a tariff, Home imposes a negative terms-of-trade externality on Foreign.

For very low tariffs, the first effect will dominate so that it is welfare improving for Home to raise the tariff, given a specific tariff of Foreign. For very high tariffs, the second effect dominates so that it is welfare improving for Home to lower the tariff, given a specific tariff of Foreign. For every tariff of Foreign, there exists an optimal tariff for Home such that changing the tariff only leads welfare losses. Calculating this tariff for a range of tariffs in Foreign yields the best response function of Home, i.e., the best response of Home for a given tariff of Foreign.

Following the same procedure for Foreign yields the optimal response function of Foreign. Intersecting the two best-response functions yields the Nash-equilibrium tariff. No country will have an incentive to deviate from this tariff because it already maximizes steady state consumption. The Nash-equilibrium tariff of the static model is 35.1%, which is the exact same value as in LL, which assures us that the slightly different setup of the model does not matter for the results.

Note that from a supranational perspective the Nash-equilibrium is sub-optimal. From a supranational perspective the optimal tariff would be zero for both countries. But in fact the two countries play a Prisoner's Dilemma. If they cannot commit to zero tariffs, then the terms-of-trade externality gives them an incentive to "betray" the other country, resulting in a Nash-equilibrium with positive tariffs.

5 The dynamic adjustment after a unilateral drop in tariffs

Let me now turn to the discussion of dynamic adjustment. Figure 1 illustrates the dynamic adjustment of selected variables to a unilateral cut in the import tariff charged by Home from 35.1% to 33%. To improve the visibility of short run adjustments, the figure illustrate only the first 20 periods. Time is on the horizontal axis, measured in quarters. On the vertical axis the percent deviation of a specific variable from its pre-liberalization steady state is illustrated (except for the inflation rates). The solid line represents the case with rigid prices, the dashed line the case with flexible prices.[11] Nominal variables are only reported for the model with rigid prices because they are meaningless in the model with flexible prices.

As expected the decrease in tariffs leads to an immediate increase in imports because they become relatively cheaper. The availability of cheap imports puts downwards pressure on the aggregate price index, which increases real wages. Higher real wages in turn tend to increase prices, because prices are set as a markup over marginal costs. On the market for domestically produced varieties, this cannot be compensated by lower tariffs or adjustments in the real exchange rate and therefore the price of domestically produced varieties goes up relative to imported varieties. This results in a marked decline in the demand for domestically produced varieties. On the export market the increase in real wages is compensated by a real exchange rate depreciation. The sudden increase in demand for foreign products induced by the drop in tariffs pushes up the price level of Foreign relative to Home, leading to an exchange rate depreciation of Home. On the one hand this counteracts the effect of the decrease in the tariff

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[11]The development of variables under flexible prices is virtually the same as in LL, reassuring that the main difference between both models lies in the rigidity of prices, while the slightly different setup of the model does not seem to matter much.
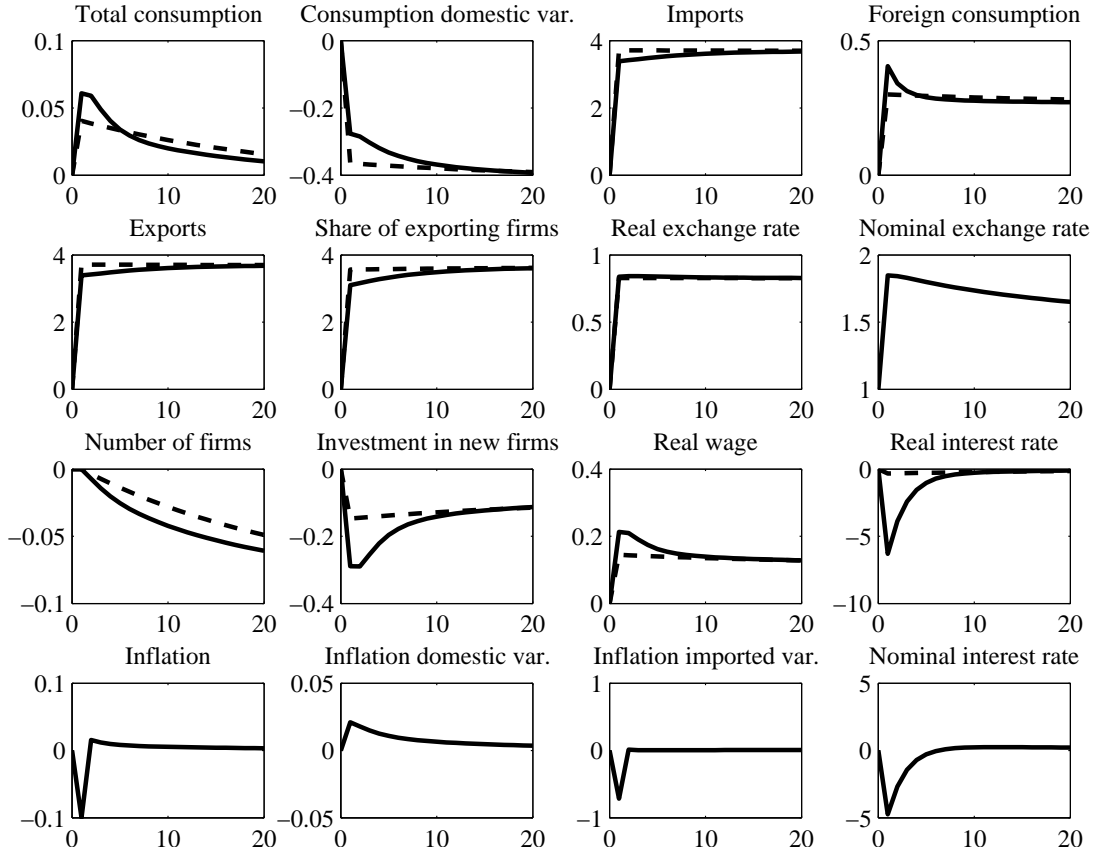
Figure 1: Effects of a 2.1 percentage point reduction of the Home tariff, starting from the Nash-equilibrium tariff in the static model. Quarters on the horizontal axis, percent deviations from the old steady state on the vertical axis. Solid line: model with rigid prices. Dashed line: model with flexible prices.

on imports. On the other hand this increases the demand for exports. As a consequence, the trade balance (not depicted) does not move by much.

Consumption goes up in the short run, overshooting its long run equilibrium.[12] We know that consumption must go down in the long run - otherwise the old steady state could not be a Nash-equilibrium of the static model. By definition of the Nash-equilibrium of the static model, the real exchange rate depreciation in not enough to offset the decreasing income from tariffs and so consumption

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[12]Qualitatively this result is similar to the consumption overshooting in Bergin and Lin (2012) and the productivity overshooting in Chaney (2005). Empirical evidence distinguishing the short- and long-run effects of trade liberalization is very scarce. Indirect evidence is provided by Bergin and Lin (2012) who show that the increase at the extensive margin is larger in the short-run than in the long-run.

must go down in the long run.

This development is mainly explained by the availability of cheaper imports and by the lower investment in new firms. We know already from Melitz (2003) that trade liberalization leads to a decrease in the number of firms. In a static model this adjustment happens immediately but in a dynamic model the adjustment is a slow process. The investment in an existing plant is already sunk and therefore it pays off to keep producing, even though, due to the cut in tariffs, profits for some plants might be lower than expected. The plants keep on operating until they are hit by an exogenous exit shock.

However, because the number of plants is too high, incentives to invest in new plants go down. The ensuing decrease of investments in new plants implies that more resources can be devoted to produce the consumption good. This reduces the drop in the consumption of domestic varieties and thus pushes up total consumption. Naturally, this effect is only short-lived. As the number of plants decreases, incentives to invest in new plants increase and fewer resources are left to produce the consumption good. Thus, as the number of plants decreases, the investment in new plants increases and consumption decreases.

Figure 1 shows the development of both an economy with flexible prices and an economy with rigid prices. Qualitatively the adjustment of most variables does not differ by much between the two economies, but quantitatively there are some notable differences. Perhaps surprisingly the real exchange rate does not belong to these. Even though producer prices are much slower to adjust in the model with rigid prices, there is virtually no difference in the real exchange rate. The reason is that the flexible nominal exchange rate mechanism compensates partly for the rigidity of prices.

Nevertheless, the slow adjustment of prices has real consequences. A direct implication of price rigidity is that the increase in the price level of domestically produced varieties is slowed down. Due to the increase in real wages firms would like to raise their prices, but due to price adjustment costs this process is slowed

down. This has two important consequences. On the one hand, the drop in production for the domestic market is subdued. On the other hand, the profitability of plants is reduced and so investment in new plants drops by even more. As a consequence, more resources go into the production of the consumption good in the initial periods after trade liberalization so that consumption goes up by more under rigid prices than under flexible prices. In the medium run this difference is reduced and the cost of adjusting prices pushes aggregate consumption in the model with rigid prices below its level in the model with flexible prices.

Due to the adjustment in the nominal exchange rate, the real exchange rate is basically the same as in the model with flexible prices. Nevertheless, the increase in imports and exports is smaller. The reason for both phenomena lies in the the higher production for the domestic market. On the one hand this is binding resources, implying that the production for the foreign market cannot increase by as much. On the other hand the higher availability of domestic varieties reduces the demand for imports.

Looking at the nominal variables, it is notable that the reduction in tariffs leads to an immediate drop in the inflation of imported varieties. That drop is so large that the aggregate inflation rate also decreases, even though the price of domestically produced varieties (which make up a larger share of aggregate consumption) increases. This has important repercussions through monetary policy. The central bank notices the deflation and reacts by decreasing the nominal interest rate to stimulate demand and to counteract deflation.[13] In later periods inflation is closer to target but monetary policy is still relatively expansive due to the desire of the monetary authority to smooth interest rate movements.

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[13]Looking at total consumption it appears as if the output gap is substantially positive in the very short. However, the gap between the data-consistent measures of total consumption, which defines the output gap, is much smaller.

6 Rigid prices and Nash-equilibrium tariffs

To determine the Nash-equilibrium tariffs, I again calculate the best-response functions for both countries. However, in contrast to the Nash-equilibrium tariff of the static model, I take account of the adjustment process, by assuming that the policy maker chooses to maximize the discounted present value of consumption, instead of just maximizing steady state consumption. Intersecting the best response functions under the assumption that the policy maker's planning horizon is infinite yields a Nash-equilibrium tariff of 33% in the model with flexible prices,[14] and 33.5% in the model with rigid prices. As in LL taking account of the dynamic adjustment process leads to lower Nash-equilibrium tariffs. This is due to the short-run boom in consumption induced by the drop in tariffs.

An important question raised in LL is how the planning horizon of the policy authority affects the setting of tariffs. Typically tariffs are set by elected politicians (at least in developed countries), who tend to have a shorter planning horizon than infinity. In LL it was shown that politicians with a shorter planning horizon set lower tariffs, due to the overshooting nature of consumption. Here I repeat this exercise and compare the results to LL.

Figure 2 illustrates the Nash-equilibrium tariff, set by a policy maker who only cares about the next x years, with x indicated at the horizontal axis. Put differently, when calculating the best-response functions only consumption up to period x is included in the calculation. The pattern of the curve is the same, whether prices are flexible or not. It is still the case that policy makers with a shorter planning horizon set lower tariffs. However, there are some important differences, too.

In the economy with rigid prices consumption increases by more in the short run in response to a cut in tariffs. Therefore, policy makers with a very short planning horizon tend to set lower tariffs in the model with rigid prices. In the

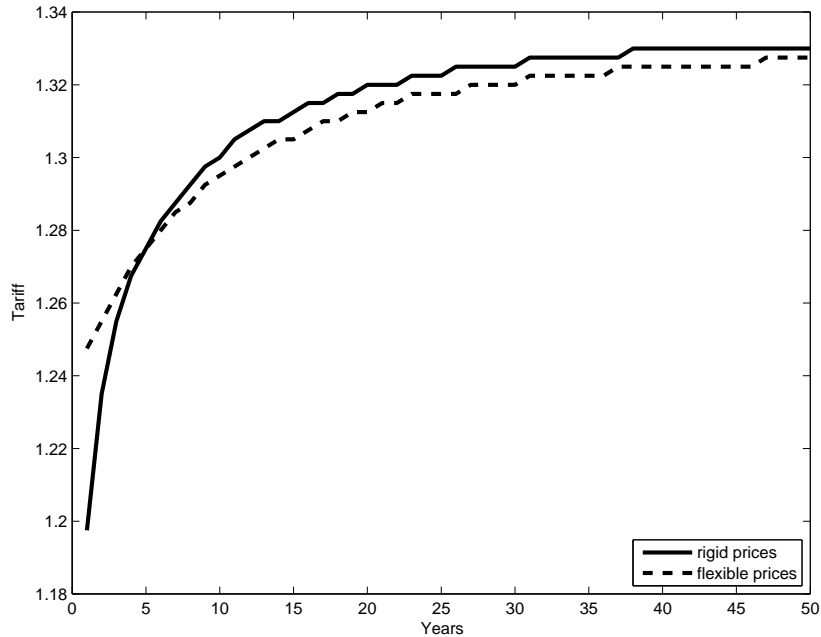---

[14]Again, this is the exact same value as in LL.

Figure 2: Optimal tariff in dependence of policy maker's planning horizon.

medium run, however, consumption is lower in the model with rigid prices and thus policy makers with an intermediate or long run planning horizon tend to set higher tariffs. Thus, the planning horizon of the policy maker matters even more in the model with rigid prices, the span of possible tariffs is larger and the optimal tariffs increase much more steeply in response to increases in the planning horizon. In the next section I will analyze the role of monetary policy and illustrate, that it matters a great deal. Monetary policy can even overturn the result that policy makers with a shorter planning horizon tend to set lower tariffs.

7 Monetary policy and Nash-equilibrium tariffs

So far I have assumed that both countries are identical in terms of their stance on monetary policy, i.e., the parameters in the Taylor rule of both countries were assumed to be the same. I will now relax this assumption and assume instead that

the central bank of one country is more aggressive in fighting inflation than the other country. More specifically, I assume that the Taylor rule of Foreign is still the same as in the benchmark, while in the Taylor rule of Home the coefficient on inflation is raised from 1.62 to 5.[15]
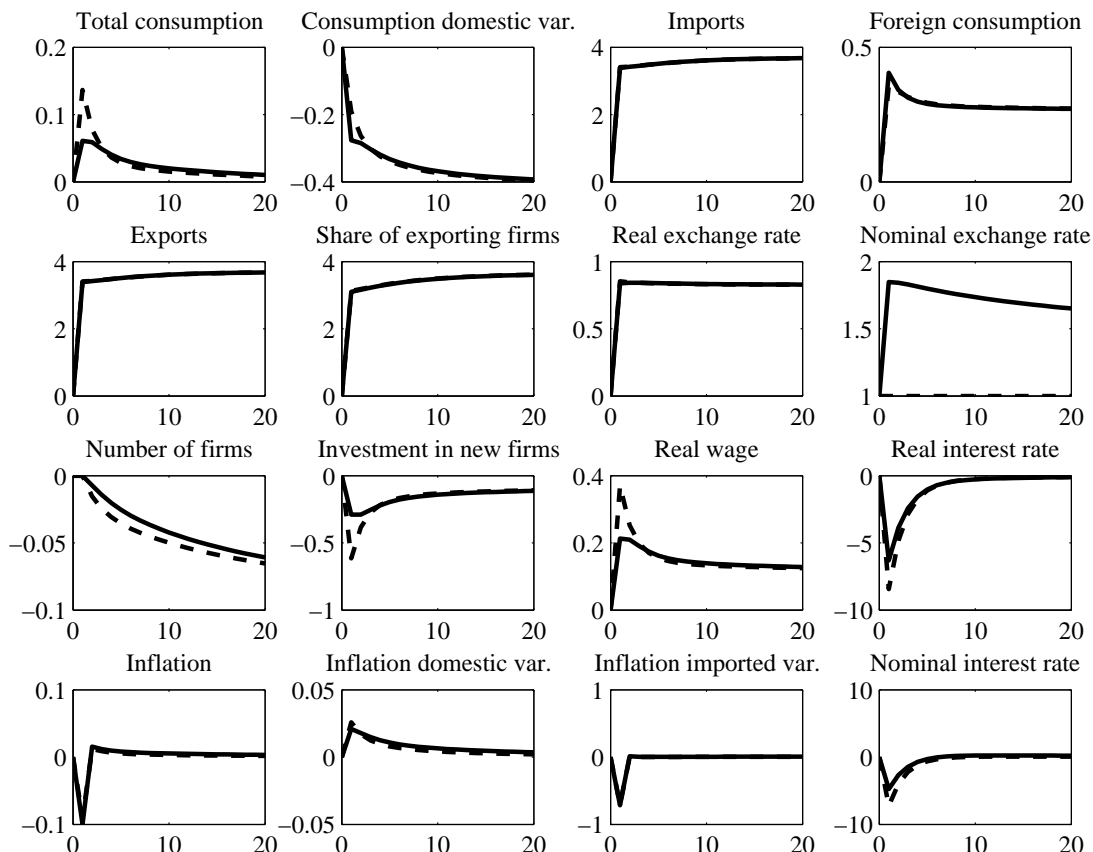

Figure 3: Effects of a 2.1 percentage point reduction of the home tariff, starting from the Nash-equilibrium tariff in the static model. Quarters on the horizontal axis, percent deviations from the old steady state on the vertical axis. Solid line: benchmark case. Dashed line: Home's central bank fights inflation more aggressively.

The ensuing adjustment dynamics are illustrated in figure 3. Due to the influx of cheap imports initiated by lower import tariffs, the inflation rate turns negative. A central bank that fights deviations from its target of zero inflation more aggressively will try to counteract this development by stimulating demand through lower interest rates. Consequently, aggregate consumption is

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[15]I choose this extreme variation for illustrational purposes.

much higher, at the cost of a much more pronounced reduction in the investment in new plants.

Due to the flexible nominal exchange rate mechanism expansive monetary policy has only minor implications for the price index of imported products and thus for import demand. But the reduction in the demand for domestically produced varieties is slowed down considerably with the consequence that the price index of domestically produced varieties is increased. Put differently, due to the flexible nominal exchange rate, the central bank can only fight deflation by pushing up the inflation of domestically produced varieties.

Again, Nash-equilibrium tariffs are determined by calculating best response functions for policy makers with differing planning horizons. The result is illustrated in figure 4 and reveals marked differences from the benchmark case, where both central banks follow a less aggressive Taylor rule. In the long run, the aggressiveness of a central bank does not seem to play a role but in the short run the implications are stark.
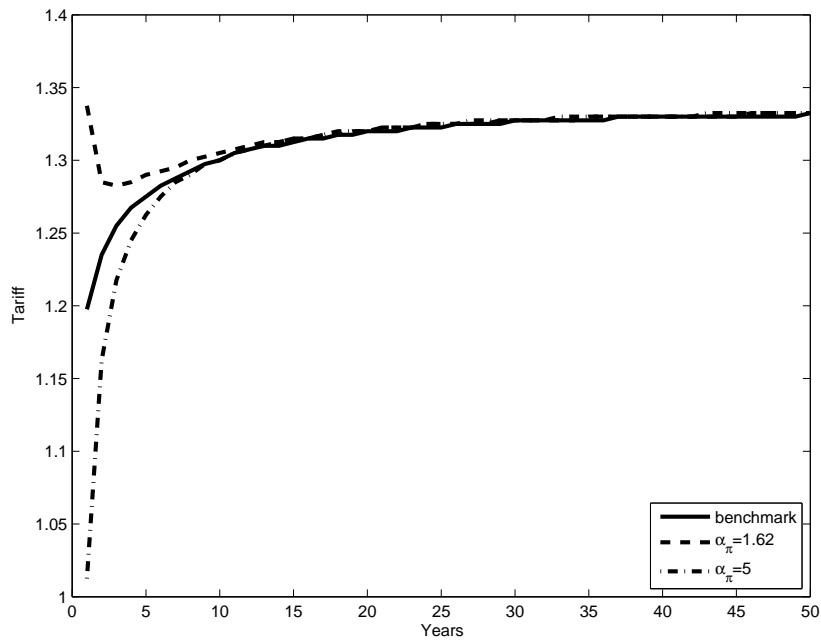

Figure 4: Optimal tariff in dependence of policy maker's planning horizon.

In the country with aggressive monetary policy a cut in tariffs leads to a strong boom in the initial periods after the cut. This induces policy makers with a short planning horizon to set very low tariffs, even coming close to zero tariffs for very short planning horizons. For the other country, things look very different. The very low tariff in Home gives Foreign much leeway to exploit the effect of higher tariffs on the terms of trade. As a consequence, Nash-equilibrium tariffs in Foreign can even be higher under short planing horizons than under long planning horizons.[16]

Thus, monetary policy plays a crucial role in the setting of optimal tariffs, even to such an extent that it can overturn the result in LL that policy makers with shorter planning horizons always set lower tariffs than policy makers with longer planning horizons.

8 Conclusion

Using a dynamic trade model with endogenous firm entry, firm heterogeneity and selection into export markets I show that nominal price rigidity and monetary policy can have important effects on the optimal setting of tariffs, a relationship so far not considered in the literature.

Nominal price rigidity tends to strengthen the boom in consumption that follows a unilateral drop in tariffs. The boom in consumption follows from the availability of cheap imports and the temporary reduction in the creation of new firms. Nominal price rigidity slows down the price increase of domestic varieties. This slows down the drop in demand for domestically produced varieties but also reduces the profits of firms and thereby the investment in new firms. Both effects tend to increase consumption and thus nominal price rigidity reinforces the short

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[16]This result depends, of course, on how aggressive monetary policy is. If monetary policy in Home is less aggressive than in this example (but still more aggressive than in Foreign), a monotonically increasing curve might reemerge, but the pattern that Home sets lower tariffs would still be the same.

run boom in consumption.

If policy makers have short planning horizon (as they tend to have, due to short legislative periods), this has important consequences for the level of tariffs they choose. Nominal price rigidity can induce policy makers to set lower tariffs, because of their strengthening effect on the consumption boom.

Naturally, in such an environment monetary policy begins to matter. From the macro literature it is well known that monetary policy affects the short run adjustment of most macroeconomic variables. Here monetary policy, modelled as a standard Taylor rule, counteracts the deflation following a drop in tariffs by lowering the nominal interest rate and stimulating demand. The more aggressively monetary policy fights deflation, the larger the boom in consumption, and thus the lower the tariffs set by a policy maker with a short planning horizon.

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9 Appendix

9.1 Model equations

$$1 = M_t^{\frac{1-\phi}{1-\theta}} \tilde{\rho}_{d,t}^{1-\phi} + (X_t^* M_t^*)^{\frac{1-\phi}{1-\theta}} (\tilde{\rho}_{x,t}^*)^{1-\phi} \tag{15}$$

$$\tilde{\rho}_{x,t}^{-\phi} (X_t M_t)^{\frac{\theta-\phi}{1-\theta}} Y_t^* = \frac{1}{\tau^*} \frac{(\theta-1) k_p}{\gamma} \tilde{z}_{x,t} f_x \tag{16}$$

$$L_t = M_t \frac{\tilde{y}_{d,t}}{Z_t \tilde{z}_d} + M_t X_t \frac{\tilde{y}_{x,t}}{Z_t \tilde{z}_{x,t}} \tau^* + M_{e,t} \frac{f_e}{Z_t} + M_t X_t \frac{f_x}{Z_t} \tag{17}$$

$$1 = (1-\delta) \beta E_t \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{\tilde{\rho}_{d,t+1}}{\tilde{\rho}_{d,t}} \left(\frac{\mu_{d,t}}{\mu_{d,t+1}} \left(1 - X_{t+1} \frac{f_x}{f_e} \right) \right. \tag{18}$$

$$\left. + \frac{1}{(\theta-1) f_e \tilde{z}_d} \left(\frac{\mu_{d,t}}{\mu_{d,t+1}} \tilde{y}_{d,t+1} + X_{t+1} \frac{Q_{t+1}}{t_{t+1}^*} \frac{\tilde{\rho}_{x,t+1}}{\tilde{\rho}_{d,t+1}} \frac{\mu_{d,t}}{\mu_{x,t+1}} \tilde{y}_{x,t+1} \right) \right)$$

$$L_t^\varphi = C_t^{-\sigma} w_t \tag{19}$$

$$1 + i_t = (1 + i_{t-1})^{\alpha_i} \left((1 + i)(1 + \tilde{\pi}_{C,t})^{\alpha_\pi} GAP_t^{\alpha_y} \right)^{1-\alpha_i} \tag{20}$$

$$C_t^{-\sigma}(1 + \eta a_t) = E_t C_{t+1}^{-\sigma} \beta \frac{1 + i_t}{1 + \pi_{C,t+1}} \tag{21}$$

$$C_t^{-\sigma}(1 - \eta a_t^*) = E_t C_{t+1}^{-\sigma} \beta \frac{1 + i_t^*}{1 + \pi_{C,t+1}^*} \frac{Q_{t+1}}{Q_t} \tag{22}$$

$$M_t = M_{t-1}(1-\delta) + M_{e,t-1}(1-\delta) \tag{23}$$

$$\tilde{z}_{x,t} = (k_p/\gamma)^{1/(\theta-1)} \psi_t \tag{24}$$

$$X_t = (z_{min}/\psi_t)^{k_p} \tag{25}$$

$$\mu_{d,t} = \phi / \left[(\phi-1)(1 - \frac{\nu}{2}\pi_{d,t}^2) + \nu(\pi_{d,t}+1)\pi_{d,t} - \right. \tag{26}$$

$$\left. \nu E_t \beta \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} (\pi_{d,t+1}+1)^2 \frac{\pi_{d,t+1}}{\pi_{C,t+1}+1} \frac{\tilde{y}_{d,t+1}}{\tilde{y}_{d,t}} \left(\frac{M_{t+1}}{M_t} \right)^{\frac{\theta}{\theta-1}} \right]$$

$$\mu_{x,t} = \phi / \left[(\phi-1)(1 - \frac{\nu}{2}\pi_{x,t}^2) + \nu(\pi_{x,t}+1)\pi_{x,t} - \right. \tag{27}$$

$$\left. \nu E_t \beta \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} (\pi_{x,t+1}+1)^2 \frac{\pi_{x,t+1}}{\pi_{C,t+1}+1} \frac{\tilde{y}_{x,t+1}}{\tilde{y}_{x,t}} \left(\frac{M_{t+1} X_{t+1}}{M_t X_t} \right)^{\frac{\theta}{\theta-1}} \right]$$

$$\tilde{\rho}_{d,t} = \mu_{d,t} \frac{w_t}{Z_t \tilde{z}_d} \tag{28}$$

$$\tilde{\rho}_{x,t} = \mu_{x,t} \frac{\tau^* t_t^*}{Q_t} \frac{w_t}{Z_t \tilde{z}_{x,t}} \tag{29}$$

$$\tilde{y}_{d,t} = \tilde{\rho}_{d,t}^{-\phi} M_t^{\frac{\theta-\phi}{1-\theta}} Y_t \tag{30}$$

$$\tilde{y}_{x,t} = \tilde{\rho}_{x,t}^{-\phi} \left(M_t X_t\right)^{\frac{\theta-\phi}{1-\theta}} Y_t^* \tag{31}$$

$$Y_t = C_t + \frac{\nu}{2} \pi_{d,t}^2 \tilde{\rho}_{d,t} M_t^{\frac{1}{1-\theta}} \tilde{y}_{d,t} M_t^{\frac{\theta}{\theta-1}} + \frac{\nu}{2} \pi_{x,t}^2 \tilde{\rho}_{x,t} (M_t X_t)^{\frac{1}{1-\theta}} \tilde{y}_{x,t} (M_t X_t)^{\frac{\theta}{\theta-1}} \tag{32}$$

$$\frac{1 + \pi_{d,t}}{1 + \pi_{C,t}} = \frac{\tilde{\rho}_{d,t}}{\tilde{\rho}_{d,t-1}} \left(\frac{M_t}{M_{t-1}}\right)^{\frac{1}{1-\theta}} \tag{33}$$

$$\frac{1 + \pi_{x,t}}{1 + \pi_{C,t}} = \frac{Q_t}{Q_{t-1}} \frac{\tilde{\rho}_{x,t}}{\tilde{\rho}_{x,t-1}} \left(\frac{M_t X_t}{M_{t-1} X_{t-1}}\right)^{\frac{1}{1-\theta}} \frac{t_{t-1}^*}{t_t^*} \tag{34}$$

$$a_t + Q_t a_t^* = \frac{1 + i_{t-1}}{1 + \pi_t} a_{t-1} + Q_t \frac{1 + i_{t-1}^*}{1 + \pi_t^*} a_{t-1}^* + tb_t \tag{35}$$

$$tb_t = \frac{Q_t}{t_t^*} M_t X_t \tilde{\rho}_{x,t} \tilde{y}_{x,t} - \frac{1}{t_t} M_t^* X_t^* \tilde{\rho}_{x,t}^* \tilde{y}_{x,t}^* \tag{36}$$

9.2 The relevance of bond adjustment costs

For the flexible price economy I ran I simulate for both $\eta = 0.0025$, as in Ghironi and Melitz (2005), and $\eta = 0.5$ as used in this paper. Figure 5 compares the two cases. It can be seen that the level of η does not matter for the results. The reason is that in any case the movement of the trade balance is negligible.

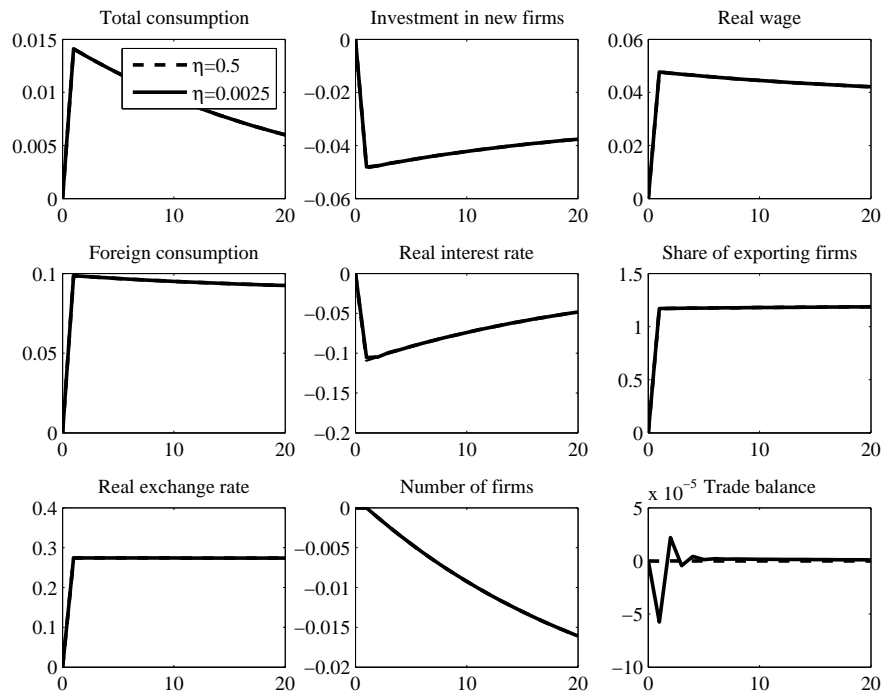

Figure 5: Effects of a reduction of the Home tariff for different levels of η.