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Wolfgang Lechthaler

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BEN BERNANKE IN DOHA: THE EFFECT OF MONETARY POLICY ON OPTIMAL TARIFFS

Wolfgang Lechthaler[1]

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 the setting of 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.

Keywords: tariffs; dynamic trade model; monetary policy

JEL classification: E52, F11, F12, F13

Wolfgang Lechthaler
Kiel Institute for the World Economy
Kiellinie 66, D-24105 Kiel, Germany
phone: +49-431-8814-272
Email: Wolfgang.lechthaler@ifw-kiel.de

[1]Institute for the World Economy, Kiellinie 66, 24105 Kiel, Germany

1 Introduction

The interaction of monetary policy and 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 the 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 become relevant, since it is well know that both have 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 price rigidity and monetary policy can have a substantial effect on the level of tariffs set by politicians.

To analyze this question I use a dynamic two-country 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 increase in tariffs. Following Ossa (2014) I consider three alternatives for setting the tariff: unilaterally optimal tariffs, Nash-equilibrium tariffs (trade wars), and cooperatively set tariffs (trade talks). I show that in each case the resulting tariffs depend on the planning horizon of the policy maker that sets the tariff.

[1]Felbermayr, Jung, and Larch (2013) have shown that including firm heterogeneity is crucial when analyzing optimal tariffs because the restriction to homogenous goods shuts off an important channel.

A unilateral increase in tariffs leads to a short run drop in consumption.[2] There are two main reasons for this result. On the one hand, imported varieties become more expensive and thus less of them can be consumed. On the other hand, the higher tariff leads to weaker competition, implying a larger number of plants in the long run. In the transition period this leads to a considerable increase in investments in new plants. Since a larger number of workers is bound by the construction of new plants, fewer are available to produce consumption goods.

So far this resembles the results in Larch and Lechthaler (2013) (LL henceforth), who study at Nash-equilibrium tariffs in a dynamic context with flexible prices. The novelty of this paper with respect to LL is a broader perspective (including the analysis of optimal tariffs and cooperatively set tariffs), as well as the introduction of rigid prices, modelled as Rotemberg price adjustment costs, and the relevance of monetary policy that this implies. Rigid prices imply a slower adjustment in the level of consumption because the increase in production for the domestic market is less extreme and because monetary policy, modelled as a standard Taylor rule, raises the nominal interest rate to counteract the surge in inflation caused by higher import prices. In the medium run, though, consumption is higher 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]

Another advantage of using a dynamic model with price rigidities is the pos-

[2]Qualitatively this result is similar to the consumption overshooting in response to trade liberalization 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 adjustment at the extensive margin is larger in the short-run than in the long-run.

[3]For the new 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.

sibility to analyze the role that monetary policy plays for the setting of tariffs. To this end section 7 compares several alternatives to the standard Taylor rule. I show that a monetary authority that fights deviations from its inflation target more aggressively increases the short-run cost of raising tariffs and therefore induces short-sighted politicians to set lower tariffs. In the extreme case that the monetary authority keeps prices stable, short-sighted politicians might even decide to abolish tariffs completely. Targeting the output gap has the opposite effect, but matters quantitatively little.

Section 8 provides robustness checks and extensions of the model that include other relevant features. Most importantly, a version of the model with endogenous labor supply and wage rigidity is presented. I show that these extensions further push down the optimal tariff, because workers react to an increase in the tariff by reducing their labor supply. This section also demonstrates that heterogenous productivity and endogenous entry are crucial features in determining optimal tariffs.

So does this model help in rationalizing observed tariffs? After all, most theoretical analyses typically yield much higher optimal tariffs than what is observed in the data (see, e.g., Ossa (2014) for a quantitatively rigorous analysis of optimal tariffs). The standard explanation for this phenomenon is that trade agreements push tariffs below unilaterally optimal tariffs. This is, of course, also true in my model, but it also provides a potential alternative explanation. Raising tariffs entails short-run costs which are ignored in static analyses. These short run costs higher in the presence of nominal rigidities, aggressive monetary policy and endogenous labor supply. A model entailing these features can yield very low optimal tariffs even in the absence of trade agreements.

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 (see, e.g., Krugman (1991), Bond and Syropoulos (1996), Bagwell and Staiger (1999), Yi (2000), Ornelas (2005), Demidova and Rodrï¿½guez-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. 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 barriers, while I 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 discuss optimal tariffs, in section 5 Nash-equilibrium tariffs, and section 4 cooperative tariffs. Section 7 is devoted to the effects of monetary policy. Section 8 presents extensions and robustness checks. Section 9 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,

[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 pro-

Jung, and Larch (2013) 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 analyze 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 an exogenous and 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 which gives rise to sluggish price adjustment in response to shocks.

The product 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.

ductivity are driven out of the market, while remaining 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)).

Thus in contrast to Melitz (2003) endogenous entry and selection into export markets does not take 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 endogenous entry, which allows for a tractable solution of the model.

The economy consists of two countries, Home and Foreign, each with its own currency which implies that each country has its own monetary authority (in contrast to a currency union where only on monetary authority exists). 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 aggregate consumption good $C = \left[\int_0^1 C_i^{(\phi-1)/\phi}\right]^{\phi/(\phi-1)}$, that is a CES aggregate of intermediate products C_i with elasticity of substitution ϕ, and invests in domestic and foreign bonds, a_t and $a_{*,t}$. The household earns income from labor, w, from interest payments, r and r^*, from the profits of firms that are distributed in a lump-sum manner, T^f, and from the tariffs that the government earns and distributes to the households in a lump-sum manner, T^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, T^a (see, e.g., Schmitt-Grohe and Uribe (2003) or Ghironi and Melitz (2005)). These considerations imply the intertemporal budget constraint (in real terms, i.e., in terms of consumption goods)

$$\begin{aligned} & a_{t+1} + Q_t a_{*,t+1} + \frac{\eta}{2}(a_{t+1})^2 + \frac{\eta}{2}Q_t(a_{*,t+1})^2 + C_t = \\ & (1+r_t)a_t + Q_t(1+r_t^*)a_{*,t} + w_t L + T_t^f + T_t^t + T_t^a, \end{aligned} \tag{1}$$

where $Q = SP^*/P$ is the real exchange rate, with P being the domestic price index, P^* the foreign price index, and S the nominal exchange rate. Maximizing the intertemporal utility function $E_0 \sum_{t=0}^{\infty} \beta^t \frac{C_t^{1-\sigma}}{1-\sigma}$ with elasticity of intertemporal substitution, σ, and discount factor, β, subject to the budget constraint 1 yields two consumption Euler equations (one for domestic bonds, one for foreign bonds), a demand equation for each domestically produced variety, C_{di}, and a demand equation for each imported variety, C_{xi}:

$$C_t^{-\sigma}(1 + \eta a_t) = E_t C_{t+1}^{-\sigma} \beta \left(1 + r_t\right) \tag{2}$$

$$C_t^{-\sigma}(1 - \eta a_t^*) = E_t C_{t+1}^{-\sigma} \beta \left(1 + r_t^*\right) \frac{Q_{t+1}}{Q_t} \tag{3}$$

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

$$C_{xi,t} = C_t \left(\frac{P_{xi,t}^*}{P_t}\right)^{-\phi} \tag{5}$$

where P_{di} is the price of a domestically produced variety, and P_{xi}^* the price of an imported variety.

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. However, 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, with elasticity of substitution θ. 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, $f_e w$. Then the productivity z of the plant is drawn from a Pareto distribution $G(z)$ with minimum z_{min}, and shape parameter k. 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, but not all plants are used for exporting. In the case of exporting, the intermediate inputs are first 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, $t^* \geq 1$.

Iceberg trade costs and tariffs are conceptually different. The former imply a waste of resources. If foreign consumers want to consume x units of a domestic good, τx goods need to be produced and shipped. $(\tau - 1)x$ of the shipped goods 'melt away' so that only x remains to be consumed. In contrast, tariffs constitute a transfer of money and not a waste of resources. The quantity produced and the quantity consumed is the same, but there is gap between the amount that consumers pay and the amount that producers get, with the difference going to the government.

The fixed cost of exporting only has to be paid for those plants that are actually exporting. This 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 among firms (every firm exports), but there is selection into export markets among plants. 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 product 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 discounted cost given by:

$$E_t \sum_{s=t} \beta_{t,s} \left[\frac{P^y_{di,s}}{P_s} Y_{di,s} + \frac{P^y_{xi,s}}{P_s} \tau^* Y_{xi,s} + M_{ei,s} f_e w_s + X_{i,s} M_{i,s} f_x w_s \right] \tag{6}$$

where $\beta_{t,s}$ is the stochastic discount factor, 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 cost of exporting, while tariffs don't. As explained above iceberg trade costs constitute a waste of resources and thus increase the marginal cost. In contrast, tariffs constitute a transfer. 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:

$$\frac{P^y_{xi,t}}{P_t} \frac{1}{X_{i,t}} \tau^* Y_{xi,t} \left(\frac{k + (1-\theta)}{(1-\theta)\, k} \right) + M_{i,t} f_x w_t = 0 \tag{7}$$

$$f_e w_t = (1-\delta)\, \beta_{t,t+1} * \tag{8}$$

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

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 quadratic price adjustment costs ala Rotemberg, with the parameter ν governing the extent of price adjustment costs. As is standard, 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 adjust to be $P_x = tP^h_x/S$. Thus the price adjustment cost has to be paid for changes in P^h_x, and not for changes in P_x.

Naturally this has implication for the effect of tariff changes on price setting and the dynamic adjustment to tariff changes. In response to an increase in the tariff, the firm could costlessly increase the price on the foreign market (if it leaves P_x^h constant). This is different under local currency pricing, the alternative price setting mechanism, under which the price adjustment cost has to be paid for changes in P_x, the local price. I analyze local currency pricing in section 8 and show that it does not qualitatively change my results, only quantitatively.

Then, taking account of price adjustment costs, the firm's problem is to maximize

$$E_t \sum_{s=t}^{\infty} \Delta_{t,s} \left[\frac{P_{di,s}}{P_s} Y_{di,s} - \frac{P_{di,s}^y}{P_s} Y_{di,s} - \frac{\nu}{2} \left(\frac{P_{di,s}}{P_{di,s-1}} - 1 \right)^2 \frac{P_{di,s}}{P_s} Y_{di,s} \right] + \tag{9}$$
$$E_t \sum_{s=t}^{\infty} \Delta_{t,s} \left[\frac{P_{xi,s}^h}{P_s} Y_{xi,s} - \frac{P_{xi,s}^y}{P_s} \tau^* Y_{xi,s} - \frac{\nu}{2} \left(\frac{P_{xi,s}^h}{P_{xi,s-1}^h} - 1 \right)^2 \frac{P_{xi,s}^h}{P_s} Y_{xi,s} \right]$$

subject to domestic demand, $Y_{di} = (P_{di}/P)^{-\varphi} Y$, and foreign demand, $Y_{xi} = \left(t^* P_{xi}^h/(P^* S)\right)^{-\varphi} Y^*$. Firm's profits are maximized by setting the price as a markup over marginal cost (remember that P_{di}^y/P and P_{xi}^y/P is the marginal cost of domestically sold and exported varieties, resp.)

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

$$\frac{P_{xi,t}}{P_t^*} = \phi / \left[\begin{array}{c} (\phi - 1)\left(1 - \frac{\nu}{2}(\pi_{xi,t}^h)^2\right) + \nu \pi_{xi,t}^h \left(1 + \pi_{xi,t}^h\right) - \\ \nu E_t \Delta_{t,t+1} \left(\pi_{xi,t+1}^h\right) \left(1 + \pi_{xi,t+1}^h\right)^2 \frac{1}{1+\pi_{t+1}^C} \frac{Y_{xi,t+1}}{Y_{xi,t}} \end{array} \right] t_t^* \tau_t^* \frac{P_{xi,t}^y}{Q_t P_t} \tag{11}$$

where $\pi_{d,t} = P_{d,t}/P_{d,t-1} - 1$ is the inflation rate of domestically sold varieties and $\pi_{x,t}^h = P_{x,t}^h/P_{x,t-1}^h - 1$ is the inflation rate of exported varieties. Note that both the iceberg trade cost and the tariff have a similar effect on the export price but for different reasons. One, the iceberg trade cost, increases marginal costs, while the other, the tariff, acts like a tax.

In the absence of price changes (as in a steady state), the markup reduces to the common $\phi/(\phi-1)$. 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 for price adjustment costs

$$Y_t = C_t + \frac{\nu}{2}\pi_{d,t}^2 \frac{P_{d,t}}{P_t} Y_{d,t} + \frac{\nu}{2}(\pi_{x,t}^h)^2 \frac{P_{x,t}}{P_t} Y_{x,t} \tag{12}$$

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

$$L_t = M_t \frac{\tilde{y}_{d,t}}{Z_t \tilde{z}_d} + M_t X_t \frac{\tilde{y}_{x,t}}{Z_t \tilde{z}_{x,t}} \tau^* + M_{e,t} f_e + M_t X_t f_x \tag{13}$$

where $\tilde{y}_d$ ($\tilde{y}_x$) denotes the average production of a domestic firm (exporter) and $\tilde{z}_d$ ($\tilde{z}_x$) the average productivity of a domestic firm (exporter). 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

$$a_t + Q_t a_{*,t} = \frac{1+i_{t-1}}{1+\pi_{C,t}} a_{t-1} + Q_t \frac{1+i_{t-1}^*}{1+\pi_{C,t}^*} a_{*,t-1} + \frac{1}{t_t^*} Q_t M_t X_t \tilde{\rho}_{x,t} \tilde{y}_{x,t} - \frac{1}{t_t} M_t^* X_t^* \tilde{\rho}_{x,t}^* \tilde{y}_{x,t}^* \tag{14}$$

where i is the nominal interest rate, $\tilde{\rho}_x$ is the average price of an exporter, and thus $1/t_t^* Q_t M_t X_t \tilde{\rho}_{x,t} \tilde{y}_{x,t}$ are aggregate exports and $1/t_t M_t^* X_t^* \tilde{\rho}_{x,t}^* \tilde{y}_{x,t}^*$ are aggregate imports.

Finally, the tariff-income of the government is distributed in a lump sum manner across all workers and is given by:

$$T_t^t = \frac{t_t - 1}{t_t} M_t^* X_t^* \tilde{\rho}_{x,t}^* \tilde{y}_{x,t}^* \tag{15}$$

2.4 Monetary policy

Monetary policy follows a standard Taylor rule of the form

$$1 + i_t = (1 + i_{t-1})^{\alpha_i} \left((1 + i)\,(1 + \pi_{C,t})^{\alpha_\pi}\, \bar{y}^{\alpha_y}\right)^{1-\alpha_i} \tag{16}$$

where $\bar{y}$ is the output gap, the gap between GDP in the model economy and GDP in a counterfactual economy with flexible prices. 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.

In contrast to Ghironi and Melitz (2005) I do not net-out changes in the number of varieties to get what they call data-consistent variables. The argument for the use of data-consistent variables is that changes in the number of available varieties are hard to measure. Nevertheless, I do not use data-consistent variables for three reasons. First, in response to a sharp increase in tariffs, as I use in most of my experiments, the number of imported varieties decreases substantially. It is hard to imagine that this would stay unnoticed by a statistical authority. Second, the idea of data-consistent inflation is based on the idea that the change in the price of a given product can easily be measured, while the number of products cannot. However, when in response to an increase in tariffs a large number of products is no longer available, the change in the price of these products can hardly be measured. Third, and most importantly, in contrast to Ghironi and Melitz (2005), in this model the number of consumed varieties is actually constant, because endogenous entry takes place at the plant-level of the firm. So in this model there is actually no problem in measuring the number of consumed varieties.

3 Parameterization

While this analysis is partly motivated by and related to Ossa (2014), my attempt is not to give a quantitative assessment of optimal tariffs, but rather to describe the implications of taking account of adjustment dynamics. To this end the model is kept deliberately simple and restricted to two large economies. Since the model focusses on intra-industry trade, the natural choice is to choose the US and the EU as my model economies. The trade structure of the US economy and the EU economy is remarkably similar. Both economies are of roughly equal size, and their (bilateral) trade accounts are roughly balanced. The share of exporting firms and the share of international trade in GDP is also very similar. However, according to data from the World Trade Organization (WTO) there is some difference in the tariffs both economies charge (see https://tao.wto.org/). Over past ten years, the US charged on average a tariff of 1.4% for imports from the EU, while the EU charged on average a tariff close to 2% for imports from the US. Thus in the following I will assume a symmetric calibration except for the status-quo of tariffs.[6]

In most aspects the parameterization 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). 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

[6]As explained further below this slight asymmetry allows me to analyze cooperatively set tariffs, which would trivially be zero in a complete symmetric calibration.

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 $z_{\min}$. Defining $v \equiv \{k/[k-(\theta-1)]\}^{1/(\theta-1)}$, the average productivities $\tilde{z}_D$ and $\tilde{z}_x$ are given by $\tilde{z}_D = vz_{\min}$ and $\tilde{z}_x = vz_x$. The share of Home's exporting firms is then $X = 1 - G(z_x) = (vz_{\min}/\tilde{z}_x)^k$.

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 σ 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 year (see Ghironi and Melitz (2005)).

The iceberg trade cost is chosen to match the share of international trade to GDP. According to World Bank data this share was pretty stable around 30% over the last decade for the US and a bit smaller for the EU (see http://databank.worldbank.org/data/ This implies $\tau = \tau^* = 1.64$. The fixed cost of exporting f_x is set such that the proportion of exporting plants matches the 21 percent reported in Bernard, Eaton, Jensen, and Kortum (2003), implying $f_x = 0.0047$.[7] I set the scale parameter for the bond adjustment costs to $\eta = 0.0025$, as Ghironi and Melitz (2005).

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

[7] According to Eurostat data the share of exporting firms in the EU is at 18 percent slightly smaller (see http://epp.eurostat.ec.europa.eu/newxtweb/submitdimselect.do). Calibrating f_x^* to match this share would yield $f_x^* = 0.0054$.

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 Optimal tariffs

In my analysis I follow the structure in Ossa (2014), starting with unilaterally optimal tariffs, proceeding with Nash-equilibrium tariffs, and finishing with cooperative tariffs. This section analyzes optimal tariffs from the US perspective, i.e., the level of tariffs set by a US government if it does not fear retaliation from the EU.[8]

Before starting the discussion it is important to note that from an aggregate world-perspective tariffs are optimally zero in both countries. As shown in Baldwin (2005), from a planner's perspective that seeks to maximize the utility of the world economy, free trade is optimal in the (static) Melitz model. When an individual firm decides about market entry or about the productivity cut-offs, it does not internalize the effects of its decisions on consumer welfare. However, it does also not internalize the effects on other firms' profits. It turns out that both effects cancel out each other so that firms' decisions are socially optimal. Bilbiie, Ghironi, and Melitz (2016) show that the same is true in a dynamic, closed-economy version of the model, as long as preferences are CES. Finally, CG show that with exogenous labor supply and stable prices (as they are in steady state) this generalizes to a open-economy setting with nominal rigidities. Since entry and selection are efficient, positive tariffs can only distort the economy and are thus optimally zero.

[8]Since the difference in status-quo tariffs is very small, the results for optimal EU-tariffs are almost identical.

However, even though tariffs are optimally zero from an aggregate world-perspective, it can still make sense to raise tariffs from the perspective of a single country. Imposing a tariff on imports has two counteracting effects on the imposing economy. On the one hand, it raises government revenue. This revenue is redistributed to the domestic population and thus raises welfare. On the other hand, imposing tariffs distorts production and raises the price of imported goods which hurts domestic consumers. However, under monopolistic competition the tariff will not lead to a one-to-one increase in the consumer price, implying that part of the cost is borne by the foreign producers. Put differently, by charging a tariff, the US imposes a negative terms-of-trade externality on the EU. For very low tariffs, the first effect will dominate so that it is welfare improving for the US to raise the tariff, given a specific tariff of the EU. For very high tariffs, the second effect dominates so that it is welfare improving for the US to lower the tariff, given a specific tariff of the EU.[9] It follows that there exists an optimal tariff that maximizes welfare.

The standard practice in the trade literature is to ignore the adjustment path, and thus to set the tariff such that it maximizes steady state consumption. In this case the optimal tariff set by the US (given the EU-tariff of 2%) is 33.7%, which lies in the range of results in Ossa (2014), who finds optimal, sector-specific tariffs between 20% and 80%, depending on the competitiveness of a given sector. However, as figure 1 illustrates the short-run effects of an increase in tariffs differ substantially from the long-run effects.[10]

Figure 1 illustrates the dynamic adjustment of selected variables to a unilateral increase in the import tariff charged by the US from 1.4%, the actual tariff, to 33.7%, the optimal tariff of the static analysis. Time is on the horizontal axis, measured in quarters. To improve the visibility of short run adjustments, the fig-

[9]For further details see, e.g., Felbermayr, Jung, and Larch (2013).

[10]All the dynamic results are based on non-linear, deterministic simulations using the Dynare-package for Matlab.

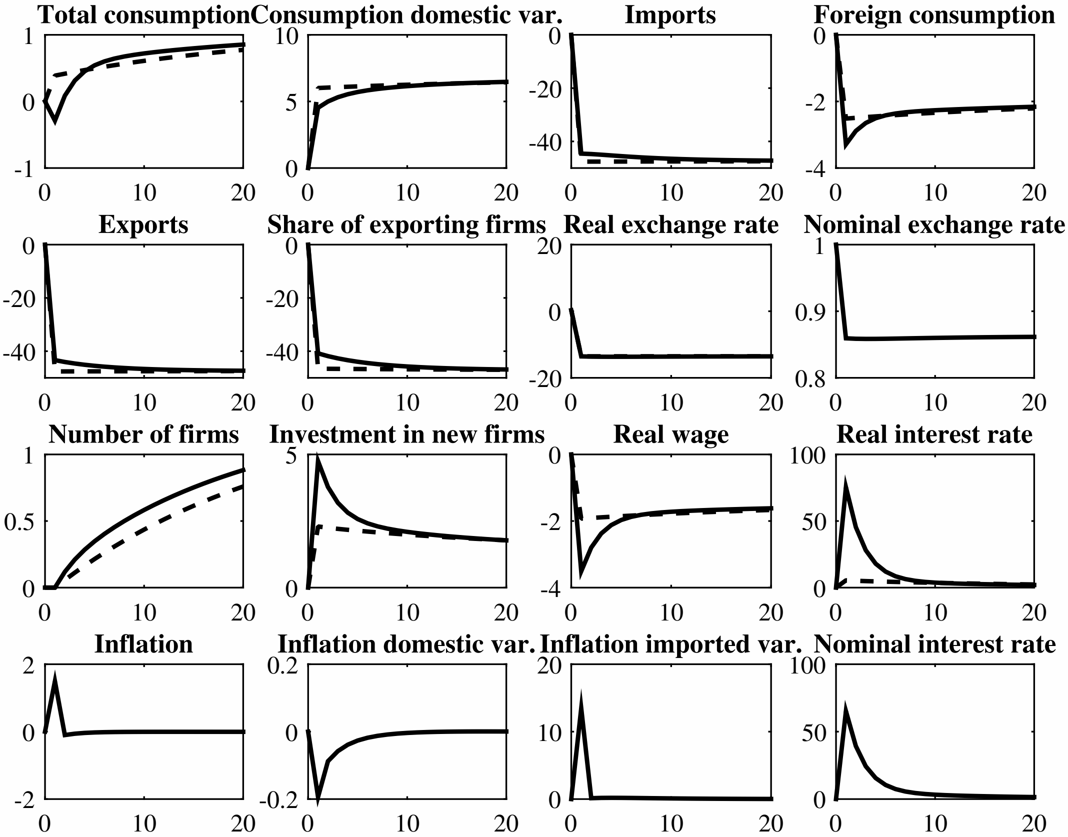

Figure 1: Effects of an increase in the US tariff from 1.4% to 33.7%. Quarters on the horizontal axis, percent deviations from the old steady state on the vertical axis. Solid line: model with rigid prices. Dashed line: model with flexible prices.

ure illustrate only the first 20 periods. 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. Nominal variables are only reported for the model with rigid prices because they are meaningless in the model with flexible prices. I will first focus my discussion on the development of the variables that are common to both versions of the model and then turn to the role of nominal rigidities and monetary policy.

The immediate and direct effect of import tariffs is to make imports more expensive which leads to an immediate decrease in imports. The reduced availability of cheap imports puts upwards pressure on the aggregate price index, which decreases real wages. Lower real wages in turn tend to decrease prices, because prices are set as a markup over marginal costs. On the market for domestically produced varieties, this is not compensated by higher tariffs (or adjustments in the real exchange rate) and therefore the price of domestically produced varieties goes down relative to imported varieties. This results in a marked increase in the demand for domestically produced varieties.

On the export market the decrease in real wages is compensated by a real exchange rate appreciation. The sudden decrease in US-demand for EU-products induced by the increase in tariffs pushes down the price level of the EU relative to the US, leading to a real exchange rate appreciation of the US. On the one hand this counteracts the effect of the increase in the tariff on imports. On the other hand this decreases the demand for exports. As a consequence, the trade balance (not depicted) does not move by much.

We know that consumption must go up in the long run - otherwise the tariff in the new steady state would not be the optimal tariff of the static model. Basically, the real exchange rate appreciation is not enough to offset the increasing income from tariffs and so consumption goes up in the long run. In the short-run, however, consumption lies considerably lower than its long run equilibrium, and even lower than in the original steady state in the scenario with rigid prices.[11]

Low short-run consumption is mainly explained by the reduced availability of cheap imports and by a temporary boost in the investment in new firms.[12] We know from Melitz (2003) that more open economies tend to have a lower number firms, due to the pro-competitive effect of trade. This implies that an

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

[12]That consumption might drop below its initial steady state level in the short run is not really important for the story in this paper. What's important is that consumption in the short run is lower than in the new steady state.

increase in tariffs leads to an increase in the number of firms. In a static model this adjustment happens immediately but in a dynamic model the adjustment is a slow process. Thus the investment in new firms is elevated for some time until the new steady state level of firms is reached.

This enhanced investment in new plants implies that fewer resources can be devoted to produce the consumption good. This reduces the consumption of domestic varieties and thus total consumption. Naturally, this effect is only short-lived. As the number of plants increases, incentives to invest in new plants decrease and more resources are left to produce the consumption good. Thus as the number of plants increases, the investment in new plants decreases and consumption recovers.

Let us now turn to the effect of price-rigidity. 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.[13]

Nevertheless, the slow adjustment of prices has real consequences. A direct implication of price rigidity is that the decrease in the price level of domestically produced varieties is slowed down. Due to the decrease in real wages firms would like to lower their prices, but due to price adjustment costs this process is slowed down. This has two important consequences. On the one hand, the increase in production for the domestic market is subdued. On the other hand,

[13]The nominal exchange rate by itself is irrelevant and indeterminate in this model, what matters for the solution of the model is the real exchange rate. However, the flexibility of the nominal exchange rate matters because it helps adjusting the real exchange rate and it implies that both countries can set nominal interest rates independently. The change in the nominal exchange rate can be backed out from the inflation rates of both countries and the change in the real exchange rate.

the profitability of plants is increased and so investment in new plants increases by even more. As a consequence, even fewer resources can go into the production of the consumption good in the initial periods after the increase in tariffs so that consumption even drops below its initial level. In the medium run this difference is reduced and the cost of adjusting prices pushes aggregate consumption in the model with rigid prices above 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 decrease in imports and exports is smaller. The reason for both phenomena lies in the lower production for the domestic market. On the one hand this frees resources, implying that the production for the foreign market need not decrease by as much. On the other hand the lower availability of domestic products increases the demand for imports.

Looking at the nominal variables, it is notable that the increase in tariffs leads to an immediate increase in the inflation of imported varieties. That increase is so large that the aggregate inflation rate also increases, even though the price of domestically produced varieties (which make up a larger share of aggregate consumption) decreases.[14] This has important repercussions through monetary policy. The central bank notices the inflation and reacts by increasing the nominal interest rate to reduce demand and thus to counteract inflation. In later periods inflation is closer to target but monetary policy is still relatively contractive due to the desire of the monetary authority to smoothen interest rate movements.

Figure 1 and the discussion so far already strongly suggest, that the optimal tariff is different when adjustment dynamics are taken account of. Although the

[14]There is a substantial literature analyzing the effects of trade openness on inflation that was initiated by Romer (1993). This literature typically finds that trade openness is associated with lower inflation, but largely focusses on long run outcomes. Some exceptions are Aron and Muellbauer (2007), Jin (2006) and Mukhtar (2010) who use time-series techniques and find that trade openness lowers inflation also in the short run. That protectionism would lead to a surge in inflation is also a common concern in the popular press (see, e.g., the Chicago Tribune (http://www.reuters.com/article/us-markets-saft-idUSKCN0WA1M3) or Money (http://www.chicagotribune.com/sns-yourmoney-1112petruno-story.html).

increase in tariffs from 1.4% to 33.7% raises consumption in the long run, it lowers consumption in the short run. This short run cost is ignored in static analysis but can be taken account of in a dynamic analysis. Thus I compute the optimal tariff as the tariff that maximizes the present discounted value of consumption over all future periods. Not surprisingly the resulting tariff is lower than the optimal tariff based on static analysis - for the model with rigid prices the optimal tariff is 31.5%, and for the model with flexible prices it is 31%.

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 most 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 slow adjustment of consumption.

Figure 2 illustrates the optimal 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 optimal tariff only consumption up to period x is included in the calculation.[15] 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.

As shown above, in the economy with rigid prices consumption decreases by more in the short run in response to an increase in tariffs. Therefore policy makers with a very short planning horizon tend to set lower tariffs in the model with rigid prices. In the medium run, however, consumption is higher in the model with rigid prices and thus policy makers with an intermediate or long run planning horizon tend to set higher tariffs under rigid prices. 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

[15]More specifically, I run a tight grid of potential US-tariffs for the given EU-tariff of 2%, calculate the transition path with Dynare and then choose the tariff that maximizes the present discounted value of consumption of up to x periods.

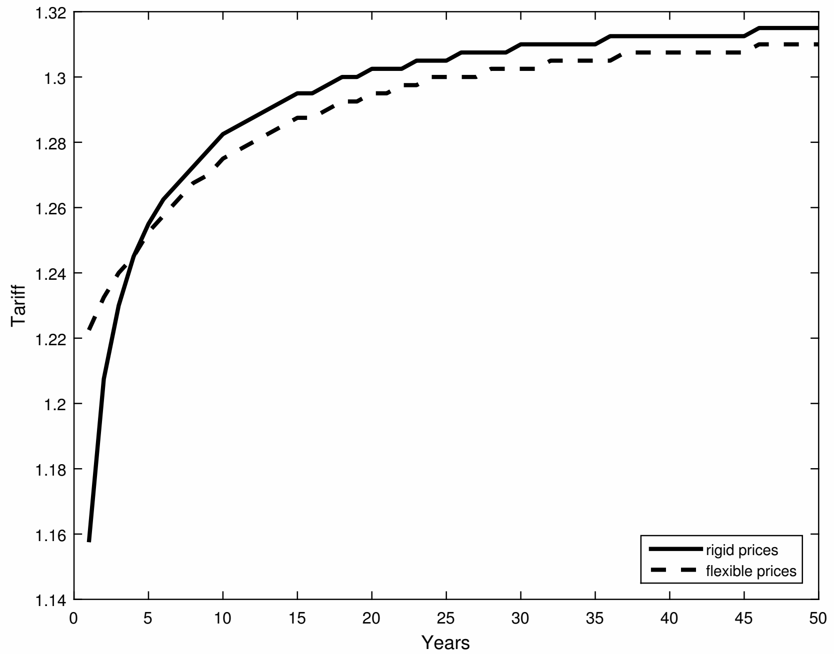

Figure 2: Optimal tariff in dependence of the policy maker's planning horizon.

steeply in response to increases in the planning horizon.

In the following sections I will first discuss the cases of Nash equilibrium tariffs and cooperatively set tariffs and then turn to the discussion of monetary policy.

5 Nash equilibrium tariffs

Having analyzed optimal tariffs, I now turn to the discussion of Nash equilibrium tariffs, i.e., the tariffs that would arise in a trade war, to use the terminology of Ossa (2014). While in the previous section, only one country, the US, was allowed to change its tariff, in this section it is assumed that both countries can change their tariff, and they do so in a non-cooperative way.

To calculate the Nash equilibrium tariffs I calculate the best response functions of both countries. In section 4 I calculated the optimal tariff for the US given the empirically observed tariff for the EU. To determine the best response function I repeat the same exercise for a wide range of potential tariffs in the EU.

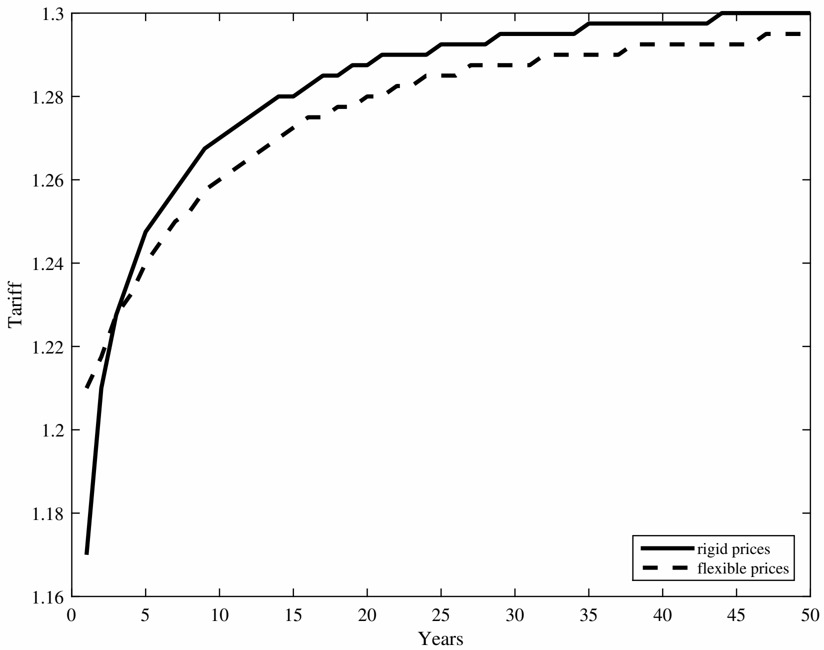

Figure 3: Nash-equilibrium tariff in dependence of the policy maker's planning horizon.

Then I do the same from the perspective of the EU, i.e., calculating the optimal tariff in the EU for a wide range of given tariffs in the US.

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 consumption. In analogy to figure 2, figure 3 shows Nash-equilibrium tariffs in dependence of the policy maker's planning horizon.[16] Again short-sighted politicians tend to set lower tariffs, and the policy makers's planning horizon matters more under rigid prices. As in Ossa (2014) the Nash-equilibrium tariff is very close to the optimal tariff.

[16]Note that the Nash-equilibrium tariff is the same for both countries. The only asymmetry that I have assumed across the two countries is the tariff that both countries charge in the baseline calibration. Since the starting value does not matter for the Nash-equilibrium, both countries charge the same tariff.

6 Cooperative tariffs

This section analyzes cooperatively set tariffs, or trade talks in the terminology of Ossa (2014). I follow Ossa's approach and assume that the gains from cooperation, i.e., the gains from higher consumption through lower tariffs, are split equally across the two countries, and that transfers between the two countries are not allowed. Furthermore, I assume that the starting points, or the threat points, are the tariffs observed in section 3, the status quo in the data.

As discussed above, from a world perspective free trade is optimal in this model.[17] Tariffs only make sense from an individual country's perspective through the terms-of-trade externality. Thus if the starting point is a symmetric equilibrium, both countries would gain equally from lower tariffs and agree on abolishing them completely. Conversely, starting from an equilibrium with asymmetric tariffs, the gains from free trade would also be asymmetric - the country which had to pay the higher tariff in the original steady state would gain more from abolishing all tariffs. Thus in this case cooperation will generally not result in zero tariffs for both countries.

Figure 4 illustrates the cooperatively set tariffs in dependence of the planning horizon of the policy maker in both countries. The tariff chosen is zero for the US which had the lower tariff in the status quo, since choosing the lowest possible tariff for the US maximizes the joint welfare. In contrast, the tariff set by the EU stays positive (albeit small). Although, further reducing the EU-tariff would increase joint welfare, the resulting gains would be larger for the US than for the EU and thus would violate the bargaining protocol. Thus the EU-tariff is set in such a way so as to assure that the gains from cutting tariffs are the same for both countries.

Importantly, but not surprisingly, the same pattern applies as in the previous

[17] Ossa (2014) uses a model with multiple sectors. As he notes, in this setup free trade is only optimal when markups across sectors are identical. If they are not then differential tariffs can be used to correct the distortions generated by the differences in markups.

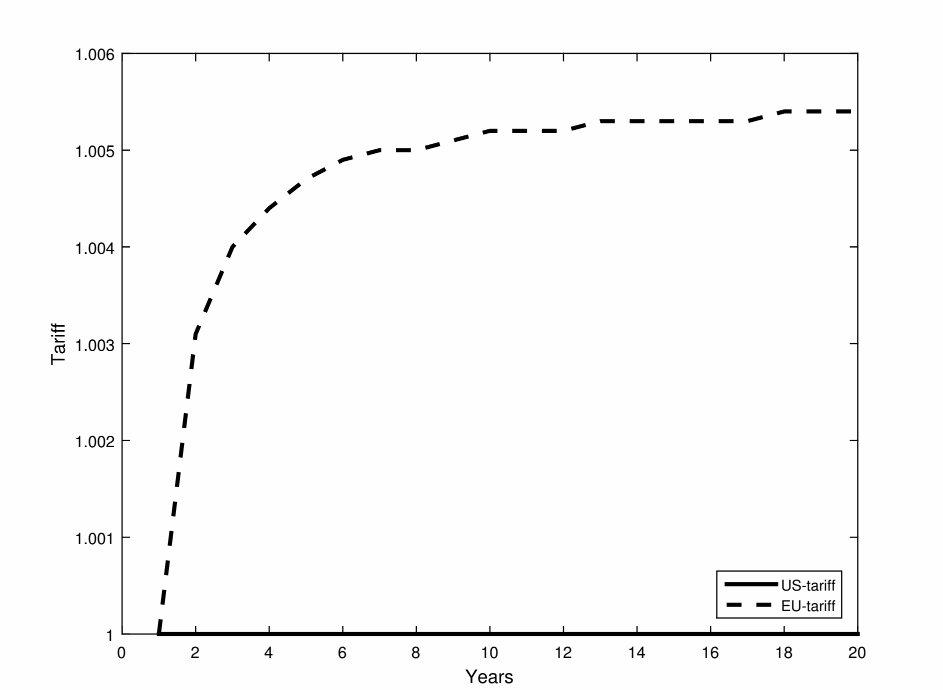

Figure 4: Cooperative tariffs in dependence of the policy maker's planning horizon.

sections concerning the planning horizon of the policy maker. Because increasing tariffs leads to short-run drop in consumption, short-sighted policy makers tend to set lower tariffs.

7 Monetary policy and optimal tariffs

One of the main novelties of this paper compared to the analysis in LL is the introduction of sticky prices which implies a potential role for monetary policy. In a model with sticky prices, monetary policy has real short-run effects and thus can influence the adjustment process, even if it does not affect the steady state. In this section I take a closer look at the role of monetary policy.

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

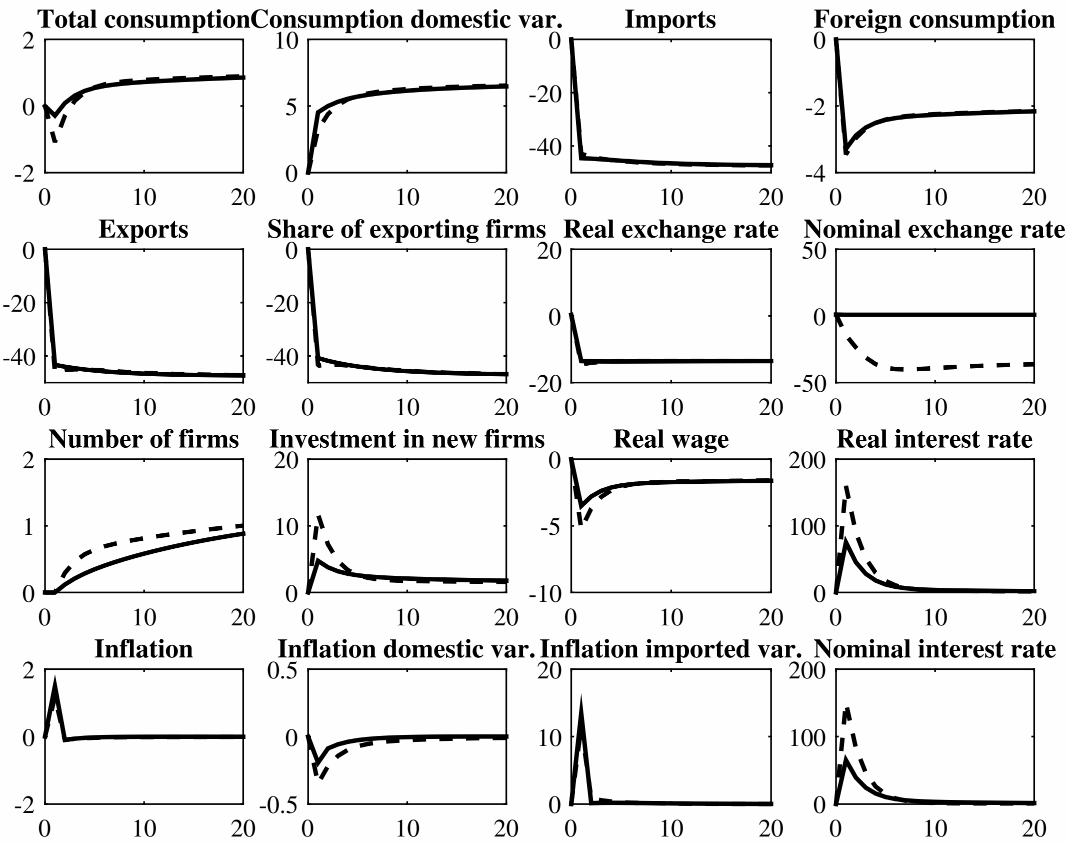

Figure 5: Effects of an increase in the US tariff from 1.4% to 33.7%. Quarters on the horizontal axis, percent deviations from the old steady state on the vertical axis. Solid line: benchmark case ($\alpha_\pi = 1.62$). Dashed line: US central bank fights inflation more aggressively ($\alpha_\pi = 5$).

the other country. More specifically, I consider two additional scenarios, one in which the US central bank puts a heavy weight on inflation and one in which the European central bank puts a heavy weight on inflation, while the central bank of the other country uses the same Taylor rule as specified above ($\alpha_\pi = 1.62$). For illustrative purposes I assume that the coefficient in the Taylor rule is $\alpha_\pi = 5$, which is arguably too high, but later I will consider a more realistic case.

The ensuing adjustment dynamics are illustrated in figure 5, which again shows impulse response functions for an increase in the tariff from 1.4% to 33.7%. As discussed above the increase in tariffs directly makes imports more expensive. Although there is a counteracting effect through lower domestic prices, the inflation rate goes up. A central bank that fights deviations from its target of zero inflation more aggressively will try to counteract this development by curbing aggregate demand through a higher nominal interest rate. Consequently, the real interest rate increases by more and aggregate consumption decreases much more, when monetary policy is more aggressive. Thus aggressive monetary policy enhances the short run cost of raising tariffs.

Due to the flexible nominal exchange rate mechanism contractionary monetary policy has only minor implications for the price index of imported products and thus for import demand. But the increase in the demand for domestically produced varieties is slowed down considerably with the consequence that the price index of domestically produced varieties is decreased. Put differently, due to the flexible nominal exchange rate, the central bank primarily fights inflation by pushing down the price of domestically produced varieties.

Again, I calculate the optimal tariff, i.e., the tariff without fear of retaliation, for policy makers with different planning horizons.[18] The result is illustrated in the upper-right panel of figure 6 which shows optimal US tariffs for the previously used benchmark (solid line, with $\alpha_\pi = 1.62$), as well as the case when US monetary policy is more aggressive (dashed line), and when EU monetary policy is more aggressive (dot-dashed line), while the other country uses the benchmark rule.

Figure 6 reveals that in the long run, the aggressiveness of a central bank does not seem to play a role but in the short run it does. If the US features aggressive monetary policy an increase in tariffs leads to a strong drop in consumption in the initial periods. This induces policy makers with a short planning horizon to set very low tariffs, even below 10% for very short planning horizons. If the monetary authority of the EU is the aggressive one, things look very different. Tariffs chosen by the US are higher than in the benchmark calibration, but the difference is quantitatively less severe.

[18]The result for Nash-equilibrium tariffs and cooperatively set tariffs are equivalent and available upon request.

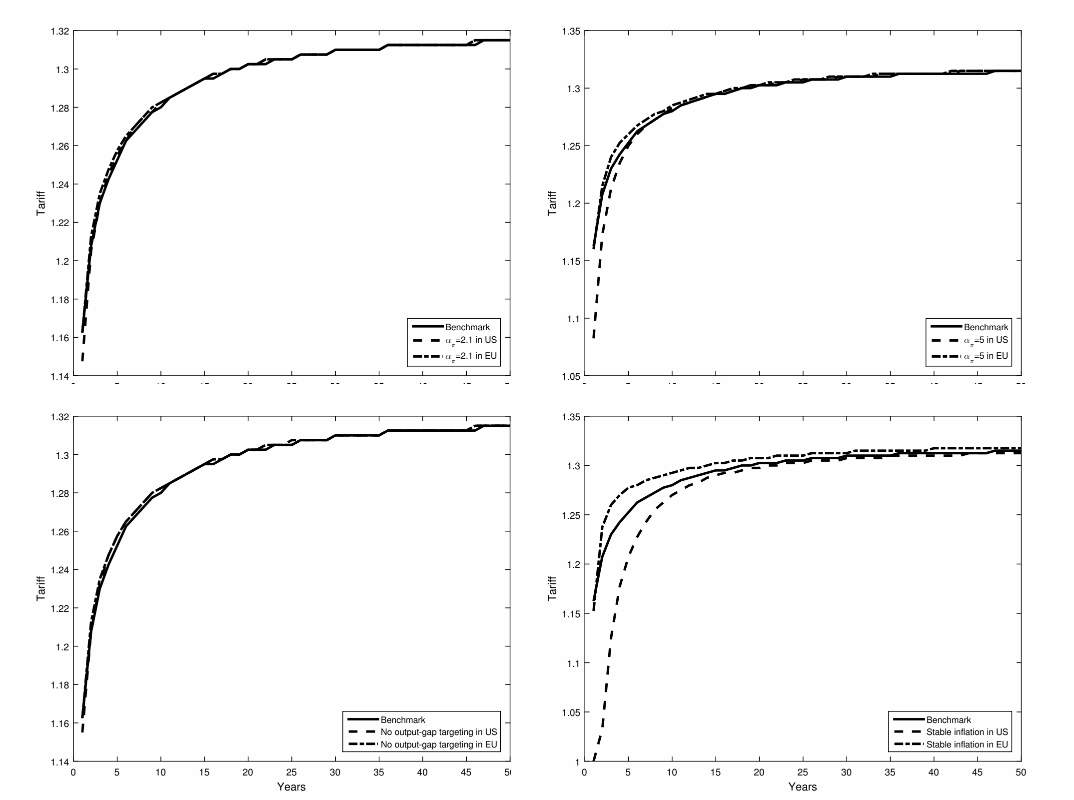

Figure 6: Optimal US tariffs - the role of monetary policy. Benchmark uses the monetary policy parameters as described in section 3 ($\alpha_\pi = 1.62$). In the monetary policy experiments one country is assumed to deviate, while the other country sticks to the benchmark rule.

The upper-left panel of figure 6 shows the more realistic case where the more aggressive central bank uses $\alpha_\pi = 2.1$, which lies in the range of estimates for the ECB (see, e.g., Gerdesmeier and Roffia (2004)). As expected the effects still go in the same direction but are much less pronounced.

The lower two panels in figure 6 show two further alternative specifications for monetary policy. The lower-right panel shows the extreme case where one of the two central banks is so aggressive that it completely shuts off any fluctuations in inflation.[19] The lower-left panel shows the case where one of the two central banks does not target the output gap.[20]

Obviously, targeting the output gap does not matter much for the results concerning the setting of optimal tariffs. In contrast, price stability has a huge

[19]Price stability is an important benchmark in monetary models since it is often optimal.
[20]The ECB's mandate is actually to target inflation but not the output gap.

impact. Price stability can only be assured by aggressively fighting changes in inflation, which implies very strong reactions to changes in tariffs. This strong reaction by the central bank makes increasing tariffs at home less attractive, especially to short-sighted politicians. Even though the long-run benefits of higher tariffs are still the same, the short-run costs are enhanced. This implies that the optimal tariff depends even more on the planning horizon of the policy maker and might be very low and even zero for policy makers who only care about the immediate future. Conversely, the aggressiveness of the foreign central bank has the opposite effect but is quantitatively less important.

8 Extensions and robustness checks

This section provides several extensions and robustness checks. First a version of the model that includes an endogenous supply of the labor input is provided. In this model, the role of wage rigidity is analyzed. For the benchmark version of the model producer currency pricing was assumed, here I consider the alternative approach, local currency pricing. Finally, the role of the strength of price rigidity and the role of firm heterogeneity and endogenous firm entry is analyzed.

8.1 Endogenous labor supply and wage rigidity

For the analysis so far I have assumed that the labor supply is given exogenously. In this section, I endogenize labor supply by assuming that households optimally choose it, weighing against each other the benefit of work, the wage payment, against the cost of work, the disutility that is generated by it. To incorporate wage rigidity, I follow the standard practice and assume that workers, in offering their labor supply, are monopolistic competitors. This gives them the power to set wages and charge a markup over their marginal cost of providing labor.

The utility function of a worker changes to $E_0 \sum_{t=0}^{\infty} \beta^t \frac{C_{i,t}^{1-\sigma}}{1-\sigma} - \frac{L_{i,t}^{1+\varphi}}{1+\varphi}$, where the last term is the disutility from providing labor and φ is the inverse of the Frisch elasticity of labor supply. The household chooses labor supply to maximize utility subject to its demand function $L_i = (W_i/W)^{\phi_w} L$, where ϕ_w is the elasticity of substitution among labor varieties. Under flexible wages the corresponding first order condition is

$$W_{i,t} = \frac{\phi_w}{\phi_w - 1} \frac{L_{i,t}^{\varphi}}{C_{i,t}^{-\sigma}}. \tag{17}$$

Households charge a constant markup over their disutility from providing labor supply.

In this setup the question arises as to what the objective of the policy maker is. Maximizing utility would, of course, include the disutility of labor. It is, however, hardly conceivable that a politician would appreciate a decrease in employment because it increases leisure. Thus a consumption-maximizing politician is probably still the best approximation. In any case, I report here the results of both approaches. The left panel in figure 7 reports the optimal tariff set by a policy maker who only cares about consumption, while the right panel reports the optimal tariff set by a policy maker who cares about total utility.

The dashed line in figure 7 shows the implications of endogenous labor supply for the optimal setting of tariffs, while the sold line shows the benchmark used for previous simulations (e.g., the solid line in figure 2). For this exercise I assume $\varphi = 2$ which is in the range of the micro evidence (see, e.g., Chetty, Guren, Manoli, and Weber (2013)), and $\phi_w = 4$ as in Erceg, Henderson, and Levin (2000). It can be seen that this modification yields a quantitatively big change, the optimal tariff for a policy maker who maximizes the present discounted value over an infinite horizon drops from 31.5% to 13% for consumption maximization and to 22% for utility maximization.[21]

[21] Naturally the quantitative magnitude depends on the choice of φ. For larger values, which imply a lower elasticity, the difference to the benchmark becomes smaller, for smaller values the difference becomes larger. Further results are available upon request.

The level of optimal tariffs is generally lower with endogenous labor supply, because the long run increase in consumption that is associated with an increase in tariffs induces households to reduce their labor supply, counteracting the first effect. Thus there is less to gain from raising tariffs and policy makers set lower tariffs. A policy maker who cares about utility sets a higher tariff than a policy maker who only cares about consumption because he appreciates the reduction in labor supply which reduces the disutility from work. In both scenarios it is still the case that short-sighted politicians tend to set lower tariffs.

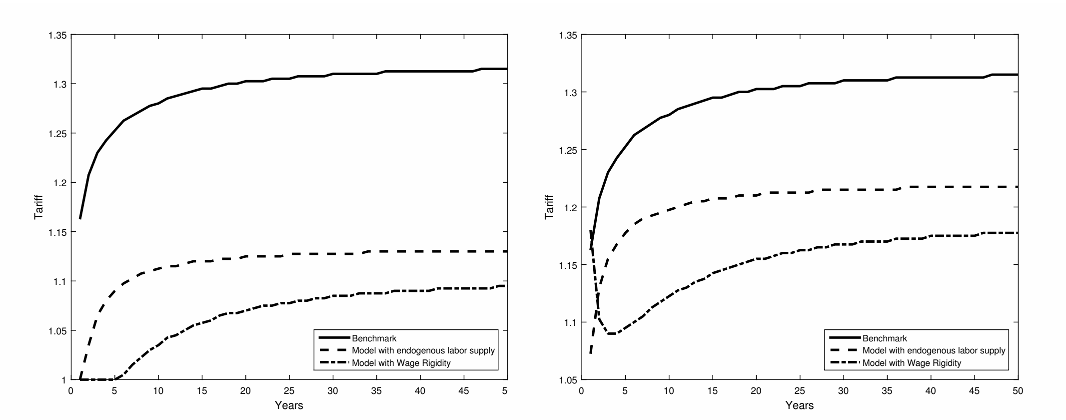

Figure 7: Endogenous labor supply and wage rigidity; left panel: policy maker maximizes consumption; right panel: policy maker maximizes utility.

The dot-dashed line in figure 7 adds the case of wage rigidity. For this exercise I assume that changing the wage is subject to quadratic wage adjustment costs, in analogy to the quadratic price adjustment. This changes the first order condition for optimal wage-setting to

$$\frac{W_{i,t}}{P_t} = \frac{L_{i,t}^{\varphi}}{C_{i,t}^{-\sigma}}\phi^w / \left[\begin{array}{c} (\phi^w - 1)\left(1 - \frac{\nu^w}{2}\pi_{w,t}^2\right) + \nu^w \pi_{w,t}\left(1 + \pi_{w,t}\right) \\ -E_t \Delta_{t,t+1} \nu^w \left(1 + \pi_{w,t+1}\right)^2 \frac{\pi_{w,t+1}}{1+\pi_{t+1}^C} \frac{L_{t+1}}{L_t} \end{array} \right].$$

In steady state, when $\phi^w = 0$, this equation collapses to the constant markup in equation 17. As Erceg, Henderson, and Levin (2000) I use the same level of wage adjustment cost as for the price adjustment cost, $\nu^w = \nu$. For a consumption-maximizing policy maker this further pushes down the optimal tariff. The reason is that under wage rigidity the drop in the real wage that follows an increase in tariffs is subdued which reduces the demand for labor. Consequently, the initial drop in the labor supply is stronger, leading to an even stronger short-run drop in consumption. This further reduces the incentives for policy makers to raise tariffs. Note, that for this exercise the empirical tariffs for the US and the EU (1.4% and 2%) lie well inside the range of optimal tariffs for policy makers who only care about the next six years or less. Thus the dynamic perspective on the setting of tariffs can provide a rational for the empirically observed tariffs even without trade talks.

The picture looks different for utility-maximizing policy makers. The short-run decrease in the disutility of providing labor is so strong that it actually makes raising tariffs more attractive for very short-sighted policy makers. So this scenario represents the only case where short-sighted policy makers choose higher tariffs. Note, however, that this only holds for very short-sighted policy makers. After a planning horizon of 4 years or more the old pattern, with short-sighted policy makers choosing lower tariffs, reemerges.

8.2 Local currency pricing

So far I have assumed producer currency pricing (PCP), i.e., a producer sets the price charged at the foreign market in terms of its domestic currency. I will now consider the alternative case, local currency pricing, in which a producer sets the price in terms of the foreign currency. In this case the markup charged on the foreign market changes to

$$\frac{P_{xi,t}}{P_t^*} = \phi / \begin{bmatrix} (\phi - 1)\left(1 - \frac{\nu}{2}\left(\pi_{xi,t}\right)^2\right) + \nu\left(1 + \pi_{xi,t}\right)\pi_{xi,t} \\ -E_t\Delta_{t,t+1}\nu\left(1 + \pi_{xi,t+1}\right)^2 \frac{\pi_{xi,t+1}}{1+\pi_{t+1}^{C*}} \frac{t_t^*}{t_{t+1}^*} \frac{Q_{t+1}}{Q_t} \frac{Y_{xi,t+1}}{Y_{xi,t}} \end{bmatrix} \tau^* t_t^* \frac{P_{xi,t}^y}{Q_t P_t}$$

where $\pi_{x,t} = \frac{P_{xi,t}}{P_{xi,t-1}} - 1$.

The left panel of figure 8 shows the optimal tariff in dependence of the planning horizon of the policy maker. Again the basic pattern remains unchanged, short-sighted policy makers tend to set lower tariffs, but in this case policy makers generally tend to set higher tariffs. The reason is that under local currency pricing a change in tariffs implies larger adjustment costs for the exporting price. This in turn implies a lower increase in inflation, a lower increase in the nominal interest rate and thus consumption can grow faster.

Remember that under PCP, producers set the foreign price in terms of the domestic currency and so whenever the tariff changes, the price charged on the foreign market automatically changes with it without implying any cost for the firms. This is different under local currency pricing. If price adjustment costs have to paid for changes in the local price, an increase in tariffs that is passed on to consumers implies an increase in price adjustment costs.

Because of this higher cost of adjusting the price (relative to PCP), price adjustment is considerably slowed down. Consequently the surge in import-price inflation is subdued and with it the increase in consumer price inflation. The central bank no longer needs to increase the nominal interest rate so strongly to fight this surge in inflation. Thus the real interest rate is lower and consumption can grow more quickly. Because of the faster growth in consumption, raising tariffs becomes more attractive to policy makers, relative to PCP. Note, however, that even in this scenario it is still the case that policy-makers tend to set lower tariffs the more short-sighted they are.

8.3 The role of the extent of price rigidity

The right panel of figure 8 shows the case of increased priced adjustment costs, with $\nu = 120$ instead of $\nu = 80$, as in the benchmark. The figure illustrates that this change hardly has a noticeable impact. The main effect of raising the price adjustment cost is that the deflation in domestic prices becomes slightly less severe. Consequently, aggregate inflation increases a bit more and with it

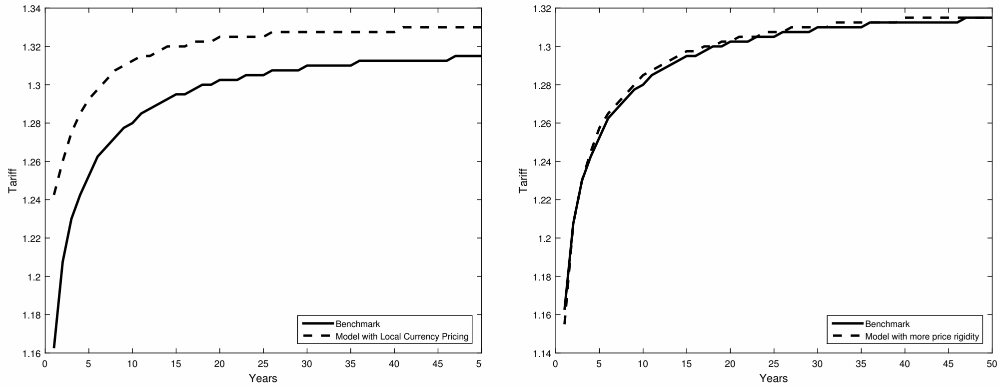

Figure 8: Local currency pricing and more price rigidity.

the nominal interest rate set by the central bank. This dampens consumption in the very short run inducing policy makers with a very short planning-horizon to set lower tariffs, but quantitatively the difference is very small.

This does, of course, not mean that the cost of adjusting prices is irrelevant. After all the cost of price adjustment is the only difference between the flexible-price case and the rigid-price case in figure 2. But once price adjustment costs have reached a certain level, further increases in it no longer matter much.

8.4 The role of plant heterogeneity and endogenous entry

This section discusses the importance of plant heterogeneity and endogenous entry for the setting of tariffs. As described above, in the benchmark version of the model an increase in tariffs induces a drop in the number of exporting plants, but an increase in plant entry, with plant entry overshooting its new long run equilibrium. The need to finance this investment puts downwards pressure on consumption during the transition process.

As the left panel of figure 9 illustrates shutting off plant heterogeneity and thus selection into export markets considerably increase the optimal tariff for policy makers of all planning horizons. The reason is that in this scenario all plants export and thus all plants are affected by the increase in tariffs, whereas only a small share of all plants exported in the model with selection into export markets. As a consequence the profitability of firms increases by less, relative to the benchmark. Plant investment still goes up but by much less than in the benchmark. Because fewer resources go into the creation of new plants, consumption can grow faster and approaches the new steady state level much quicker. The quicker increase in consumption makes raising tariffs more attractive and thus policy makers set higher tariffs.

The right panel of figure 9 illustrates that the same is true, and even to a bigger extent, for the version of the model in which not only plant heterogeneity is shut off, but also endogenous entry. Even policy makers with a very short planning horizon set tariffs above 35%. In this scenario there is no investment in new plants and thus no need to forgo consumption to build up the stock of plants as in the other scenarios. Consequently, consumption approaches its new steady state level much quicker. It is still the case that short-sighted politicians prefer lower tariffs, but the quantitative importance of this effect is almost negligible. We conclude that plant heterogeneity and endogenous entry matter a great deal for the setting of tariffs, a results that mirrors Felbermayr, Jung, and Larch (2013).

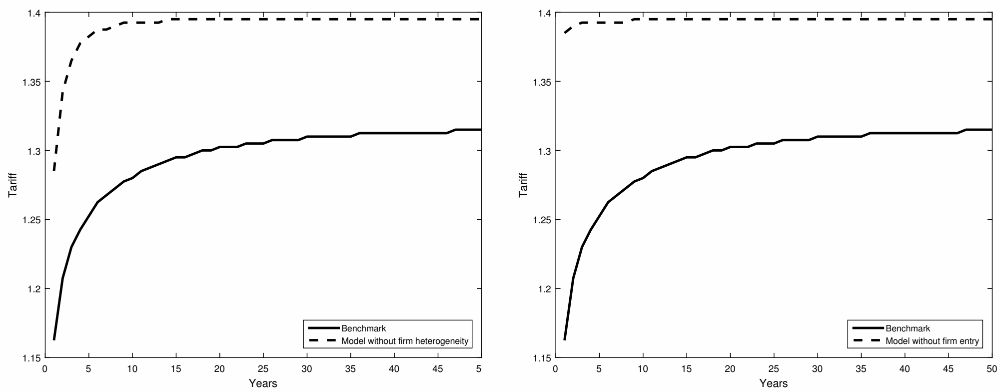

Figure 9: Firm heterogeneity and firm entry.

9 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.

In response to a unilateral, permanent increase in the tariff, consumption goes up in the long run. However, nominal price rigidity tends to slow down the rise in consumption and can even lead to short run drop in consumption. The drop in consumption follows from the reduced availability of cheap imports and the temporary increase in the creation of new plants. Nominal price rigidity slows down the price decrease of domestic varieties. This slows down the increase in demand for domestically produced varieties but also increases the profits of firms and thereby the investment in new firms. Both effects tend to decrease consumption in the short run and thus nominal price rigidity slows down the adjustment to the new steady state.

If policy makers have short planning horizons (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 consumption growth is slowed down.

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 inflation following an increase in tariffs by raising the nominal interest rate and lowering aggregate demand. The more aggressively monetary policy fights inflation, the lower consumption, and thus the lower the tariffs set by a policy maker with a short planning horizon. Endogenous labor supply and wage rigidity increase the short run costs of raising tariffs even further and can help to rationalize the low tariffs observed in the data.

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10 Appendix

10.1 Model equations

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

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

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

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

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

$$1 + i_t = (1 + i_{t-1})^{\alpha_i} \left((1+i)\,(1+\pi_{C,t})^{\alpha_\pi}\, \bar{y}_t^{\alpha_y} \right)^{1-\alpha_i}$$

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

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

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

$$\tilde{z}_{x,t} = (k/(k-(\theta-1)))^{1/(\theta-1)} z_{x,t}$$

$$X_t = (z_{min}/z_{x,t})^k$$

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

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

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

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

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

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

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

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

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

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

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

$$a_t + Q_t a_t^* = \frac{1+i_{t-1}}{1+\pi_{C,t}} a_{t-1} + Q_t \frac{1+i_{t-1}^*}{1+\pi_{C,t}^*} a_{t-1}^* + tb_t$$

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