Optimal trade policy with trade imbalances☆

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A B S T R A C T

Optimal trade and capital control policies are characterized under a dynamic model with endogenous trade imbalances. In the absence of capital controls, optimal trade protection is counter-cyclical. Optimal use of capital controls, however, dampens the time-variation of optimal trade taxes. Generally, trade imbalances are not predictive of optimal policy. However, optimal trade policy and equilibrium trade imbalances move together when a country grows consistently faster or slower than the rest of the world. Quantifying the model for the U.S. economy shows that welfare gains from optimal policy are largely due to static terms-of-trade effects, implying that gains from time-varying tariffs or capital controls are small.

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1. Introduction

A salient feature of international trade is the presence of trade imbalances. The level and direction of these imbalances may be affected by various policies including trade policy and capital controls. How should governments conduct their trade policy under trade imbalances? The previous literature has largely avoided this question by focusing on static models in which trade is balanced by assumption and, thus, various dynamic aspects of trade policies are overlooked. Our goal in this paper is to explore the relationship between inter-temporal trade and optimal trade policy.

In comparison to static trade policy analyses, the problem of optimal policy under a dynamic setting has at least two novel features. First, trade policy could fluctuate over time, which creates the possibility for tariffs to affect saving and investment decisions in expectation of future changes in trade policy.[1] A second feature of trade policy in dynamic settings is the emergence of an additional tax instrument, namely, an inter-temporal trade or capital control tax, which may be a complement or substitute for trade policy.

The potential interdependence between capital controls and trade policies may have important implications about the design and benefits of trade agreements. For example, following negotiated trade liberalizations, governments may have an

[1] For instance, if governments announce a commitment to gradually reduce import tariffs over time, households are induced to decrease their current consumption in order to save for consumption at more favorable prices in the future. Similarly, a surge in the United States' trade deficit in 2018 was attributed to a looming trade war with China and other countries. Other examples include increased investment in the export sector in expectation of free trade agreements (McLaren, 1997), increased imports in anticipation of tariff hikes (Alessandria et al., 2019), or trade flow dynamics that are induced by asymmetric phase-in of tariff cut commitments across countries (Alessandria et al., 2017; Alessandria and Choi, 2019).

incentive to use capital controls more actively to manipulate their terms of trade, thereby frustrating the intent of trade agreements to some degree.[2] Our dynamic framework allows us to evaluate the extent to which such arguments might be valid.

Our first objective is to characterize the pattern of unilaterally optimal import and export taxes/subsidies across products and time.[3] To this end, we use a two-country-multiple-product Ricardian model with time-varying labor productivity in which international lending and borrowing allows the households to smooth their consumption over time. Under this model, we show that within a period, optimal export tax/subsidies are differential but optimal import tariffs are uniform across products. This finding is similar to that of Beshkar and Lashkaripour (2019) and Costinot et al. (2015), who study optimal trade policy under static Ricardian models. We, however, show that under our dynamic Ricardian model, optimality requires the variation of both import and export taxes/subsidies over time.

The key parameter that explains the variation in optimal trade taxes over time is the productivity of the home country relative to the rest of the world. In particular, we find that import taxes and export subsidies are counter-cyclical. Intuitively, this result is obtained because the government is interested in manipulating its inter-temporal terms of trade by reducing exports in booms and limiting imports in low-productivity periods.

To better understand this result, note that the households ignore their collective effect on international interest rates and, thus, save too much in booms and borrow too much in downturns, which negatively affects the interest rate for domestic households. To correct for this "inefficiency", the government's optimal policy response would be to decrease (increase) the price of consumption in high-productivity (low-productivity) periods by way of lower (higher) import tariffs and export subsidies.

Our second objective is to characterize the optimal capital control taxes and their interdependence with trade policies. We first make the observation that if the government has access to time-varying import *and* export taxes, capital control taxes are not necessary for the implementation of optimal policy. However, capital control taxes become useful if any of the trade tax instruments are unavailable, or if the government cannot vary them over time.

Our final objective is to provide a quantitative assessment of optimal trade and capital control policies in an environment with endogenous trade imbalances. We are particularly interested in *(i)* generating insights about the magnitude of variation in optimal policies over time under different constraints on policy instruments, and *(ii)* decomposing the gains from optimal policy into *static* and *dynamic* terms-of-trade gains.

An important advantage of our dynamic framework for quantitative analysis is its ability to fit the trade data that involves trade imbalances. The balanced-trade assumption in the previous literature poses a problem for quantitative analysis as it violates the observed trade data. As explained by Ossa (2014, 2016), the static trade literature has so far dealt with this problem in two ways. The first approach is to introduce aggregate trade imbalances as constant nominal transfers into the budget constraints. The second approach is to conduct the analysis under the counterfactual in which trade is balanced (Dekle et al. 2007; Ossa 2014.) Our dynamic approach, however, provides a more satisfactory solution by allowing trade imbalances to occur endogenously.

We quantify our model using data on trade flows and production for the United States from 1995 to 2016. To do so, we extend the "exact hat algebra" methodology (Dekle et al. 2007) to the primal version of our dynamic Ramsey problem. This technique enables us to quantify the model and perform our optimal policy exercise using only estimates of elasticity of substitution and data on observed trade shares and production.

To measure the magnitude of variation in optimal policies, we consider two scenarios in which the set of available policy instruments is rich-enough to implement the optimal allocation. In our first exercise, we assume that the government of the United States chooses time-varying trade taxes (i.e., import tariffs and export subsidies) to implement its policy. We then consider a case in which export tax/subsidy is no longer available but capital control taxes are introduced to the set of available policy instruments. As discussed earlier, the government could achieve its optimal allocation under either of these scenarios.[4]

The intertemporal pattern of optimal tariffs, however, depend critically on what other policy instruments are used by the government. In particular, if trade taxes are the only policy instruments at the government's disposal, there will be a significant variation in optimal policy over time. For instance, in the case of the United States, optimal tariffs vary between 27% and 33%, and export subsidies vary between zero and 6% between 1995 and 2016. Nevertheless, if capital controls are used in lieu of export subsidies, the time-variation of import tariffs is virtually vanished—with tariffs hovering around 25% for the entire period.

These intertemporal patterns of import tariffs may be understood by noting that the government's objective from modifying its policy over time is to achieve the desired *intertemporal* relative prices. Since trade taxes are applied to current consumption, they must vary over time to affect the relative price of aggregate consumption in different periods. In con-

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trast, capital control is a direct tax on intertemporal trade, which could generate the desired intertemporal relative prices without changes in tariffs.

To measure the degree to which gains from optimal policy in our model emanates from static vs. dynamic terms-of-trade effects, we introduce some constraints on available policy instruments that help isolate each of these channels for gains from optimal policy. First, we calculate gains from protection assuming that the only available policy instrument is a *constant* import tariff, which precludes the manipulation of dynamic terms of trade. We find that this restriction has a negligible effect on the welfare gains from optimal policy, which implies that dynamic terms of trade gains are very small for the United States. Similarly, we find that under free trade, the welfare-effects of optimal capital control taxes are also very small. Therefore, under our model and observed trade flows, capital control taxes in the United States cannot effectively undermine free trade agreements.

Literature

The distinguishing feature of our paper is to characterize the optimal trade policy under a dynamic model in which trade imbalances are endogenously determined. This is in contrast with much of the literature that either uses static models to analyze optimal trade policy (e.g., Beshkar and Lashkaripour 2019, henceforth BL) or assumes free trade and focuses on capital control (e.g., Costinot et al. 2014, henceforth CLW). CLW's key finding is that optimal capital control policy induces a pro-cyclical consumption pattern. We show that this consumption pattern may be also achieved using time-varying trade policy.

Similar to CLW, Schmitt-Grohé and Uribe (2017) also find that optimal capital control would reduce borrowing during recessions, causing a counter-cyclical protection pattern. Unlike our model, the main reason to use capital control in their model is to correct an inefficiency arising from the interaction of the collateral constraint with the price of the non-tradable goods. Heathcote and Perri (2016) consider a tax on interest income from international bonds that is proportional to the aggregate net foreign asset position, and show that the optimal level of such a tax is positive. Our analysis is more general as we do not impose any requirement on capital control taxes to be conditional on foreign asset positions.

Empirical evidence on the intertemporal pattern of trade policy is rare and the existing studies deliver diverging results. As discussed by Lake and Linask (2016), the conventional wisdom is that import protection is counter cyclical, which is supported by various observations on the use of temporary trade barriers within the framework of the WTO (e.g., Bown and Crowley 2013). However, more recent works such as Lake and Linask (2016) suggest that import protection, particularly in developing countries, are pro-cyclical. Our theoretical results, which are based on a terms-of-trade framework, are more in line with the conventional wisdom mentioned above.

Staiger and Sykes (2010) take on the issue of interdependence between trade policy and currency manipulation and ask if governments could frustrate the intent of trade agreements by manipulating the value of their currency. They conclude that the trade effects of such policies could not be identified well-enough to make a judgement about whether these policies frustrate the intent of trade agreements. Our quantitative analysis lends support to this view by showing negligible effect of capital control taxes on welfare.

Bagwell and Staiger (1990) consider trade wars and self-enforcing trade agreements in a dynamic environment in which the countries' endowments are subject to shock, but no inter-temporal trade takes place. The dynamics in their model is related to the fact that governments could exchange trade policy concessions over time. Keeping the balanced trade requirement for each period, Bagwell and Staiger (2003) extend their previous work to study trade policy over persistent business-cycle shocks.

While we find that *unilaterally optimal* trade and capital control policies do not generate significant fluctuations in trade imbalances, several papers in the literature find that the *observed* trade policies do in fact cause substantial changes in net trade flows.[5] In particular, Alessandria and Choi (2019) find that the faster pace of tariff cuts in the United States compared to its trading partners was an important cause of the large expansion in the US trade deficit as a share of its total trade.[6] Similarly, Alessandria et al. (2017) show that about 70% of the post-WTO surge in China's trade surplus may be attributed to the decline in trade barriers over this time period. In these studies, the large effect of trade policy changes on trade imbalances are due to their transitory nature.[7] Similarly, our optimal trade policies reduce the level of trade flows. However, they do not significantly change the variation in trade as a fraction of GDP.

Capital controls could interact with exchange rate policies and other government interventions–the so-called macroprudential policies—that are aimed at enhancing financial stability. Using a model of small open economy, in which the government is unable to manipulate its intertemporal terms of trade using capital control, Davis and Presno (2017) show that capital controls allow optimal monetary policy to focus less on the foreign interest rate and more on domestic variables. Brunnermeier and Sannikov (2015) study the tradeoff between financial stability and optimal allocation of capital under a

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[5] To be sure, note that we find that optimal policy reduces the *size* of trade imbalances, but it does not have a clear effect on the *variation* of imbalances over time.

[6] Reyes-Heroles (2016) shows that the decline in the trade costs has been a major driver of trade imbalances. He estimates that about 69% of the increase in trade imbalances from 1970 to 2007 can be attributed to lower trade costs in goods markets.

[7] More precisely, the large effect of trade policy changes in these studies is due to asymmetric pace of policy changes in different countries, which is a transitory phenomenon.

stochastic growth model with shocks to capital endowments and frictions in international capital markets that prevents risk sharing. In this paper we abstract from the potential use of capital controls as macro-prudential policy.

In Section 2, we present the basics of the model. In Section 3 we present the planner's problem and establish our first result on the intra-temporal pattern of optimal trade policy under a dynamic trade model. In Section 4, we derive optimal trade and capital control policies and characterize their variation over the business cycles and under certain growth paths. We introduce our quantitative analysis in Section 5. Section 6 provides some concluding remarks. The Appendix includes proofs and further description of our quantitative methodology.

2. The basic model

We use a multi-period, two-country, *K*-industry model in which consumption and production takes place in each period of time, $t \in \{0, \cdots, T\}$, where T is a finite natural number or ∞. Each country, $i, j \in \{h, f\}$, produces a distinct variety in each industry. We let $p_{t,i,k}^j$ and $x_{t,i,k}^j$ denote, respectively, period-t price and quantity of consumption in country j of country i's variety of product k. With appropriate interpretation of subscripts and superscripts, bold-faced variables denote vectors and capitalized variables denote aggregate values.

Consumers can trade a one-period bond on the world capital market. In period t, the consumer in country j can buy a claim for a unit of the numeraire in period $t+1$ at a price of q_t^j per unit. We let b_{t+1}^j denote the quantity of bonds purchased by consumers in country j with a maturity date of $t+1$. Throughout our analysis, we assume that agents in both countries have perfect foresight about evolution of the fundamentals.[8]

Producers' Problem

We adopt a Ricardian framework in which each goods is produced using labor as the only input to production. Labor productivity in industry k of country i at time t, denoted by $a_{t,i,k}$, is independent of the quantity of production. Labor is perfectly mobile across industries within the same country. The population of labor in each country is assumed to be constant over time, and we normalize the population in each country to 1. Producers are perfectly competitive and, thus, their price is equal to marginal costs of production:[9]

$$p_{t,i,k} = \frac{w_{t,i}}{a_{t,i,k}},$$

where $w_{t,i}$ is the wage in country i in period t.

Consumers' Problem

The lifetime utility of the representative consumer in country j is given by

$$\sum_{t=0}^{T} \beta^t u\big(g(\mathbf{x}_t^j)\big), \tag{1}$$

where, β is the discount factor,[10] $\mathbf{x}_t^j$ is country j's vector of consumption in period t, $g\big(\mathbf{x}_t^j\big)$ is the aggregate consumption (i.e., utility) in period t, and $u(\cdot)$ is a concave function that represents intertemporal preferences. The consumer's per-period budget constraint in country j is given by

$$\mathbf{p}_t^j \cdot \mathbf{x}_t^j + q_t^j b_{t+1}^j = w_{t,j} + b_t^j - \mathcal{T}_t^j, \tag{2}$$

where $\mathcal{T}_t^j$ is a lump-sum tax paid by the consumers in country j.

The optimization problem of the consumer in country j is to choose a vector of consumption and bonds for each period $\{\mathbf{x}_t^j, b_t^j\}$ to maximize its lifetime utility (1) subject to its per-period budget constraints (2). Letting χ_t^j denote the Lagrange multiplier on the budget constraint of country j's consumers in period t, the optimal consumer choice implies

$$\beta^t \frac{du\big(g(\mathbf{x}_t^j)\big)}{dx_{t,i,k}^j} = \chi_t^j p_{t,i,k}^j, \quad \forall i, k \tag{3}$$

and

$$q_t^j = \frac{\chi_{t+1}^j}{\chi_t^j}. \tag{4}$$

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[8] As we will show later, policies are independent of history of the fundamentals and only depend on the contemporaneous value of fundamentals, i.e., productivity, trade costs and discount factors, etc. One can show that—as in Lucas and Stokey (1983)-introducing uncertainty together with the assumption of complete markets does not change this result. Moreover, the relationship between optimal policy and fundamentals does not change with uncertainty. In other words, the only difference between the optimal allocations under perfect foresight and with shocks is that the Lagrange multiplier on the implementability constraint, (16), is different between the two specifications.

[9] Absent domestic taxes, producer and consumer prices are equal $p_{t,i,k} = p_{t,i,k}^i$.

[10] In our theoretical analysis, we assume that β is constant over time. We will relax this assumption in our calibration exercise in Section 5.

Combining these conditions and noting that price index in the home country is given by $P_t^h = \frac{p_{t,j,k}^h}{\frac{dg(\mathbf{x}_t^h)}{dx_{t,j,k}^h}}$ for any j, k, the Euler

equation for the home consumer may be written as

$$q_t^h = \beta \frac{u'\left(g\left(\mathbf{x}_{t+1}^h\right)\right)}{u'\left(g\left(\mathbf{x}_t^h\right)\right)} \frac{P_t^h}{P_{t+1}^h}. \tag{5}$$

Policy Instruments

We assume that the home government is policy active, while the foreign government takes a laissez faire approach. The policy instruments at the disposal of the home government include import and export tax/subsidy as well as a tax on international borrowing and lending of domestic households. Together with iceberg transport costs, $d_{t,i,k}^j$, trade taxes create a wedge between home and foreign prices. To be specific, the ad valorem export tax on good k in the home country, $\tau_{t,h,k}$, is implicitly given by:

$$p_{t,h,k}^f \equiv \left(1 + \tau_{t,h,k}\right) d_{t,h,k}^f p_{t,h,k}^h. \tag{6}$$

Similarly, the import tax, $\tau_{t,f,k}$, is implicitly given by:

$$p_{t,f,k}^h \equiv \left(1 + \tau_{t,f,k}\right) d_{t,f,k}^h p_{t,f,k}^f. \tag{7}$$

Finally, the home government imposes a capital control tax, $\tau_{t,b}$, which is a tax on the home consumer's purchase of foreign assets, namely,

$$q_t^h \equiv \left(1 + \tau_{t,b}\right) q_t^f. \tag{8}$$

An equilibrium in this world economy is defined as follows:

1. Consumers maximize their utility (1) subject to the budget constraint (2) while taking as given prices and transfers.
2. Firms maximize profits, taking prices as given.
3. Home government's budget constraint is satisfied:

$$\mathcal{T}_t^h = \sum_k \tau_{t,h,k} d_{t,h,k}^f p_{t,h,k}^h x_{t,h,k}^f + \sum_k \tau_{t,f,k} d_{t,f,k}^h p_{t,f,k}^f x_{t,h,k}^h + \tau_{t,b} q_t^f b_t^h.$$

4. All markets (i.e., labor, goods and international bonds) clear. Bond market clearing is given by $b_t^f + b_t^h = 0$.

Marginal utility wedges

In order to study border taxes, it is useful to define the wedge between the foreign and home marginal utilities. To begin, note that the wedge between the home and foreign marginal utility from the consumption of the foreign variety of product k is given by

$$\theta_{t,f,k} \equiv \frac{\frac{du(g(\mathbf{x}_t^h))}{dx_{t,f,k}^h}}{\frac{du(g(\mathbf{x}_t^f))}{dx_{t,f,k}^f}} \frac{1}{d_{t,f,k}^h}. \tag{9}$$

Similarly, the intra-temporal wedge for the home variety of product k is

$$\theta_{t,h,k} = \frac{\frac{du(g(\mathbf{x}_t^h))}{dx_{t,h,k}^f}}{\frac{du(g(\mathbf{x}_t^f))}{dx_{t,h,k}^h}} d_{t,hk}^f. \tag{10}$$

Finally, we define the inter-temporal wedge as the home-to-foreign ratio of the marginal rate of substation between the aggregate consumption of two consecutive periods, namely,

$$\theta_{t,b} \equiv \frac{\frac{u'(g(\mathbf{x}_{t+1}^h))}{u'(g(\mathbf{x}_t^h))}}{\frac{u'(g(\mathbf{x}_{t+1}^f))}{u'(g(\mathbf{x}_t^f))}}. \tag{11}$$

Absent any policies, the ratio of marginal utilities between the foreign and home country is equal to the relative shadow value of income in the two countries.[11] Trade and capital control taxes create additional wedges between marginal utilities.

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[11] The levels of the marginal utility wedges on their own do not represent distortions. What constitutes a deviation from the competitive equilibrium is a relative wedge—or, equivalently, the ratio of marginal rates of substitution—that differs from the relative transportation costs.

In particular, the relationship between the wedges and import tax ($\tau_{t,f}$), export tax ($\tau_{t,h}$), and the capital control tax ($\tau_{t,b}$) is given by the following equations:

$$1 + \tau_{t,f,k} \equiv \frac{p^h_{t,f,k}}{p^f_{t,f,k} d^h_{t,f,k}} = \frac{\chi^f_t}{\chi^h_t} \theta_{t,f,k}, \tag{12}$$

$$1 + \tau_{t,h,k} \equiv \frac{p^f_{t,h,k}}{d^f_{t,h,k} p^h_{t,h,k}} = \frac{\chi^h_t}{\chi^f_t} \frac{1}{\theta_{t,h,k}}, \tag{13}$$

$$1 + \tau_{t,b} \equiv \frac{q^h_t}{q^f_t} = \frac{\frac{\chi^h_{t+1}}{\chi^f_{t+1}}}{\frac{\chi^h_t}{\chi^f_t}} = \theta_{t,b} \frac{\frac{P^h_t}{P^h_{t+1}}}{\frac{P^f_t}{P^f_{t+1}}}. \tag{14}$$

3. The Planner's problem

To find the optimal policy of the home government, we use the *primal* approach as in Lucas and Stokey (1983), by solving a planning problem in which the equilibrium quantities are directly chosen by the government. We then find the set of trade and capital control taxes that implement the optimal allocation. Later, we will also consider scenarios in which the government's policy space is subject to varying degrees of constraints imposed by trade agreements and domestic rules.[12]

Under the primal approach, the planner's problem is to choose the vector of allocations for all periods, $\mathbf{x}^h$, to maximize the welfare of the representative consumer in the home country, i.e.,

$$\max_{\{\mathbf{x}^h_t\}^T_{t=0}} \sum_{t=1}^T \beta^t u\big(g(\mathbf{x}^h_t)\big), \tag{P}$$

subject to

1. Per-period labor-market clearing conditions:[13]

$$\big(\mathbf{x}^h_{t,h} + \mathbf{d}^f_{t,h} \odot \mathbf{x}^f_{t,h}\big) \cdot \frac{1}{\mathbf{a}_{t,h}} = 1,$$
$$\big(\mathbf{d}^f_{t,h} \odot \mathbf{x}^h_{t,f} + \mathbf{x}^f_{t,f}\big) \cdot \frac{1}{\mathbf{a}_{t,f}} = 1. \tag{15}$$

2. Implementability condition:

$$\sum_{t=0}^T \beta^t \nabla u\big(g(\mathbf{x}^f_t)\big) \cdot \mathbf{x}^f_t = \sum_{t=0}^T \beta^t \big[\nabla u\big(g(\mathbf{x}^f_t)\big)\big]_f \cdot \mathbf{a}_{t,f}. \tag{16}$$

where $\big[\nabla u\big(g(\mathbf{x}^f_t)\big)\big]_f$ is the vector of marginal utilities for the good that the foreign country produces. This condition requires that the total expenditure allocated to foreign consumers by the home planner is equal to the value of their income.

3. No domestic distortion in either country (given that the available tax instruments are levied only on international exchanges), which implies that marginal utilities from consumption of the domestically-produced goods in each country are proportional to their input requirement:

$$\frac{\partial g(\mathbf{x}^f_t)}{\partial x^f_{t,f,k}} = \frac{\chi^f_t}{a_{t,f,k}}, \tag{17}$$

$$\frac{\partial g(\mathbf{x}^h_t)}{\partial x^h_{t,h,k}} = \frac{\chi^h_t}{a_{t,h,k}}. \tag{18}$$

A few features of this optimal policy problem are worth mentioning. First, since the government distributes its tax revenues in a lump-sum fashion, the budget constraint of the domestic consumer imposes no extra constraint on the planning problem. Second, since taxes are only imposed on international flows, production is domestically efficient. Eq. (17) specifies that for any two goods produced in each country, marginal rate of substitution must be equal to marginal rate of transformation or, equivalently, the relative productivities.

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[12] CLW and Costinot et al. (2015) have demonstrated the benefits of applying this approach to international trade policy problems.

[13] Recall that *d* denotes trade costs. Moreover, we use $\odot$ to denote element-wise multiplication of vectors.

The first-order condition for the optimality of the planner's problem (P) with respect to the allocation of the import good, $x_{t,f,k}^h$, may be written as:

$$\beta^t \frac{\partial u(g(\mathbf{x}_t^h))}{\partial x_{t,f,k}} = \frac{\kappa_t^f}{a_{t,f,k}},$$

where κ_t^f is the Lagrange multiplier on the resource constraint of the foreign country (17). Moreover, substituting the equilibrium price, $p_{t,f,k} = \frac{w_{t,f}}{a_{t,f,k}}$, in the foreign consumer's optimality condition, we obtain

$$\beta^t \frac{\partial u(g(\mathbf{x}_t^f))}{\partial x_{t,f,k}^f} = \frac{\chi_t^f w_{t,f}}{a_{t,f,k}}.$$

The above two equations imply that

$$\theta_{t,f,k} \equiv \frac{\beta^t \frac{\partial u(g(\mathbf{x}_t^h))}{\partial x_{t,f,k}}}{\beta^t \frac{\partial u(g(\mathbf{x}_t^f))}{\partial x_{t,f,k}}} = \frac{\kappa_t^f}{\chi_t^f w_{t,f}}.$$

The left-hand side of this equation is the optimal wedge between the home and foreign's marginal utility of consuming the t, f, k variety, while the term on the right-hand side includes only economy-wide variables. Therefore, we confirm that the optimality of uniform tariffs under a static Ricardian model with balanced trade (BL and Costinot et al. 2015) carries over to a dynamic Ricardian model with trade imbalances.

Proposition 1. *Under a dynamic Ricardian model: (i) The optimal import tariffs are uniform across goods but generally differential across periods. (ii) The optimal export taxes will be also uniform across goods if intra-temporal preferences, g, takes a CES form across all goods and varieties.*

This Proposition states that, generally, optimality requires uniform import tariffs and differential export taxes, while optimal export taxes will be also uniform in the case of CES preferences. To understand the optimality of uniform tariffs note that the relative marginal costs of production in the foreign country is not affected by home tariffs. That is because the unit labor requirement is constant (due to Ricardian technologies) and wages are equalized across producers due to labor mobility. Across periods, however, wages do not necessarily equalize and, as a result, optimal tariffs could vary over time. The next section is dedicated to understanding the properties of this variation of optimal policies over time.

4. Intertemporal structure of optimal policies

In this section, we provide a few theoretical insights into the time-variation of optimal trade and capital control policies. To simplify the analysis, we henceforth assume CES preferences and zero trade costs, i.e., $d_{t,j,k}^{-j} = 1$. As we know from part (ii) of Proposition 1, under CES preferences, optimal import and export taxes are uniform within a period. Therefore, under CES preferences the home government's optimal policy problem reduces to choosing taxes on aggregate import and export volumes, rather than on individual traded varieties.

Formally, we assume that

$$g(\mathbf{x}_t^j) \equiv X_t^j \equiv \left[\sum_k \alpha_k \left(x_{t,h,k}^j \right)^{1-\frac{1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}},$$

where, $X_{t,i}^j$ denotes the aggregate volume of goods exported from i to j in period t. We can similarly define aggregate productivity as

$$A_{t,i} = \left[\sum_k (\alpha_k)^\sigma \left(a_{t,i,k} \right)^{\sigma-1} \right]^{\frac{1}{\sigma-1}}.$$

Moreover, we assume that intertemporal preferences are also characterized by a CES function, namely,

$$u(X_t^j) = \frac{\eta}{\eta-1} \left(X_t^j \right)^{\frac{\eta-1}{\eta}},$$

where, η is the intertemporal elasticity of substitution.

Using these assumptions, the planner's problem (P) may be written using aggregate values only, namely,

$$\max_{\{X_{t,h}^h, X_{t,f}^h\}_{t=0,\ldots,T}} \sum_{t=0}^T \beta^t u(X_t^h) \tag{P$'$}$$

subject to

$$X_{t,h}^h + X_{t,h}^f = A_{t,h},$$
$$X_{t,f}^h + X_{t,f}^f = A_{t,f}, \tag{19}$$

$$\sum_{t=0}^{T} \beta^t \left(\frac{du(X_t^f)}{dX_{t,f}^f} X_{t,f}^f + \frac{du(X_t^f)}{dX_{t,h}^f} X_{t,h}^f \right) = \sum_{t=0}^{T} \beta^t \frac{du(X_t^f)}{dX_{t,f}^f} A_{t,f}. \tag{20}$$

Before introducing the necessary conditions for optimality, note that the necessary conditions would be also sufficient if our programming problem is convex. This is guaranteed when the constraint set is strictly convex and objective of the maximization problem is strictly concave. Standard concavity properties of the CES function together with concavity of *u* guarantee that the objective is strictly concave. To ensure the convexity of the constraint set, we make the following assumption:

Assumption 1. $\sigma \geq \eta \geq 1$.

In other words, we assume that goods are more substitutable within a period than across periods. As we show in Appendix A, under this assumption, the optimization (P') is equivalent to one in which the constraint set is convex. This implies that the first-order conditions are necessary and sufficient for optimality.[14]

Using the properties of the CES preferences, and letting μ to denote the Lagrange multiplier of the implementability constraint (20), the FOC with respect to $X_{t,h}^h$ may be written as

$$\frac{(X_t^h)^{\frac{1}{\sigma} - \frac{1}{\eta}} (X_{t,h}^h)^{-\frac{1}{\sigma}}}{(X_t^f)^{\frac{1}{\sigma} - \frac{1}{\eta}} (X_{t,h}^f)^{-\frac{1}{\sigma}}} = \mu \left[1 - \frac{1}{\eta} + \left(\frac{1}{\eta} - \frac{1}{\sigma} \right) \left(\frac{X_t^f}{X_{t,f}^f} \right)^{\frac{1}{\sigma}} \frac{A_{t,f}}{X_t^f} \right]. \tag{21}$$

The LHS of this equation is the marginal-utility wedge for the consumption of the home good, namely, $\theta_{h,t} \equiv \frac{\frac{du(X_t^h)}{dX_{t,h}^h}}{\frac{du(X_t^f)}{dX_{t,h}^f}}$, which

is decreasing in $X_{t,h}^h$. The RHS of this equation is the marginal cost of consuming the home good for the home consumer, which is increasing in $X_{t,h}^h$. Similarly, the FOC with respect to $X_{t,f}^h$ may be written as

$$\frac{(X_t^h)^{\frac{1}{\sigma} - \frac{1}{\eta}} (X_{t,f}^h)^{-\frac{1}{\sigma}}}{(X_t^f)^{\frac{1}{\sigma} - \frac{1}{\eta}} (X_{t,f}^f)^{-\frac{1}{\sigma}}} = \mu \left[1 - \frac{1}{\eta} + \left(\frac{1}{\eta} - \frac{1}{\sigma} \right) \left(\frac{X_{t,f}^f}{X_t^f} \right)^{-\frac{1}{\sigma}} \frac{A_{t,f}}{X_t^f} + \frac{1}{\sigma} \frac{A_{t,f}}{X_{t,f}^f} \right], \tag{22}$$

where, the LHS represent the marginal-utility wedge for the consumption of the foreign good, $\theta_{f,t} \equiv \frac{\frac{du(X_t^h)}{dX_{t,f}^h}}{\frac{du(X_t^f)}{dX_{t,f}^f}}$.[15]

It is useful to write the above optimality conditions in terms of trade shares,

$\lambda_{t,f}^f \equiv \left(\frac{X_{t,f}^f}{X_t^f} \right)^{\left(\frac{1-\sigma}{\sigma} \right)}$, and local consumption shares, $\pi_t^j \equiv \frac{X_{t,j}^j}{A_{t,j}}$:[16]

$$\frac{\theta_{t,h}^*}{\mu} = 1 - \frac{1}{\eta} + \left(\frac{1}{\eta} - \frac{1}{\sigma} \right) \frac{\lambda_{t,f}^f}{\pi_t^f}, \tag{23}$$

$$\frac{\theta_{t,f}^*}{\mu} = 1 - \frac{1}{\eta} + \left(\frac{1}{\eta} - \frac{1}{\sigma} \right) \frac{\lambda_{t,f}^f}{\pi_t^f} + \frac{1}{\sigma} \frac{1}{\pi_t^f}. \tag{24}$$

where, we use asterisks on the wedges to denote optimal values.

Eqs. (23) and (24) illustrate the main determinants of optimal wedges—or equivalently, optimal taxes as we describe below. First, as expected, it highlights the role of trade imbalances. In particular, if trade was balanced, expenditure must equal income in each period and, thus, $\lambda_{t,f}^f = \pi_t^f$. As an example, in periods when π_t^f is high relative to $\lambda_{t,f}^f$, i.e., when the

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[14] While useful for theoretical analysis, this assumption is unnecessary for our quantitative analysis and, hence, will be relaxed in Section 5.
[15] See Appendix D for the derivation of these formula.
[16] We refer to the share of country *j* output that is consumed in country *j* as *local consumption shares*.

foreign country's expenditure is high relative to its output, the wedge on exports must be high. This is resulting from the increased monopoly power of the home government when the foreign country is buying a higher share of home output. Moreover, both intra- and inter-temporal elasticities matter for optimal trade policies. Finally, the home government has extra motive to create a wedge on imports–captured by the term $\frac{1}{\sigma}\frac{1}{\pi_t^f}$ in (24).

4.1. Optimal trade and capital control policies

So far we have characterized the optimal marginal utility wedges using the primal approach to optimization. We now use the relationship between wedges and policy instruments, established in equations (12)–(14), to determine the level of policies that could implement these optimal wedges. Given the aggregation afforded by the CES assumption, conditions (12)–(14) may be written as

$$1 + \tau_{t,f} = \frac{\chi_t^f}{\chi_t^h} \theta_{t,f}^*, \tag{25}$$

$$1 + \tau_{t,h} = \frac{\chi_t^h}{\chi_t^f} \frac{1}{\theta_{t,h}^*}, \tag{26}$$

$$1 + \tau_{t,b} = \frac{\frac{\chi_{t+1}^h}{\chi_{t+1}^f}}{\frac{\chi_t^h}{\chi_t^f}}, \tag{27}$$

These conditions forms a system of three equations and five unknowns $(\tau_{t,f}, \tau_{t,h}, \tau_{t,b}, \frac{\chi_t^h}{\chi_t^f}, \frac{\chi_{t+1}^h}{\chi_{t+1}^f})$ for each pair of consecutive periods. The optimal wedges, $\theta_{t,h}^*$ and $\theta_{t,f}^*$, therefore, may be produced using different combinations of taxes. This indeterminacy reflects Bond's (1990) argument that the solution to optimal trade policy determines all tax levels relative to a numeraire. In particular, the optimum may be obtained without capital control taxes.

Optimal trade policy in absence of capital controls

Letting $\tau_{t,b} = 0$ for all t, the following equations characterize the changes of optimal trade taxes in consecutive periods in absence of capital controls:

$$\frac{1 + \tau_{t,f}}{1 + \tau_{t-1,f}} = \frac{\theta_{t,f}^*}{\theta_{t-1,f}^*}, \tag{28}$$

and

$$\frac{1 + \tau_{t,h}}{1 + \tau_{t-1,h}} = \frac{\theta_{t-1,h}^*}{\theta_{t,h}^*}. \tag{29}$$

These equations show that optimality requires a change in import and export taxes in consecutive periods that is proportional to the change in the level of optimal intra-temporal wedges.

It is worth noting that trade taxes and subsidies in a given period determine the ratio of relative prices in the home and foreign country, $\frac{\frac{p_{t,f}^h}{p_{t,h}^h}}{\frac{p_{t,f}^f}{p_{t,h}^f}} \equiv \frac{\theta_{t,f}}{\theta_{t,h}}$, in that period. Therefore, the optimal level of *total* trade restrictions in period t is uniquely determined by the ratio of optimal wedges:

$$\left(1 + \tau_{t,f}\right)\left(1 + \tau_{t,h}\right) = \frac{\theta_{t,f}^*}{\theta_{t,h}^*}. \tag{30}$$

Under the balanced trade requirement (BT), the above formula would be the only restriction on policies that is needed for the implementation of optimal allocation. In other words, under BT, import and export taxes are perfectly substitutable *in each period*. Under a dynamic model without capital controls, however, both import and export taxes are generally necessary for the implementation of the optimal policy.

Finally, note that under BT, the expenditure and local consumption shares are equal, i.e., $\lambda_{t,f}^f = \pi_t^f$. Moreover, the FOCs under this requirement are identical to (23)–(24) except that the Lagrangian of the optimization problem would be specific to each period and, thus, takes a subscript t, i.e., μ_t. Taking note of this yields the following formula for optimal import and export tax combination

$$\left(1 + \tau_{t,h}\right)\left(1 + \tau_{t,f}\right) = 1 + \frac{1}{\lambda_{t,h}(\sigma - 1)},$$

which is the formula obtained by Gros 1987 for the optimal trade protection under a static model.

Capital control policy

It is clear from the system of equations (25)–(27) that the capital control tax could substitute one of the trade policy instruments. In particular, if export taxes are set equal to zero ($\tau_{t,h} = 0, \ \forall t$), generating the optimal wedges requires the following import and capital control taxes:

$$1 + \tau_{t,f} = \frac{\theta_{t,f}^*}{\theta_{t,h}^*},$$

$$1 + \tau_{t,b} = \frac{\theta_{t+1,h}^*}{\theta_{t,h}^*}.$$

To interpret this result, note that in any given period, the optimal tariff is determined by the marginal rate of substitution between the home and foreign goods in that period. The optimal capital control taxes, on the other hand, reflect the anticipated rate of change in the optimal marginal utility wedges in the next period.

4.2. Cyclical behavior of optimal tariffs and capital controls

To characterize the time-variation of optimal trade taxes, it is useful to rewrite the optimality conditions (23) and (24) using fraction of outputs consumed in each country. Letting $z_t \equiv \frac{A_{t,h}}{A_{t,f}}$ denote the relative productivity of home to foreign country in period t, the FOCs may be written exclusively in terms of z_t, π_t^h, π_t^f and the parameters of the model (See Appendix C). Therefore, in each period, the fraction of home and foreign production that is consumed at home is pinned down by the relative productivity, z_t, in that period. The effect of future and past productivities on the current allocation operates only through the time-invariant Lagrange multiplier, μ. This observation also implies that

Proposition 2. *Up to a normalization, the optimal import and export taxes/subsidies in period t are uniquely determined by the relative productivities in period t, i.e., z_t.*

Noting that two periods with equal relative productivities could have different levels of trade imbalances, this proposition implies that the size and direction of current trade balance has no bearing on the current optimal trade policy. Therefore, in general, there is no relationship between optimal trade policy and trade balance in a given period.

The intuition provided above for determinants of wedges suggest that when z_t is low and income in the foreign country is relatively high, it should be optimal to have high import tariffs and export subsidies. Unfortunately, we cannot show this analytically. We can, however, show that

Proposition 3. *Under optimal trade policy, the share of foreign production that is consumed abroad, π_t^f, is decreasing in z_t.*

This Proposition implies that there are forces towards making import tariffs and export subsidies, i.e., the general level of protection, counter-cyclical. In other words, optimal trade policy encourages a pro-cyclical consumption pattern. This finding is similar to the key finding of CLW for the case of capital control taxes under free trade.

As we discussed in the introduction, this result may be understood by noting that a country's *inter-temporal* terms of trade may be improved by a marginal reduction in the national saving rate during booms or a reduction in total borrowing during downturns. This goal may be achieved by relatively higher import tariffs and export subsidies during downturns.

So far in this subsection we have analyzed the cyclical behavior of trade taxes assuming that capital control taxes are not in use. We now ask if the introduction of capital control taxes have any impact on the time-variation of import tariffs. Setting export tax/subsidies equal to zero for all periods, optimal tariffs should satisfy

$$\tau_{t,f} = \frac{\frac{1}{\sigma} \frac{1}{\pi_t^f}}{1 - \frac{1}{\eta} + \left(\frac{1}{\eta} - \frac{1}{\sigma}\right) \frac{\lambda_{t,f}^f}{\pi_t^f}}.$$

To understand the variation of optimal tariffs in the presence of capital control, we can compare the above formula for optimal tariffs—absent export taxes—with Eq. (24). In particular, if π_t^f and $\pi_t^f / \lambda_{t,f}^f$ move together over time, the fluctuations in $\tau_{t,f}$ is dampened relative to those of the optimal import and export taxes. Note that π_t^f is the ratio of consumption of domestic goods to output while $\pi_t^f / \lambda_{t,f}^f$ is the ratio of total consumption to total output. Since these two statistics are often positively correlated, the above suggests that absent export taxes and with capital controls optimally chosen, variations in import tariffs are dampened. Our quantitative exercise suggests that this is in fact the case: with optimal capital control taxes, optimal tariffs do not vary as much over time.

We can also discuss the cyclical behavior of optimal capital controls. While we cannot show this analytically, it is often the case that import taxes are procyclical while export taxes are countercyclical. When the government shuts down export taxes and uses capital controls instead, these cyclical properties translate to a relationship between growth and capital control. In particular, if the home country is expected to have a high growth relative to the foreign country in the next period, it is optimal to impose a tax on accumulation of foreign debt. This is reminiscent of the finding in CLW who find a similar result assuming free trade.
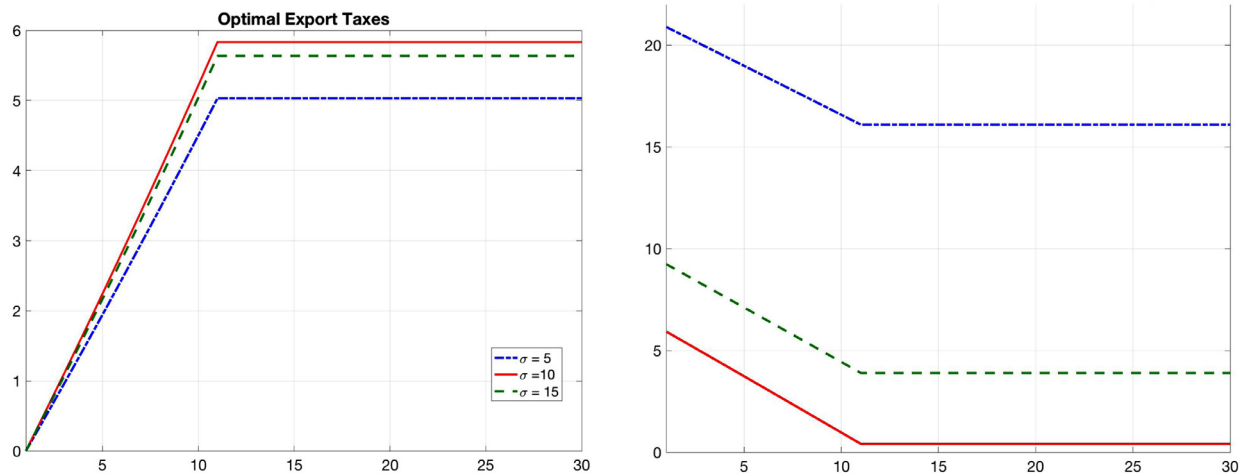
Fig. 1. Optimal export taxes (left) and import tariffs (right) over time, when the home country grows faster than the rest of the world.
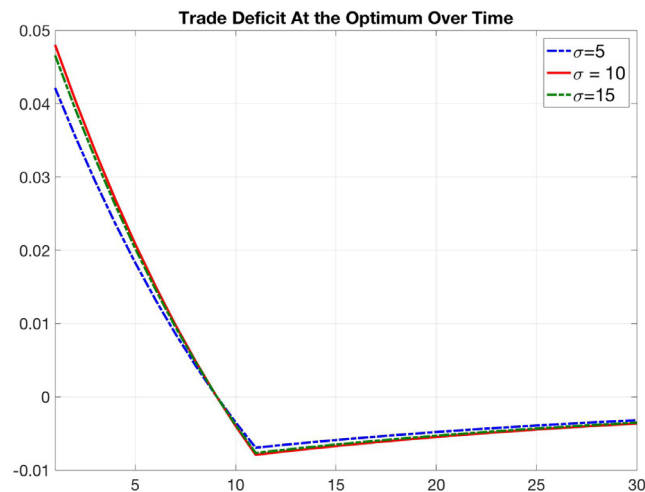

Fig. 2. Trade deficit in the home country over time.

4.3. The relationship between trade imbalances and optimal policy

As we discussed following Proposition 2, in general, there is no relationship between optimal trade policy and the degree of trade imbalances in a given period. However, we could identify likely growth scenarios under which the optimal trade policy and trade imbalances appear move together. In particular, consider a scenario in which the home country experiences a period of high growth, i.e., one in which the productivity of the home country increases relative to the foreign country. Proposition 3 suggests that as home's relative productivity increases over time, optimality requires a reduction in the total protection afforded to the domestic industries, namely, a decrease in export subsidies and import tariffs.

For illustration, we construct a numerical example with two countries as follows. The two countries have the same level of productivity at time zero. For the first 10 years, the home country and the foreign country grow at an annual rate of 4% and 2%, respectively. After that productivities remain constant. As depicted in Fig. 1, during the growth period, the optimal import tariffs and export subsidies of the home country decline over time.

Fig. 2 depicts the level of trade deficits in each period under optimal policy. As can be seen in this Figure, during the period of faster growth in the home country, the level of trade deficits goes down. This reduction in trade deficits coincides with the reduction in the level of optimal tariffs during this time, which was illustrated in Fig. 1. Generally, during a time span in which the home country grows consistently faster than the rest of the world, the optimal level of trade protection and the magnitude of trade deficits decline over time. Conversely, during a period in which the home country grows slower than the rest of the world, a decrease in the magnitude of trade surplus over time coincides with an increase in the level of trade protection. The comovement of optimal policy and trade imbalances under these likely growth patterns may explain the relative popularity of protectionist policies at the time of persistently-growing trade deficits.

5. Quantitative analysis

In this section, we provide a quantitative version of the model described above and fit it to the economy of the United States. To do so, we adjust our model by allowing for time-varying trade costs and discount factors in order to perfectly fit the data on GDP, exports and imports in the United States and the rest of the world from 1995 to 2016. During this time period, the U.S. adopted historically-low tariffs after the inception of the WTO in 1995. Therefore, we fit the data under the assumption that the trade policy of the US in this period is free trade.

We rewrite the optimal policy problem in terms of moments observable in the data, thereby extending the so-called exact hat algebra to optimal policy problems. Using this approach, we calculate the optimal trade and capital control taxes under various scenarios. We mainly consider three scenarios: first, unilaterally optimal trade policy without any restrictions; second, optimal capital controls assuming free trade obligations under WTO; and third, unilaterally optimal tariffs when capital control and export taxes are unavailable.

5.1. The hat-algebra for the primal approach

Gravity models of international trade, such as the one we use in this paper, lend themselves very well to quantitative analyses. In general, quantifying the effect of trade costs (including transport costs and trade taxes) on trade flows requires the estimates of various structural parameters of the model such as productivities and preference shocks. Under gravity models, however, the only parameters that need to be calibrated are trade elasticities. In particular, the effects of changes in trade taxes may be quantified without any knowledge on other parameters of the model that are invariant to changes in trade taxes.

This feature of the gravity models can be seen by rewriting the equilibrium conditions in terms of *changes* in the variables as a response to changes in trade policy. This technique, originally known as *calibrated share form* in the Computational General Equilibrium literature, was reintroduced to the quantitative trade literature by Dekle et al. (2007). Costinot and Rodríguez-Clare (2014) provide a detailed discussion of this method, which they refer to as the "exact hat algebra". Finally, Ossa (2016) provides a survey of this method as applied to the problem of optimal trade policy.

To evaluate the quantitative effects of trade and capital control policy, we first adapt the hat-algebra technique to our setting, which involves the primal approach to a dynamic Ramsey problem.[17] Before doing so, we first extend the model to allow for time-varying discount rates. In particular, we assume that preferences are given by

$$
\sum_{t=0}^{\infty} \prod_{s=0}^{t} \beta_s^j \frac{\left(\left[\sum_{k=h,f} \left(X_{t,k}^j \right)^{1-\frac{1}{\sigma}} \right]^{\frac{1}{1-\frac{1}{\sigma}}} \right)^{1-\frac{1}{\eta}}}{1 - 1/\eta}.
$$

This change generates enough flexibility in the model in order to match any pattern of trade deficit over time.

Consider the Planner's problem (P') modified to allow for time-varying discount rates defined above. Referring to variables with a bar as the free-trade variables, i.e., those observed in the data, and using the hat-algebra notation, $\hat{y} \equiv \frac{y}{\bar{y}}$ for any variable y, we can write the resource constraints (19) as

$$
\overline{X}_{t,j}^j \hat{X}_{t,j}^j + d_{t,h}^f \overline{X}_{t,j}^{-j} \hat{X}_{t,j}^{-j} = A_{t,j},
$$

for $j = h, f$ and all t. Letting $\pi_{t,j} \equiv \frac{\overline{X}_{t,j}^j}{A_{t,j}}$ denote the fraction of country j output that is consumed domestically, these conditions may be written as

$$
\pi_{t,j} \hat{X}_{t,j}^j + \left(1 - \pi_{t,j} \right) \hat{X}_{t,j}^{-j} = 1.
$$

Similarly, we can rewrite the implementability constraint (20) and the utility of the representative consumer in the home country in hat-algebra form. This results in the following optimization problem:

$$
\max_{\{\hat{X}_{t,j}^i\}_{i,j}, \hat{X}_t^f} \sum_{t=0}^{\infty} \frac{\alpha_t^h \left(\left[\sum_j \lambda_{t,j}^h \left(\hat{X}_{t,j}^h \right)^{1-\frac{1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \right)^{1-\frac{1}{\eta}}}{1 - \frac{1}{\eta}}, \tag{P1}
$$

subject to the implementability condition:

$$
\sum_{t=0}^{\infty} \alpha_t^f \left(\hat{X}_t^f \right)^{1-\frac{1}{\eta}} = \sum_{t=0}^{\infty} \frac{\alpha_t^f \lambda_{t,f}^f}{\pi_t^f} \left(\hat{X}_t^f \right)^{\frac{1}{\sigma} - \frac{1}{\eta}} \left(\hat{X}_{t,f}^f \right)^{-\frac{1}{\sigma}},
$$

---

[17] This is different from the previous papers in this literature that use a static trade model and the dual approach in computing the optimal policy (Beshkar and Lashkaripour, 2019; Ossa, 2014).

the resource constraints:

$$\pi_t^h \hat{X}_{t,h}^h + \left(1 - \pi_t^h\right) \hat{X}_{t,h}^f = 1,$$

$$\pi_t^f \hat{X}_{t,f}^f + \left(1 - \pi_t^f\right) \hat{X}_{t,f}^h = 1,$$

and the CES aggregation, $\sum_j \lambda_{t,j}^f \left(\hat{X}_{t,j}^f\right)^{1-\frac{1}{\sigma}} = \left(\hat{X}_t^f\right)^{1-\frac{1}{\sigma}}$.

In the above optimization problem, α_t^j is the time-0 value of time-t expenditure as a fraction of the present value of income at time 0. Additionally, $\lambda_{t,k}^j$ is the fraction of the expenditure in period t in country j which is spent on the output of country k.

The above formulation of the optimal policy problem highlights the sufficient statistics that are required to be measured in the data in order to solve for optimal policy. These sufficient statics include α_t^j: the share of total expenditure in country j that is spent in period t, $\lambda_{t,k}^j$: the share of j's expenditure that is spent on k's output in period t, and π_t^j: the share of output of j that is consumed domestically. It, thus, implies that both the level and changes in productivity, trade costs, and preference shocks affect optimal policies only indirectly through the sufficient statistics. Therefore, in order to understand optimal policy and its determinants, it suffices to measure these sufficient statistics. As we explain below, we construct α_t^j, λ_{ti}^j, and π_t^i based on the data on total output (GDP) of United States and the rest of the world and import and export volumes.

In addition to the problem above, we also consider two alternative policy exercises: one in which the home government (U.S.) is constrained by trade agreements to keep intra-temporal trade undistorted and one in which the home government can only change import tariffs.

5.2. Data and calibration

We use World Bank's data on real imports and exports and GDP for the United States and the rest of the world for the time period of 1995–2016. As we need time-0 measurement of expenditures, we calculate real interest rate for the U.S. and a collection of other countries. In particular, for the U.S., we use data on 10-year treasury notes and U.S. inflation measured using the CPI. We use the difference between the two to compute our measure of annual real interest rate.[18] Finally, in order to calculate real interest rates in the rest of the world, we use the data provided by Jordà et al. (2019) on 17 advanced economies. In each country, we calculate the (ex-post) real interest rate as the difference between long-term interest rates and inflation according to CPI. We then calculate a weighted average of gross interest rate across these countries weighted by their corresponding GDP (measured according to PPP).

Two observations are important to note. First, in 1995, U.S.'s international investment position is negative and around 3.6% of GDP. This justifies to some extent the choice of the zero initial assets for both countries. Second, during this time period, the United States has run an increasing trade deficit as a fraction of GDP. In order to for our model to fit the second observation, i.e., accumulation of debt over this time period, we assume that time starts at 1995 and runs until infinity. We assume that after 2017, both home and foreign country grow at rate 1.5% annually while annual real interest rates are 2%.[19] Moreover, we assume that trade costs and discount factors are constant after 2017.

In order to map our model to the data, we simplify by assuming that total consumption in the country is equal to GDP plus imports less exports. Given this assumption, for the period of 1995 to 2017, we can calculate π_t^j and $\lambda_{t,k}^j$ as follows:

$$\pi_t^j = \frac{GDP_t^j - EX_t^j}{GDP_t^j},$$

$$\lambda_{t,j}^j = \frac{GDP_t^j - EX_t^j}{GDP_t^j - EX_t^j + IM_t^j}, \quad \lambda_{t,-j}^j = 1 - \lambda_{t,j}^j.$$

Moreover, as α_t^j is the share of the time-0 value of expenditure at t in total time-0 expenditure, it is given by

$$\alpha_t^j = \frac{GDP_t^j - EX_t^j + IM_t^j}{I^j} \frac{1}{\left(1 + r_1^j\right) \cdots \left(1 + r_t^j\right)},$$

where r_t^j is real interest rate and I^j is time-0 wealth defined by

$$I^j = GDP_{1995}^j + \frac{GDP_{1996}^j}{1 + r_{1996}^j} + \cdots + \frac{GDP_{2017}^j}{\left(1 + r_{1996}^j\right) \cdots \left(1 + r_{2017}^j\right)} \frac{1}{1 - \frac{1+.015}{1+0.02}}.$$

---

[18] While the data on 10-year Treasury Inflation Protected Securities does not date back to 1995, for the period in which yields exist, our constructed measure is very close to the 10-year TIPS yield. We show both series in Fig. 9 in the Appendix.

[19] While these are somewhat optimistic estimates for growth and interest rates in the future, we also consider other values for growth and real interest rates after 2017; namely, more pessimistic values for growth of 0.5% and real interest rate of 1%. Our results remain roughly unchanged.
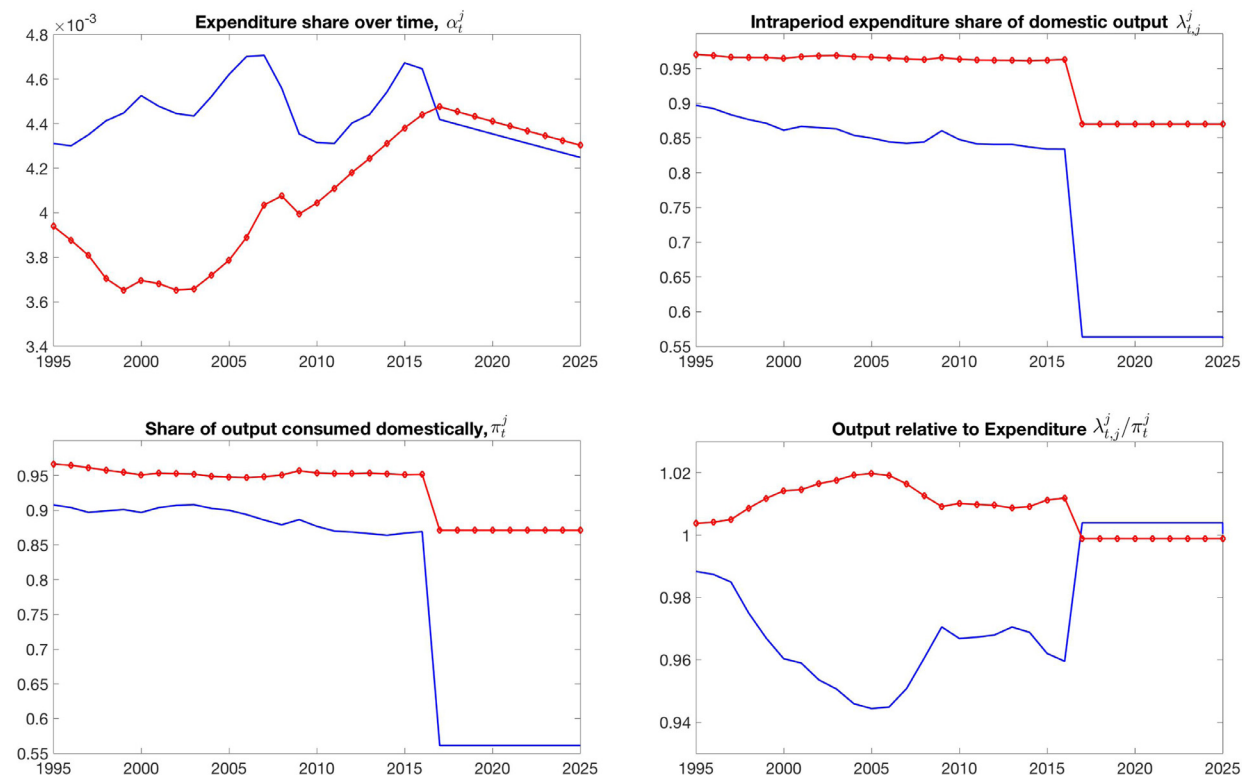
Fig. 3. Sufficient Statistics in the Calibrated Model; The solid line depicts data for the U.S. and the diamond line depicts data for the rest of the world. Data for periods after 2016 are calculated using the procedure outlined Appendix F.

In the above, we have used the assumption that after 2017, GDP grows at rate 1.5% while real interest rates are 2%. While the above calculations give us the required sufficient statistics in the periods for which we observe data, we can use properties of the model and the assumption of stationarity after 2017 to calculate the corresponding values after 2017. We describe these calculations in Appendix F.

Finally, we choose parameter values for σ and η in line with the macro and trade literatures. We assume that $\sigma = 5$ and $\eta = 0.5$ in our baseline calculations. We also consider variations in these parameters (including, for example, $\sigma = 10$ and $\eta = 1/3$) to understand their effect on optimal taxes.[20]

In Fig. 3, we show the measured statistics. Notably, α_t rises for the United States in the period leading up to the trade collapse of 2008 and then collapses in 2008. Moreover, as our optimal wedge formulas (23) and (24) identify, the main statistics that affects optimal taxes are $\lambda_{t,f}^f/\pi_t^f$ and π_t^f. Recall that $\lambda_{t,f}^f/\pi_t^f$ is the ratio of GDP to expenditure in the rest of the world. As Fig. 3 shows, this ratio exhibits a hump-shape behavior. As U.S. accumulates trade deficit in the period leading to the financial crisis and trade collapse of 2008, this ratio rises until 2005. It then falls until 2008 and then remains constant. As we show below, optimal trade taxes exhibit a very similar behavior.

5.3. Results

We quantify our model for three different scenarios regarding the policy instruments at the disposal of the government.

5.4. Optimal unrestricted taxes

We start by describing the results of our optimal policy exercise when the U.S. chooses its optimal trade policy unilaterally without any restrictions from free trade agreements. As depicted in Fig. 4, the main feature of optimal trade taxes are their U-shaped behavior over time: optimal import tariffs increase until 2003 and generally decline thereafter.

The hump-shape pattern of trade taxes reflect a similar pattern in the ratio of total output to total expenditure, $\lambda_{t,f}^f/\pi_t^f$ — see Fig. 3. As suggested by our theoretical analysis in the previous section, the gradual increase in trade protection in the

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[20] Note that for these values of σ and η, Assumption 1 is violated and the constraint set in the optimal policy problem is not concave. As a result, optimality conditions might not describe the optima. To address this issue, we use a global method for optimization and our computations suggests that the solution is unique.
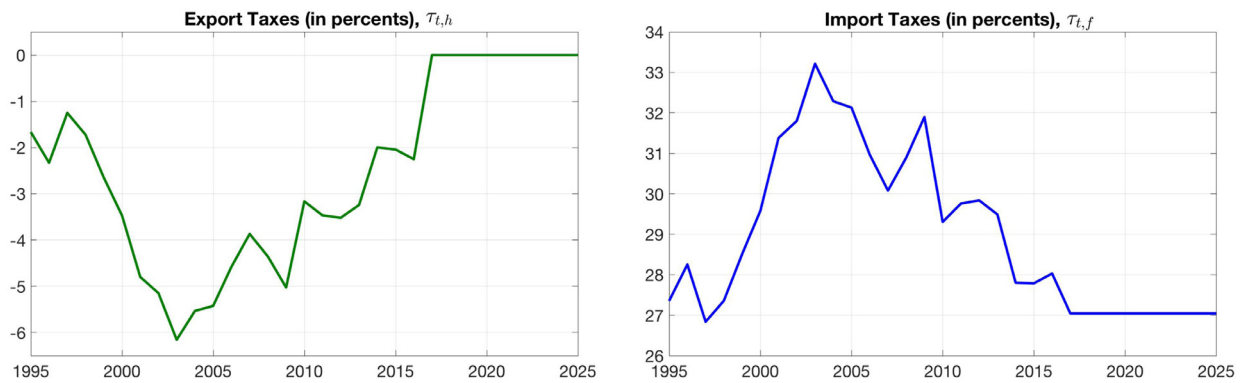
Fig. 4. Export and Import Taxes in the baseline calibration with $\sigma = 5, \eta = 1/2$.
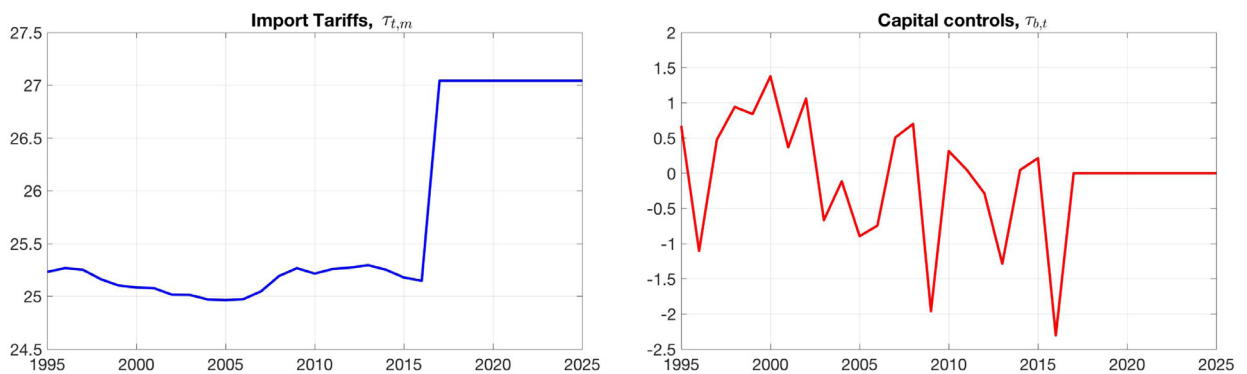

Fig. 5. Import Tariffs (left panel) and capital control taxes in the baseline calibration in percent.

first-half of our time period reflects an optimizing government's motivation to discourage borrowing by the households from the rest of the world during this relatively fast growth period. Conversely, the gradual decline in optimal level of protection after 2003 reflects the government's desire to encourage domestic consumption in lieu of lending to the rest of the world.

Finally, for the period after 2017, since both countries are assumed to be growing at the same rate, the export and import taxes are constant.

As we have mentioned earlier, the same allocations can be implemented using capital controls, i.e., taxes on international asset holdings (or debt) together with an intratemporal tariff on imports. Fig. 5 depicts optimal import tariffs and capital control taxes. Note that in the absence of export taxes, import tariffs alone regulate the intratemporal wedge, i.e., the difference between the relative price of the two goods faced by consumers at home and abroad. Therefore, the size of the optimal tariffs under this scenario is equivalent to the total intra-temporal protection, i.e., $(1 + \tau_{f,t})(1 + \tau_{h,t}) - 1$, under the previous scenario.

The optimal capital control taxes, which are applied on the stocks of asset holdings, vary around 0.5%–ranging from nearly -2.5 to 1.5. To give a perspective, note that for an interest rate of 4%, a 1% tax on the stock of assets is equivalent to a tax of $1.04/0.04 \times 1\% = 26\%$ on asset income. Also note that for the last period of our data, the calculated optimal capital control tax is somewhat large (-2.5%). This is because of the abrupt change in the allocations before and after 2016, which is caused by our assumption that the US and the rest of the world will suddenly start growing at the same pace post 2016. Moreover, the optimality of a zero capital control tax after 2016 reflects the fact that countries grow at the same rate, which eliminates the benefits of dynamic terms of trade manipulations.

5.5. Optimal restricted taxes

We now consider three hypothetical scenarios in which the policy space of the U.S. government is restricted by an international trade agreement or institutional constraints.

In our first scenario, we assume that the U.S. government refrains from using export and capital control taxes and uses import tariffs as its sole policy instrument. This exercise is motivated by the constitutional ban on export taxes in the U.S., as well as the liberal current account policies adopted and promoted by the US government since the Bretten Woods agreement. As depicted in the left panel of Fig. 6, when tariffs are the only available instruments, the pattern of optimal tariffs over time is very similar to the one under unrestricted policies (Fig. 5).
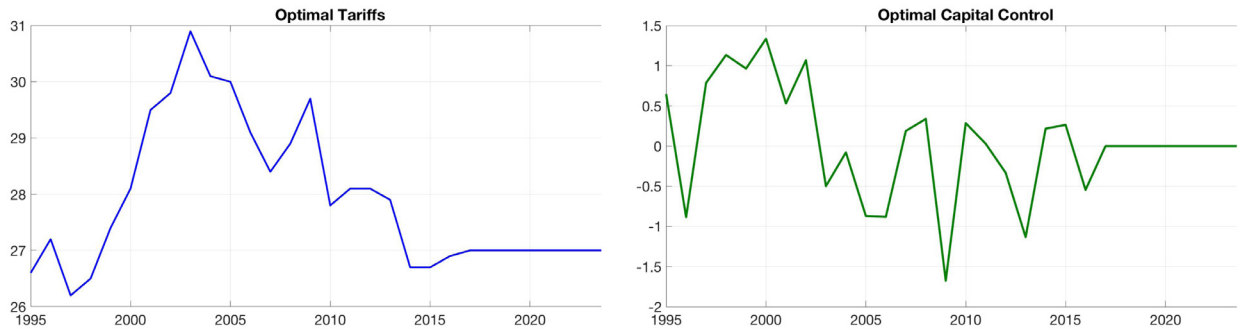
Fig. 6. Optimal Tariffs (left panel) and capital control with restrictions on policies.

Table 1
Welfare under restricted and unrestricted optimal policy. Numbers are in consumption equivalence units.

Change in Welfare	Capital Control Only	Constant Tariff	Tariff Only	Unrestricted
$\sigma = 5, \eta = 0.5$	0.001%	1.771%	1.772%	1.773%
$\sigma = 5, \eta = 0.33$	0.002%	1.772%	1.773%	1.775%
$\sigma = 10, \eta = 0.5$	0.001%	0.807%	0.808%	0.809%
$\sigma = 10, \eta = 0.33$	0.002%	0.808%	0.809%	0.811%

In our second scenario, we assume that the United States is party to a free trade agreement that eliminates all trade taxes, but leaves capital controls at the discretion of the government. The results under this scenario sheds light on the degree to which capital control taxes, which are not restricted under the WTO agreement, could substitute for the lost policy space due to the constraints imposed by the WTO on trade taxes. The right panel of Fig. 6 depicts the optimal level of capital control taxes under this scenario.

In our third scenario, we assume that the U.S. government applies a constant tariff rate over time. This scenario is studied to quantify the welfare effect of variation in tariffs over time.

In Table 1, we report the welfare gains under optimal restricted policies in consumption equivalence units and compare them with the unrestricted policy case. According to these calculations, capital controls can barely achieve any gains while tariffs can attain almost all the gains from optimal policy.

This results show that capital controls are not a good substitute for trade policies. This is mainly because of the way expenditure shares vary over time and across U.S. and the rest of the world. In particular, as shown in Fig. 3 except for the years 1995 to 2000, α_t^j's for the U.S. and the rest of the world move together, which implies that the gains from dynamic terms of trade manipulation are not very large.

Table 1 also reports the gains from imposing a constant tariff over time. We observe that the welfare levels under an optimal constant tariff is also very close to the optimum. Thus the gains from time varying trade taxes are not very large.

5.6. The effect of optimal policy on trade flows and relative prices

We now describe the effect of optimal policy on trade flows and real exchange rates. To start, consider the export-to-GDP. Since the price index (net of taxes) for exports and GDP are the same, then under optimal policy we must have

$$\frac{EX_t^{*,h}}{GDP_t^{*,h}} = \left(1 - \pi_t^h\right)\hat{X}_{t,h}^f,$$

where, π_t^h is the share of U.S. output that is consumed domestically, $\hat{X}_{t,h}^f$ is the solution of the program (P1), and $*$ refers to values under optimal policies. Similarly, we can show that the import-to-GDP ratio (net of taxes) is given by[21]

$$\frac{IM_t^{*,h}}{GDP_t^{*,h}} = \left(1 - \lambda_{t,h}^h\right)\frac{\pi_t^h}{\lambda_{t,h}^h}\frac{\left(\hat{X}_{t,f}^h\right)^{1-\frac{1}{\sigma}}}{\left(1 + \tau_{f,t}\right)\left(\hat{X}_{t,h}^h\right)^{-\frac{1}{\sigma}}}.$$

Using the above formula, Fig. 7 compare trade flows under optimal policy and the status quo (i.e., laissez-faire) economy. As expected, trade volumes are lower under optimal policy but its variation over time is not affected significantly by the implementation of optimal policy. In particular, between 1995 and 2017 the export-to-GDP ratio grew by 41.8% under the

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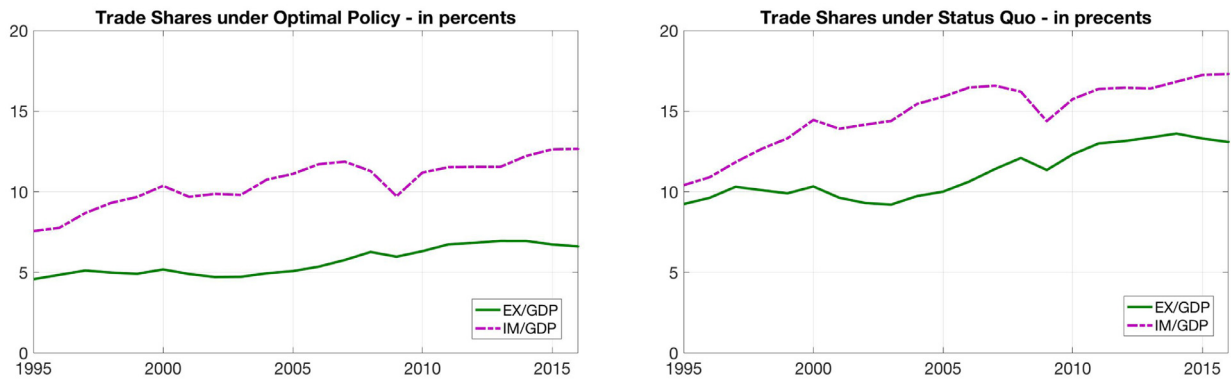[21] See Appendix F for the derivation of these relations.

Fig. 7. Trade to GDP Ratios—The left panel depicts values under optimal trade taxes. The right panel shows the values under the status quo.
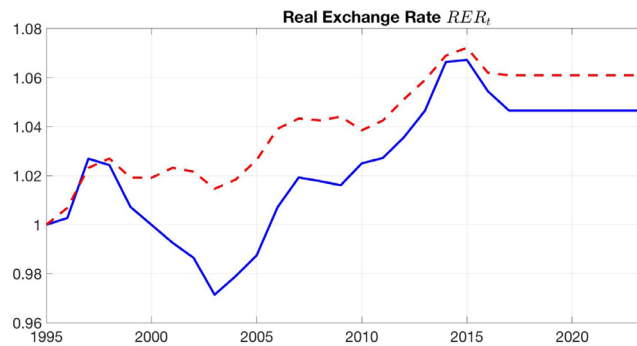

Fig. 8. Real exchange rate under optimal policy (solid line) and status quo economy (dashed line).

status quo, while this growth rate would have been 44.5% under optimal policy. For import-to-GDP ratios, these numbers are 66.3% and 67.5%, respectively.

Finally, net trade flows as measured by the ratio of exports to imports at the world prices is lower under optimal policy. This observation reflects the improvement in the terms of trade of the united states and the fact that the U.S. is able to raise a significant tariff revenue.[22]

We can also compare the real exchange rates under optimal policy and the status quo. Defined as the ratio of the price levels in the U.S. and the rest of the world, the real exchange rate moves over time according to the following equation

$$
\frac{RER^*_{t+1}}{RER^*_t} = \frac{RER_{t+1}}{RER_t} \times \frac{\left(\frac{\hat{X}^f_{t+1}}{\hat{X}^f_t}\right)^{-\frac{1}{\eta}}}{\left(\frac{\hat{X}^h_{t+1}}{\hat{X}^h_t}\right)^{-\frac{1}{\eta}}} = \frac{1+r^f_{t+1}}{1+r^h_{t+1}} \times \frac{\left(\frac{\hat{X}^f_{t+1}}{\hat{X}^f_t}\right)^{-\frac{1}{\eta}}}{\left(\frac{\hat{X}^h_{t+1}}{\hat{X}^h_t}\right)^{-\frac{1}{\eta}}}.
$$

As depicted in Fig. 8, the real exchange rate is more volatile under optimal policy. The increased volatility under optimal policy reflects the desire of the government to manipulate dynamic terms of trade by changing the relative price of consumption in the two countries over time.

As a benchmark, it is useful to compare our optimal taxes to the level of wedges that justify the trade flows in a neo-classical model of trade (see Levchenko et al. 2010 and Alessandria et al. 2013). These wedges are often measured under the assumption of stationary trade costs and no taste shocks. Since our model is flexible enough to match any pattern of trade, trade taxes act as distortions in addition to the wedges measured by these studies.

Similar to our finding for optimal trade policy, Levchenko et al. (2010) report measured wedges that are positively correlated with trade flows as a percent of GDP. However, the variation in our optimal taxes—changes of around 5 percentage points—are lower than the variation measured by Levchenko et al. (2010)—a trough-to-peak change of around 10–20 percentage points.

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[22] For ease of comparison of the two graphs in Fig. 7, we have omitted the trade shares for 2018 and afterwards. Import and export shares under optimal policy are 29.6% and 24.5%, respectively. Import and export shares in the status quo economy are 40.3% and 40.8%. Under status quo, import shares must be lower than export shares to pay for the accumulated trade deficits in 1995–2017.

6. Conclusion

In this paper, we analyzed unilaterally-optimal trade and capital control policies under a dynamic model with one factor of production. Our analysis sheds light on changes in optimal trade taxes over time and the viability of different tax instruments, i.e., tariffs, export subsidies, and capital control, as instruments for the implementation of optimal policy.

In a quantitative version of our model, which allows us to match the observed production and trade flows between the United States and the rest of the world, we show that in the absence of capital control taxes, optimality requires a significant change in import and export taxes over time. The motivation to vary trade policies over time is almost completely eliminated if the government is able to use capital control taxes.

Given the above result, an interesting question that could be addressed in future research is whether capital control could serve a useful purpose as a *flexibility* mechanism in trade agreements. Flexibility may be a desired feature for trade agreements for at least two reasons. First, if political economy preferences are subject to shocks in the future (as in Beshkar 2010, Maggi and Staiger 2011, and Beshkar and Bond 2017, among others) governments will negotiate an agreement that includes a mechanism for policy flexibility such as the WTO Agreement on Safeguards. Second, similar to Bagwell and Staiger (1990), if trade agreements must be self-enforcing, flexibility in capital control policies could reduce the governments' incentive to renege on the agreement at times when a surge in imports or a widening trade deficit increases temptations to leave an international agreement.

Although the magnitude of changes in optimal tariffs are significant, our quantitative analysis suggest that the gains from this variation is small. In particular, a constant tariff can achieve almost all of the gains from switching to optimal policy. This finding also implies that under our framework, the negative externality of optimal capital control taxes on the rest of the world is very small.

Our quantitative analysis should be taken with a grain of salt as it hinges on various simplifying assumptions that prevent us from replicating various patterns in the data. For example, our model cannot generate the high degree of persistence in trade deficits that is observed in the data. Enriching the model by allowing for the possibility of habit formation (see Alessandria et al. 2013 among others), or physical capital formation could improve this analysis by generating persistence in trade deficits.

Supplementary material

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jmoneco.2019.11.001.

References

Alessandria, G., Choi, H., Lu, D., 2017. Trade integration and the trade balance in china. IMF Econ. Rev. 65 (3), 633–674.
Alessandria, G., Kaboski, J., Midrigan, V., 2013. Trade wedges, inventories, and international business cycles. J. Monet. Econ. 60 (1), 1–20.
Alessandria, G. A., Choi, H., 2019. The dynamics of the us trade balance and real exchange rate: the j curve and trade costs?.
Alessandria, G. A., Khan, S. Y., Khederlarian, A., 2019. Taking Stock of Trade Policy Uncertainty: Evidence from China's Pre-WTO Accession.
Bagwell, K., Staiger, R., 1990. A theory of managed trade. Am. Econ. Rev. 80 (4), 779–795.
Bagwell, K., Staiger, R.W., 2003. Protection and the business cycle. Adv. Econ. Anal. Policy 3 (1).
Beshkar, M., 2010. Trade skirmishes and safeguards: A Theory of the WTO dispute settlement process. J. Int. Econ. 82 (1), 35–48.
Beshkar, M., Bond, E., 2017. Cap and escape in trade agreements. Am. Econ. J.-Microecon..
Beshkar, M., Lashkaripour, A., 2019. Interdependence of Trade Policies in General Equilibrium. Working Paper.
Bond, E.W., 1990. The optimal tariff structure in higher dimensions. Int. Econ. Rev. 103–116.
Bown, C.P., Crowley, M.A., 2013. Self-enforcing trade agreements: evidence from time-varying trade policy. Am. Econ. Rev. 103 (2), 1071–1090.
Brunnermeier, M.K., Sannikov, Y., 2015. International credit flows and pecuniary externalities. Am. Econ. J. 7 (1), 297–338.
Costinot, A., Donaldson, D., Vogel, J., Werning, I., 2015. Comparative advantage and optimal trade policy. Q. J. Econ. 130 (2), 659–702.
Costinot, A., Lorenzoni, G., Werning, I., 2014. A theory of capital controls as dynamic terms-of-Trade manipulation. J. Pol. Econ..
Costinot, A., Rodríguez-Clare, A., 2014. Trade theory with numbers: Quantifying the consequences of globalization. In: Handbook of international economics, 4. Elsevier, pp. 197–261.
Davis, J.S., Presno, I., 2017. Capital controls and monetary policy autonomy in a small open economy. J. Monet. Econ. 85, 114–130. doi:10.1016/j.jmoneco.2016.11.008.
Dekle, R., Eaton, J., Kortum, S., 2007. Unbalanced trade. Am. Econ. Rev. 97 (2), 351–355.
Gros, D., 1987. A note on the optimal tariff, retaliation and the welfare loss from tariff wars in a framework with intra-industry trade. J. Int. Econ. 23 (3), 357–367.
Heathcote, J., Perri, F., 2016. On the desirability of capital controls. IMF Econ. Rev. 64 (1), 75–102. doi:10.1057/imfer.2016.7.
Jordà, Ò., Knoll, K., Kuvshinov, D., Schularick, M., Taylor, A.M., 2019. The rate of return on everything, 1870–2015. Q. J. Econ. 134 (3), 1225–1298.
Lake, J., Linask, M.K., 2016. Could tariffs be pro-cyclical? J. Int. Econ. 103, 124–146.
Levchenko, A., Lewis, L., Tesar, L., 2010. The collapse of international trade during the 2008–09 crisis: in search of the smoking gun. IMF Econ. Rev. 58 (2), 214–253.
Lucas, R.E., Stokey, N.L., 1983. Optimal fiscal and monetary policy in an economy without capital. J. Monet. Econ. 12 (1), 55–93.
Maggi, G., Staiger, R., 2011. The role of dispute settlement procedures in international trade agreements. Q. J. Econ. 126 (1), 475–515.
McLaren, J., 1997. Size, sunk costs, and judge Bowker's objection to free trade. Am. Econ. Rev. 87 (3), 400–420.
Ossa, R., 2014. Trade wars and trade talks with data. Am. Econ. Rev. 104 (12), 4104–4146.
Ossa, R., 2016. Quantitative models of commercial policy. In: Handbook of Commercial Policy, 1. Elsevier, pp. 207–259.
Reyes-Heroles, R., 2016. The Role of Trade Costs in the Surge of Trade Imbalances. Working Paper.
Schmitt-Grohé, S., Uribe, M., 2017. Is optimal capital control policy countercyclical in open economy models with collateral constraints? IMF Econ. Rev. 65 (3), 498–527.
Staiger, R.W., Sykes, A.O., 2010. Currency manipulation and world trade. World Trade Rev. 9 (4), 583–627.