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Tariffs and "Unconventional" Monetary Policy: The Return of the ZLB*

Eiji Okano† Nagoya City University
Yang Zhou Nagoya City University

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Abstract

This paper studies the optimal monetary-policy response to import tariffs when tariff revenues interact with the government budget constraint. We develop a New Keynesian open-economy model with Calvo price setting, nominal government debt, distortionary labor income taxation, and a Bohn-type fiscal rule. In this environment, an import tariff is not only a relative-price shock but also a fiscal shock. Given the fiscal rule for the primary balance, the labor income tax adjusts residually to satisfy the government budget constraint; hence tariff revenues mechanically reduce the tax rate required to implement the rule. The induced tax cut raises the natural level of output and lowers real marginal cost. With sticky prices, this fiscal-tax channel lowers the output gap and domestic producer-price inflation, so that the constrained-efficient response to a tariff shock is monetary easing rather than tightening. The small open economy model isolates this mechanism and shows that the ZLB binds when tariff shocks are sufficiently persistent or price stickiness is sufficiently low. The two-country model provides the main quantitative result. Under benchmark tariff persistence and benchmark price stickiness, the incidence of the ZLB depends systematically on tariff size and country size. A 5 percent tariff shock does not generally bring back the ZLB, but it can do so domestically when the tariff-imposing country is sufficiently small and open; under reciprocal tariffs, the same 5 percent shock can also bind the Home ZLB when country-size asymmetry is sufficiently pronounced. The spillover to the Foreign nominal interest rate is sizable only when the tariff-imposing country is large enough. Motivated by the Trump administration's move toward reciprocal tariffs, we also study simultaneous tariff increases in both countries. Reciprocal tariffs can make the ZLB bind globally when both countries are sufficiently exposed to each other, but with strong country-size asymmetry the ZLB force is concentrated in the smaller and more open economy. Tariffs can therefore call for an unconventional monetary-policy response through a fiscal-tax channel that is absent from lump-sum tax models.

Keywords: Tariffs, Government Budget Constraint, Optimal Monetary Policy, Zero Lower Bound

JEL Classification: E31, E32, E52, E62, F13, F41

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†Corresponding author. Graduate School of Economics, Nagoya City University, 1, Aza, Yamanobata, Mizuho-cho, Mizuho-ku, Nagoya-shi Aichi, 467-8501, Japan. Tel.: +81-52-872-5721; Fax: +81-52-872-1531; E-mail: eiji_okano@econ.nagoya-cu.ac.jp

1 Introduction

Tariffs have re-entered macroeconomic policy debates not only as instruments of trade policy but also as shocks with direct implications for inflation, real activity, government revenue, and monetary policy. The conventional view is straightforward. Because an import tariff raises the domestic-currency price of imported goods, it generates immediate upward pressure on CPI inflation. If monetary policy is framed in terms of CPI stabilization, a tariff shock therefore appears to call for monetary tightening. This paper argues that this conclusion is incomplete once tariff revenues are embedded in the government budget constraint.

We study the optimal monetary-policy response to import tariffs in New Keynesian open-economy models with Calvo price setting, nominal government debt, and distortionary labor income taxation. The framework follows Gali and Monacelli [33] and Monacelli [40], but replaces the lump-sum tax environment with a government that issues nominal debt and levies a tax on labor income. Fiscal policy follows a Bohn-type rule, under which higher public debt must be backed by higher current and future primary surpluses. In this environment, an import tariff is not merely a relative-price shock. It is also a fiscal shock. The primary-balance rule pins down the required surplus, while the labor income tax is the residual instrument that satisfies the government budget constraint once tariff revenues are realized. Tariff revenues therefore mechanically reduce the labor income tax needed to implement the rule. The fiscal closure is also consistent with the recent U.S. policy background. The Trump administration paired the introduction of reciprocal tariffs with a major tax-cut package, the One Big Beautiful Bill, which the White House [52] presented as delivering large tax cuts and higher take-home pay for working households. This policy background motivates the paper's focus on an interaction between tariff revenues and distortionary tax adjustment. The analysis, however, does not require a literal one-for-one earmarking of tariff revenues to a particular tax bill. In the model, tariff revenues enter the consolidated government budget constraint, and, given the Bohn-type primary-balance rule, the labor income tax rate adjusts residually.

This fiscal channel changes both the sign and the magnitude of the optimal monetary-policy response. An increase in import tariffs raises tariff revenues. For a given primary-balance target implied by the Bohn-type rule, the residual labor-income-tax rate falls. The resulting tax cut raises the natural level of output and lowers firms' real marginal costs. With sticky prices, actual output cannot immediately track the higher natural level of output. The output gap falls, and domestic producer-price inflation comes under downward pressure. Consequently, the constrained-efficient response to an import tariff is not necessarily monetary tightening. In the baseline model, the optimal response is monetary easing.

This result contrasts with the implication of a lump-sum tax model. In the benchmark environment of Monacelli [40], an import tariff operates mainly through relative prices and expenditure switching. The optimal nominal interest-rate response is therefore much weaker and may even be positive. Once the government budget constraint and endogenous labor income taxation are introduced, however, the tariff-induced tax cut becomes a central transmission mechanism. The same tariff shock then generates a lower output gap, lower PPI inflation, and a lower optimal nominal interest rate.

The analysis also revisits the tightening bias of CPI inflation targeting. Monacelli [40] shows that stabilizing CPI inflation after a tariff shock can induce excessive monetary tightening, because the central bank must engineer a fall in domestic producer prices to offset the direct increase in import prices. We show that this bias is amplified when tariff revenues affect distortionary taxation. In the baseline model, CPI inflation targeting calls for monetary tightening precisely when the constrained-efficient policy calls for monetary easing. The wedge between CPI inflation targeting and optimal policy is therefore larger than in the lump-sum tax model.

The main result of the paper is that import tariffs can, when sufficiently persistent, sufficiently large, or internationally amplified, bring back the zero lower bound (ZLB). The small open economy model isolates the fiscal-tax mechanism: tariff-induced tax cuts raise the natural level of output, intensify downward pressure on PPI inflation, and require stronger monetary-policy accommodation. In that environment, the optimal nominal interest rate reaches the ZLB when tariff shocks are more persistent or when price stickiness is lower. The two-country model shows that this conclusion is stronger once international general-equilibrium feedback is taken into account. Under the benchmark tariff persistence and benchmark price stickiness, the ZLB can bind in the tariff-imposing country without imposing extreme parameter values, but the incidence of the constraint depends on tariff size, country size, and whether the tariff increase is unilateral or reciprocal.

A central implication of the two-country analysis is that the return of the ZLB depends systematically on tariff size and country size. When country H imposes an import tariff, its nominal interest rate can hit the ZLB for tariff shocks of 20 percent and 15 percent, and the domestic lower-bound force remains present for smaller shocks when country H is sufficiently small and open. In particular, a 5 percent unilateral tariff shock binds the Home ZLB only when $\upsilon = 0.99$, whereas a 5 percent reciprocal tariff shock binds the Home ZLB when $\upsilon = 0.73$ or $\upsilon = 0.99$. A smaller tariff-imposing country is more exposed to imported goods and therefore experiences a larger domestic effect through the relative-price and fiscal-tax channels. By contrast, the spillover to country F depends on the global size of country H. The Foreign nominal interest rate falls substantially when the tariff-imposing country is large, but it is essentially unaffected when the tariff-imposing country is very small. Thus, tariffs can generate a domestic ZLB episode even for a small open economy, whereas a global ZLB episode requires a sufficiently large tariff-imposing country.

We also examine reciprocal tariffs. This extension is motivated by the Trump administration's move to introduce reciprocal tariffs, which makes simultaneous tariff increases by trading partners a relevant policy experiment rather than a purely unilateral exercise. In the model, reciprocal tariffs activate the fiscal-tax channel in both countries, because each government receives tariff revenues and its residual labor-income-tax rate adjusts under the fiscal rule. The results show that reciprocal tariffs can generate a global ZLB episode when the two countries are of comparable size. With strong country-size asymmetry, however, the smaller and more open country experiences a much larger domestic ZLB force, while the effect on the rest of the world is limited.

This distinction between the domestic and global margins is important for interpreting the policy result. The paper does not claim that any tariff shock necessarily generates either a domestic or a worldwide liquidity trap. Instead, it shows that tariff shocks can create a ZLB-constrained commitment policy in the tariff-imposing country when the tariff shock is sufficiently large, the country is sufficiently open, or the shock is reinforced by reciprocal tariff escalation. Whether the constraint is transmitted abroad depends on country size and international spillovers. The return of the ZLB is therefore not a knife-edge implication of a single 20 percent tariff experiment; it is governed by the joint interaction among tariff size, openness, country size, and the fiscal treatment of tariff revenues.

The paper contributes to three strands of the literature. First, it contributes to the literature on tariffs and monetary policy by showing that the optimal response to tariffs depends critically on the fiscal treatment of tariff revenues. Second, it contributes to the literature on optimal monetary policy in open economies by showing that the government budget constraint can reverse the sign of the optimal interest-rate response to a tariff shock. Third, it contributes to the literature on the ZLB and unconventional monetary policy by identifying import tariffs as a source of renewed ZLB pressure through their effect on distortionary taxation and the natural level of output. The country-size experiments further show when this ZLB pressure remains domestic and when it becomes global.

The rest of the paper is organized as follows. Section 2 discusses the related literature. Section 3 presents the small open economy model with government debt, labor income taxation, and a Bohn-type fiscal rule. Section 4 characterizes the constrained-efficient allocation and studies the implications of import tariff shocks under Ramsey optimal policy, CPI inflation targeting, high tariff persistence, and lower price stickiness. Section 5 extends the analysis to a two-country economy and studies how unilateral and reciprocal tariffs interact with tariff size and country size to determine the incidence of the ZLB. Section 6 concludes.

2 Related literature

This paper is related to several strands of the literature. The first is the recent literature on tariffs and monetary policy. Bergin and Corsetti [19] show that the optimal monetary-policy response to tariff shocks is expansionary in a New Keynesian environment with global value chains and firm dynamics. Their key insight is that tariffs differ from standard productivity or markup shocks: tariffs raise the price paid by consumers on top of sticky producer prices, depress the demand faced by firms, and can generate PPI disinflation even as headline CPI inflation rises. Monacelli [40] studies tariff shocks in a small open economy New Keynesian model and shows that CPI inflation targeting generates a tightening bias. Since an import tariff raises the import-price component of CPI inflation, stabilizing CPI inflation requires a fall in domestic producer-price inflation, which calls for monetary tightening and a contraction in economic activity. Bianchi and Coulibaly [20] also challenge the conventional view that tariffs necessarily call for monetary tightening, showing that the optimal response can be expansionary when monetary easing mitigates the inefficient contraction in imports and aggregate activity. Hamano et al. [35] study foreign tariff shocks in a model with heterogeneous exporters and wage rigidity, and show that optimal monetary policy is expansionary because it facilitates the reallocation of labor between exporters and domestic firms.

Our mechanism is complementary to, but distinct from, Bianchi and Coulibaly [20]. In their model, tariff revenues create a fiscal externality because private import decisions are based on tariff-inclusive prices, whereas the social resource cost of imports excludes the tariff wedge. The Ramsey planner therefore uses expansionary monetary policy to mitigate the inefficient contraction in imports and aggregate activity. In our model, by contrast, tariff revenues operate through the consolidated government budget constraint. The Bohn-type primary-balance rule pins down the required surplus, and the labor income tax adjusts residually to satisfy the government budget constraint. The tariff-induced tax cut changes the natural level of output and real marginal cost, thereby generating downward pressure on PPI inflation and, in sufficiently large or internationally amplified cases, a binding ZLB. Thus, while both papers show that tariffs need not call for monetary tightening, the transmission mechanism and the source of the ZLB result are different.

A fast-growing literature has also studied the macroeconomic consequences of recent U.S. tariff episodes. Werning, Lorenzoni and Guerrieri [15] interpret tariffs through the lens of cost-push shocks and optimal monetary policy. Itskhoki and Mukhin [10] study optimal macro tariffs, while Bergin and Corsetti [6] analyze the monetary stabilization of sectoral tariff shocks. Kalemli-Ozcan, Soylu and Yildirim [12] emphasize global production networks, and Ostry, Lloyd and Corsetti [13] study the exchange-rate response to tariffs and retaliations. Other recent contributions analyze tariff wars and external adjustment [3], production-network propagation [4, 9], tariff-deficit linkages [7], dynamic optimal tariffs [8], and empirical or financial-market responses to recent U.S. tariff shocks [5, 11, 14]. Our paper is complementary to this literature. We focus on a distinct fiscal-tax channel: tariff revenues enter the consolidated government budget constraint, and the residual labor income tax adjusts under a Bohn-type fiscal rule. This channel changes the natural level of output and can make the ZLB bind under sufficiently large or internationally propagated tariff shocks.

Our paper shares with these studies the view that tariff shocks need not call for monetary tightening. The mechanism, however, is different. The existing tariff-and-monetary-policy literature emphasizes demand distortions, expenditure switching, production chains, dominant-currency pricing, exporter selection, labor reallocation, or the fiscal externality associated with the tariff wedge. We instead emphasize the fiscal treatment of tariff revenues within the government budget constraint. Once tariff revenues enter the government budget constraint and labor income taxes are distortionary, an import tariff is also a fiscal shock. Under a Bohn-type rule, the required primary balance is pinned down by outstanding public debt, and the labor income tax adjusts residually to satisfy the budget constraint. Tariff revenues therefore lower the tax rate required to implement the rule, raise the natural level of output, and put downward pressure on domestic producer-price inflation. Thus, the contribution of the paper is not simply to show that the optimal response to tariffs can be expansionary. It is to show that the fiscal-tax channel can make the required monetary easing strong enough for the ZLB to bind under sufficiently large or internationally propagated tariff shocks.

The second related strand is the literature on optimal monetary policy in open economies. Gali and Monacelli [33] provide a small open economy New Keynesian framework in which nominal rigidities, terms-of-trade movements, and expenditure-switching effects shape the gains from wage flexibility and monetary stabilization. Benigno and Benigno [17] analyze the implementation of international monetary cooperation through inflation targeting. Svensson [47], Buiter [24], Nakajima [41], and Fujiwara et al. [30] study open-economy liquidity traps and the role of exchange rates and international spillovers in escaping from, or amplifying, liquidity-trap episodes. Our paper contributes to this literature by showing that tariff policy interacts with fiscal policy in a way that changes the natural level of output and hence the optimal monetary-policy response. The key open-economy mechanism is not only expenditure switching through the terms of trade, but also the fiscal-tax channel generated by tariff revenues. The two-country extension further shows that international general-equilibrium feedback can strengthen this channel and make the ZLB bind even under benchmark tariff persistence.

The third strand concerns fiscal policy, government debt, and monetary-fiscal interactions. Bohn [22] provides the fiscal-rule logic according to which increases in public debt must be backed by future primary surpluses in order to stabilize debt. Gali [32] studies the macroeconomic effects of money-financed fiscal stimulus and emphasizes the role of the government budget constraint in determining the transmission of fiscal interventions. Our paper uses a Bohn-type rule to discipline fiscal policy after tariff shocks. Under this rule, tariff revenues affect the path of distortionary labor income taxes. This feature is absent in a lump-sum tax environment. As a result, the government budget constraint becomes central for the monetary-policy implications of tariffs.

The fourth related strand is the literature on the ZLB and unconventional monetary policy. Eggertsson and Woodford [29], Jung et al. [38], and Werning [51] characterize optimal monetary policy when the nominal interest rate is constrained by the ZLB. Auerbach and Obstfeld [16], Bernanke [18], Buiter [25], and Turner [50] discuss unconventional policies in liquidity-trap environments, while Wu and Xia [54] and Kaihatsu et al. [39] provide empirical measures and evidence on the macroeconomic effects of unconventional monetary policy. Billi et al. [21] study optimal monetary policy when the steady-state natural rate is permanently negative and show that the ZLB can bind most of the time under the optimal policy. Bonciani and Oh [23] study the optimal mix of forward guidance and quantitative easing at the ZLB, emphasizing the complementarity between the two instruments. Okano and Eguchi [42] study money-financed fiscal stimulus in a small open economy and emphasize how fiscal-monetary interactions shape the transmission of unconventional policy in an open-economy environment.

Our paper differs from this ZLB literature in the source of the constraint. The ZLB in our model does not arise from a permanently negative steady-state natural rate, an exogenous adverse demand shock, or a financial shock that calls for balance-sheet policy. Instead, it arises endogenously from an import tariff through the government budget constraint. Tariff revenues induce a labor income tax cut, the tax cut raises the natural level of output, and the resulting downward pressure on domestic producer-price inflation requires a large decline in the optimal nominal interest rate. When that required decline is sufficiently large, the ZLB binds and the constrained-efficient allocation requires an unconventional commitment policy. The paper therefore identifies a fiscal-tax channel through which trade policy can create a need for unconventional monetary policy even when the steady-state nominal interest rate is positive.

Finally, the paper is related to the literature on the macroeconomic effects of tariffs and exchange-rate movements. Tille [48] introduces the distinction between beggar-thy-neighbor and beggar-thyself effects of exchange-rate fluctuations, while Tille [49] provides a related journal-published analysis of how consumption substitutability shapes the international transmission of monetary shocks. Our results suggest that import tariffs can also operate as a beggar-thyself policy, although the mechanism is different. In our model, tariffs affect the economy through the government budget constraint and distortionary labor income taxation. Although tariffs are often introduced with the intention of supporting domestic production, the fiscal-tax channel can raise the natural level of output and generate deflationary pressure under sticky prices. The resulting need for monetary easing, and the possible return of the ZLB, imply that the macroeconomic costs of tariffs can be larger than in models without a government budget constraint and distortionary taxation.

3 Tariffs and Government Budget Constraint in a New Keynesian Small-open Economy Model

We develop a baseline small open economy model that closely follows Monacelli [40], itself based on Gali and Monacelli [33], and modify it by introducing a government that issues debt and levies a tax on households' labor income. Because the paper focuses on the business-cycle effects of tariff changes, government expenditure is set to zero throughout. Unlike Monacelli [40], lump-sum taxes are not available in the baseline model; the government finances its obligations through labor income taxation and debt issuance. For comparison, we also derive a lump-sum tax model. Fiscal policy follows a Bohn-type rule, according to which past increases in public debt must be systematically offset by current and future primary balances in order to stabilize debt around its steady-state level. The presentation and notation otherwise parallel Monacelli [40], except for the fiscal block.

The model has the following structure. A representative household maximizes utility subject to its budget constraint. The government issues debt and levies taxes on labor income, imports, and exports, with fiscal policy governed by a Bohn-type rule. Financial markets are complete domestically and internationally. Firms operate in monopolistically competitive goods markets; no employment subsidy is introduced to offset monopoly distortions. Price setting follows Calvo pricing. The law of one price (LOOP) holds, and demands for imports and exports are elastic with respect to the terms of trade (TOT).

3.1 Fiscal Block and the Natural Level of Output

3.1.1 Government

The flow real government budget constraint is given by:

$$\mathcal{B}_t = \mathcal{B}_{t-1}\left(1+i_{t-1}\right)\Pi_t^{-1} - SP_t, \tag{1}$$

where $\mathcal{B}_t \equiv \frac{B_t}{P_t}$ denotes real domestic government debt outstanding, B_t denotes its nominal counterpart, P_t denotes the consumer price index (CPI) and $\Pi_t \equiv \frac{P_t}{P_{t-1}}$ denotes the (gross) CPI inflation. Further:

$$SP_t = \frac{1}{P_t}\left(\tau_t W_t N_t + \tau_{M,t} P_{F,t} C_{F,t} - P_{H,t} G_t\right), \tag{2}$$

denotes the primary balance, where τ_t is tax rate for labor income, W_t is the nominal wage, N_t denotes hours worked, $\tau_{M,t}$ is an import tariff, $C_{F,t}$ is consumption of imported goods and G_t denotes the (real) government expenditure index. Note that we assume zero government expenditure at all dates, i.e., $G_t = 0$ for all t for simplicity.

The fiscal policy rule in the Home economy is given by:

$$SP_t = \phi_B \mathcal{B}_{t-1}, \tag{3}$$

which is a Bohn-type rule requiring past increases in public debt to be systematically offset by current and future primary balances so that debt is stabilized around its steady-state level. Following Gali [32], we set $\phi_B > \frac{1}{\beta} - 1$. As shown in Gali [32], the transversality condition (TVC) for the government $\lim_{k\to\infty}\prod_{h=0}^{t+k-1}\left[\left(1+i_{t+h}\right)\Pi_{t+h+1}^{-1}\right]^{-1}\mathcal{B}_{t+k} = 0$ will be satisfied.

Leading Eq.(3) one period ahead and substituting Eq.(1) gives

$$SP_{t+1} = \phi_B \mathcal{B}_{t-1}\left(1+i_{t-1}\right)\Pi_t^{-1} - \phi_B SP_t.$$

Equivalently, using Eq.(3), this can be written as $SP_{t+1} = SP_t\left(1+i_{t-1}\right)\Pi_t^{-1} - \phi_B SP_t$. This expression shows that a rise in CPI inflation reduces the real burden of outstanding government debt and, through the fiscal rule, lowers the primary balance required in the next period. In the simulations below, however, the key point is not a discretionary fiscal incentive. The primary-balance rule pins down SP_t, while the labor income tax rate is the residual fiscal instrument that satisfies Eq.(2) after tariff revenues and government purchases are taken as given. Equivalently, Eq.(2) implies

$$\tau_t = \frac{P_t SP_t + P_{H,t} G_t - \tau_{M,t} P_{F,t} C_{F,t}}{W_t N_t}. \tag{4}$$

Since we set $G_t = 0$, a higher tariff-revenue term $\tau_{M,t} P_{F,t} C_{F,t}$ mechanically lowers the labor income tax rate required to implement a given primary-balance target, other things equal. This margin is not only a modeling device. It also reflects the policy mix motivating the paper: the Trump administration's reciprocal-tariff agenda was accompanied by a tax-cut package that the White House described as raising workers' take-home pay [52]. Conversely, any decline in the primary-balance target implied by the fiscal rule is implemented through the residual labor income tax rate in Eq.(4).

An increase in the import tariff $\tau_{M,t}$ therefore enters the fiscal block twice. It directly raises tariff revenues in Eq.(2), and, through Eq.(4), it reduces the labor income tax rate needed to satisfy the Bohn-type rule in Eq.(3). This mechanical residual-tax adjustment is the fiscal-tax channel. It is central for understanding why the constrained-efficient monetary-policy response to an import tariff can involve strong monetary easing, and why unconventional monetary policy may become relevant.

3.1.2 Natural Level of Output

The natural level of output is central to the mechanism. To derive it, we first characterize real marginal cost.

Each monopolistically competitive firm j in the Home economy produces a differentiated good using the linear technology in Eq.(15). Under this technology, nominal marginal cost is $MC_t = \frac{\partial N_t(j)}{\partial Y_t(j)} W_t = \frac{W_t}{A_t}$, where A_t is a common labor productivity shifter. The real marginal cost $MC_t^r \equiv \frac{MC_t}{P_{H,t}}$ is then given by:

$$MC_t^r = -\frac{U_{n,t}}{U_{c,t}} \frac{\mathcal{G}\left(S_t, \tau_{M,t}\right)}{A_t\left(1-\tau_t\right)}, \tag{5}$$

where $\mathcal{G}\left(S_t, \tau_{M,t}\right) \equiv \frac{P_t}{P_{H,t}}$ is the CPI-PPI ratio, and $U_{n,t}$ and $U_{c,t}$ denote the marginal utilities of labor and consumption, respectively. We use an intratemporal optimality condition for households to derive Eq.(5) (see Eq.(11)). Similar to Monacelli [40], we assume $A_t = 1$ for simplicity. In the flexible price equilibrium, the real marginal cost is identical with the inverse of the constant markup over time, i.e., $MC_t^r = \mathcal{M}^{-1}$ or $mc_t^r = 0$ with $mc_t^r \equiv \log\left(\frac{MC_t^r}{MC^r}\right)$ where $\mathcal{M} \equiv \frac{\varepsilon}{\varepsilon-1}$ is the constant markup, $\varepsilon > 1$ denotes the elasticity of substitution among goods and MC^r denotes the steady-state value of the real marginal cost. Exploiting this fact, log-linearizing the previous expression, and combining it with log-linearized Eq.(20) yields:

$$y_t^n = \left(\frac{1}{\Omega_s} + \varphi\right)^{-1} \left[\left(1+\varphi\right) a_t + \frac{\Omega_{\tau_M}}{\Omega_s}\tau_{M,t} - \frac{\gamma\eta}{\Omega_s}\tau_{X,t} - \frac{\tau}{1-\tau}\hat{\tau}_t^n + \frac{1-\upsilon}{\Omega_s}\hat{g}_t\right], \tag{6}$$

with $\Omega_s \equiv \left(1-\upsilon\right)^2 + \upsilon\eta\left(2-\upsilon\right)$, $\Omega_{\tau_M} \equiv \upsilon\left(\eta-1\right)\left(1-\upsilon\right)$, $y_t^n \equiv \log\left(\frac{Y_t^n}{Y}\right)$ and $\hat{\tau}_t^n \equiv \log\left(\frac{\tau_t^n}{\tau}\right)$ where φ denotes curvature of labor disutility, $\upsilon \in [0,1]$ is the share of imported goods in domestic consumption, $\eta > 0$ is the elasticity of substitution between domestic and imported goods, Y_t^n denotes the natural level of output, Y denotes the steady-state output, τ_t^n denotes the labor income tax rate in the flexible price equilibrium, τ denotes the steady-state labor income tax rate, $a_t \equiv \log A_t$ and $\hat{g}_t \equiv \frac{G_t}{Y}$. We define $\varsigma_t \equiv \log\left(\frac{\tau_t}{\tau_t^n}\right)$ and $x_t \equiv \log\left(\frac{Y_t}{Y_t^n}\right)$ as the labor income tax gap and the output gap, respectively. While the natural level of output depends only on export and import tariffs in Monacelli [40], in our baseline model it also depends on the labor income tax. Eq.(6) shows that a labor income tax cut raises the natural level of output.

A labor income tax cut reduces real marginal cost by lowering labor costs and raises the natural level of output. In the flexible-price equilibrium, actual output and natural output coincide. With nominal rigidity, however, actual output need not adjust immediately to the higher natural level. Accommodating this increase in natural output requires an expansion of demand, which is induced by a decline in the nominal interest rate. Suppose, for example, that the central bank implements domestic inflation targeting, $\pi_{H,t} = 0$. A positive productivity shock raises natural output and puts downward pressure on domestic inflation; the central bank then lowers the nominal interest rate to support demand and stabilize domestic inflation. In the absence of monopolistic distortions, zero domestic inflation coincides with a zero output gap, as in Woodford [53] and Gali [31]. Eq.(6) shows that the tax-gap term enters with the opposite sign from productivity. Thus, a labor income tax cut calls for a lower nominal interest rate in order to stabilize domestic inflation and the output gap.

As long as the nominal interest rate can be freely adjusted, the central bank can in principle stabilize domestic inflation and the output gap, abstracting from monopoly distortions. Once the nominal interest rate reaches the zero lower bound (ZLB), however, this adjustment is constrained. As discussed above, an import tariff reduces the residual labor income tax rate required to implement the fiscal rule. This tax cut raises the natural level of output. Since the tariff shock itself and the induced tax cut both raise natural output, the required decline in the nominal interest rate is larger than in the lump-sum tax model of Monacelli [40]. If the ZLB prevents the nominal interest rate from falling sufficiently, the central bank can no longer stabilize both domestic inflation and the output gap. In this sense, a sufficiently large tariff shock can bring back the ZLB and make unconventional monetary policy necessary.

3.2 Households and Price Setting

Household behavior and price setting are otherwise close to those in Monacelli [40], except that labor income is taxed whereas Monacelli [40] assumes lump-sum taxes.

3.2.1 Domestic Households

Consumption index is given by:

$$C_t \equiv \left[(1-\upsilon)^{\frac{1}{\eta}} C_{H,t}^{1-\frac{1}{\eta}} + \upsilon^{\frac{1}{\eta}} C_{F,t}^{1-\frac{1}{\eta}}\right]^{\frac{\eta}{\eta-1}},$$

where $C_{H,t} \equiv \left(\int_0^1 C_{H,t}(j)^{\frac{\varepsilon-1}{\varepsilon}} dj\right)^{\frac{\varepsilon}{\varepsilon-1}}$ and $j \in [0,1]$ denotes a good variety.

The CPI in the Home economy is given by:

$$P_t \equiv \left[(1-\upsilon) P_{H,t}^{1-\eta} + \upsilon \tilde{P}_{F,t}^{1-\eta}\right]^{\frac{1}{1-\eta}}, \tag{7}$$

where $P_{H,t} \equiv \left(\int_0^1 P_{H,t}(j)^{1-\varepsilon} dj \right)^{\frac{1}{1-\varepsilon}}$ denotes the domestic goods price index, $\tilde{P}_{F,t} \equiv (1+\tau_{M,t}) P_{F,t}$ denotes the *cum-tariff* import price of foreign goods and $\tau_{M,t}$ denotes an import tariff. We assume the law of one price (LOOP), i.e., $P_{F,t} = P_t^* \mathcal{E}_t$ where P_t^* is the Foreign CPI in units of Foreign currency, which is identical to the Foreign domestic price in units of Foreign currency $P_{F,t}^*$ and $\mathcal{E}_t$ is the price of Foreign currency in units of Home currency, namely, the nominal exchange rate. Following Monacelli [40], we set $P_{F,t}^* = 1$ for simplicity. Therefore, Eq.(7) can be rewritten as $P_t \equiv \left\{ (1-\upsilon) P_{H,t}^{1-\eta} + \upsilon \left[(1+\tau_{M,t}) \mathcal{E}_t \right]^{1-\eta} \right\}^{\frac{1}{1-\eta}}$ where we use $\tilde{P}_{F,t} = (1+\tau_{M,t}) \mathcal{E}_t$.

3.3 Households

Households' utility is given by:

$$\sum_{t=0}^{\infty} \beta^t U(C_t, N_t), \tag{8}$$

with $U(C_t, N_t) \equiv \log C_t - \frac{1}{1+\varphi} N_t^{1+\varphi}$.

The period budget constraint for the typical household is given by:

$$\int_0^1 P_{H,t}(j) C_{H,t}(j) dj + \tilde{P}_{F,t} C_{F,t} + \mathrm{E}_t(\xi_{t,t+1} D_{t+1}) \leq D_t + W_t (1-\tau_t) N_t + P_t PR_t, \tag{9}$$

where PR_t denotes the ownership of firms. All households are identical and there is no borrowing or lending among them. Thus, all interest-bearing asset holdings by households take the form of government debt. That is, $D_t = (1+i_{t-1}) B_{H,t-1} + \left(1+i_{t-1}^*\right) \mathcal{E}_t B_{H,t-1}^*$ where D_t, $B_{H,t}$ and $B_{H,t}^*$ denote nominal payoffs held by Home households, the government debt issued by Home government and held by Home households and the government debt issued by Foreign government and held by Home households in the units of Foreign currency. $B_{H,t}$ satisfies $B_{H,t} = B_t - B_{F,t}$ where $B_{F,t}$ denotes the government debt issued by Home government and held by Foreign households.

Solving households' cost-minimization problems yields:

$$\begin{aligned} C_{H,t}(j) &= \left(\frac{P_{H,t}(j)}{P_{H,t}} \right)^{-\varepsilon} C_{H,t}, \\ C_{H,t} &= (1-\upsilon) \left(\frac{P_{H,t}}{P_t} \right)^{-\eta} \\ &= (1-\upsilon) \left(\mathcal{G}(S_t, \tau_{M,t}) \right)^{\eta}, \\ C_{F,t} &= \upsilon \left(\frac{\tilde{P}_{F,t}}{P_t} \right)^{-\eta} C_t, \\ &= \upsilon (1+\tau_{M,t}) S_t^{-\eta} \left(\mathcal{G}(S_t, \tau_{M,t}) \right)^{\eta} C_t, \end{aligned}$$

with $\mathcal{G}(S_t, \tau_{M,t}) \equiv \frac{P_t}{P_{H,t}} = \left[(1-\upsilon) + \upsilon (1+\tau_{M,t})^{1-\eta} S_t^{1-\eta} \right]^{\frac{1}{1-\eta}}$.

Plugging the previous expressions into Eq.(9) yields:

$$P_t C_t + \mathrm{E}_t(\nu_{t,t+1} D_{t+1}) \leq D_t + W_t (1-\tau_t) N_t + P_t PR_t, \tag{10}$$

Households maximize Eq.(8) subject to Eq.(10). The optimality conditions are given by:

$$U_{c,t} \frac{W_t (1-\tau_t)}{P_t} = -U_{n,t}, \tag{11}$$

$$\beta \frac{P_t C_t}{P_{t+1} C_{t+1}} = \xi_{t,t+1}, \tag{12}$$

with $U_{c,t} = C_t^{-1}$ and $-U_{n,t} = N_t^{\varphi}$. Taking conditional expectations of Eq.(12) allows us to define a gross nominal interest rate as:

$$\begin{aligned} 1 + i_t &\equiv \mathrm{E}_t \left(\xi_{t,t+1}\right)^{-1} \\ &= \left[\beta \mathrm{E}_t \left(\frac{P_t}{P_{t+1}} \frac{U_{c,t+1}}{U_{c,t}}\right)\right]^{-1}. \end{aligned} \tag{13}$$

The corresponding condition for foreign households is $1 + i_t^* = \left[\beta \mathrm{E}_t \left(\frac{P_t^*}{P_{t+1}^*} \frac{U_{c,t+1}^*}{U_{c,t}^*}\right)\right]^{-1}$, with $U_{c,t}^* = \left(C_t^*\right)^{-1}$, where C_t^* denotes Foreign consumption.

Combining Eq.(13) with its foreign counterpart, imposing the initial condition, and iterating forward gives:

$$U_{c,t}^* = U_{c,t} \mathcal{E}_t^r, \tag{14}$$

where $\mathcal{E}_t^r \equiv \frac{\mathcal{E}_t P_t^*}{P_t} = \frac{S_t}{\mathcal{G}(S_t, \tau_{M,t})} \equiv q\left(S_t, \tau_{M,t}\right)$ is the CPI real exchange rate.

3.3.1 Domestic Firms and Price Setting

Each firm produces a differentiated good with a technology as follows:

$$Y_t(j) = A_t N_t(j). \tag{15}$$

Each domestic firm can revise its price $\bar{P}_{H,t}$ at random intervals. Let $1 - \theta$ be the probability that a firm can reoptimize its price in any period t. The optimal reset price satisfies:

$$\tilde{p}_{H,t} = \mathcal{M} \frac{\mathcal{Z}_{p,t}}{\mathcal{K}_{p,t}}, \tag{16}$$

with:

$$\begin{aligned} \tilde{p}_{H,t} &\equiv \frac{\bar{P}_{H,t}}{P_{H,t}}, \\ \mathcal{K}_{p,t} &\equiv \mathrm{E}_0 \left[\sum_{k=0}^{\infty} \theta^k \nu_{t,t+k} N_{t+k} \left(\prod_{h=1}^{k} \Pi_{H,t+h}\right)^{\varepsilon}\right], & (17) \\ \mathcal{Z}_{p,t} &\equiv \mathrm{E}_0 \left[\sum_{k=0}^{\infty} \theta^k \nu_{t,t+k} N_{t+k} MC_{t+k}^r \left(\prod_{h=1}^{k} \Pi_{H,t+h}\right)^{1+\varepsilon}\right]. & (18) \end{aligned}$$

Price setting is completed by the following equation linking the (gross) PPI inflation to the optimal relative price:

$$1 = \theta \left(\Pi_{H,t}\right)^{\varepsilon - 1} + (1 - \theta) \tilde{p}_{H,t}^{1-\varepsilon}. \tag{19}$$

3.3.2 Market Clearing

To characterize the natural level of output, we also need the market-clearing condition for the Home economy:

$$\begin{aligned} Y_t &= C_{H,t} + EX_t + G_t, \\ &= (1 - \upsilon) \left(\mathcal{G}\left(S_t, \tau_{M,t}\right)\right)^{\eta} C_t + \gamma \left(\frac{S_t}{1 + \tau_{X,t}}\right)^{\eta} Y_t^* \end{aligned} \tag{20}$$

where $S_t \equiv \frac{P_{F,t}}{P_{H,t}}$ is the *ex-tariff* price of imported goods relative to Home produced goods, $C_{H,t}$ denotes the demand for domestic goods, EX_t denotes the aggregate export demand, which is given by:

$$EX_t = \gamma \left(\frac{\tilde{P}_{H,t}}{\mathcal{E}_t P_t^*} \right)^{-\eta} Y_t^*,$$

$\tilde{P}_{H,t} \equiv P_{H,t}(1 + \tau_{X,t})$ denotes the *cum-tariff* price of exported goods, $\tau_{X,t}$ is a tariff on export prices imposed by the Foreign economy. Y_t^* is Foreign output, which corresponds to Foreign consumption; hence $Y_t^* = 1$. Further, γ denotes the openness of the Foreign economy.

4 Constrained Efficient Policy in a Small Open Economy

Following Monacelli [40], we define constrained-efficient policy as the monetary policy that maximizes intertemporal household utility subject to the constraints characterizing the competitive equilibrium. The constrained-efficient problem consists of choosing allocations $\{C_t, N_t, S_t, \Pi_{H,t}, \mathcal{Z}_{p,t}, \mathcal{K}_{p,t}, SP_t, \tau_t\}$ to solve the following maximization problem:

$$\max_{C_t, N_t, S_t, \Pi_H, \tilde{p}_{H,t}, SP_t, \tau_t, i_t} \sum_{t=0}^{\infty} \beta^t \mathrm{E}_t \left(\log C_t - \frac{1}{1+\varphi} N_t^{1+\varphi} \right), \tag{21}$$

subject to Eqs.(1), (2), (3), (13), (14), (16), (17), (18), (19) and (20). The first-order necessary conditions (FONCs) are shown in Appendix B. Following Monacelli [40], we assume that import and export openness coincides, i.e., $\upsilon = \gamma$, set A_t to 1 for all t and regard import and export tariffs as exogenous variables. Additionally, we assume $G_t = 0$ for all t.

4.1 ZLB Constraint

The ZLB constraint can be incorporated formally in the set of equilibrium conditions with the complementarity slackness condition:

$$i_t \left\{ \mathrm{E}_t \left[\frac{1}{\beta} \frac{\mathcal{G}(S_{t+1}, \tau_{M,t+1})}{\mathcal{G}(S_t, \tau_{M,t})} \frac{U_{c,t}}{U_{c,t+1}} \Pi_{H,t+1} \right] - (1 + i_t) \right\} = 0, \tag{22}$$

for all t. As long as the notional nominal interest rate is positive, i.e., $i_{not,t} > 0$, $i_t = i_{not,t}$ where $i_{not,t} \equiv \mathrm{E}_t \left[\frac{1}{\beta} \frac{\mathcal{G}(S_{t+1}, \tau_{M,t+1})}{\mathcal{G}(S_t, \tau_{M,t})} \frac{U_{c,t}}{U_{c,t+1}} \Pi_{H,t+1} \right] - 1$ denotes the notional nominal interest rate. Once the notional nominal interest rate is constrained by the ZLB, i.e., $i_{not,t} \leq 0$, $i_t = 0$.

4.2 FONCs

The FONCs for the social planner are shown in Appendix B. They clarify the objective of Ramsey optimal policy. They should not be read as separate targeting rules for individual variables. Rather, each condition equates the marginal welfare effect of changing a control variable with the shadow values of the implementability constraints affected by that variable. The conditions with respect to C_t and N_t characterize the real allocation; the condition with respect to S_t characterizes the optimal adjustment of relative prices in the open economy; the conditions with respect to SP_t and τ_t describe fiscal implementation; and the conditions with respect to $\Pi_{H,t}$ and i_t characterize the inflation objective and the nominal-interest-rate constraint.

The FONC with respect to $\Pi_{H,t}$ is particularly informative because it most directly characterizes the inflation objective of Ramsey policy. Bianchi and Coulibaly [20] provide a useful benchmark for interpreting this condition. In their baseline model, a standard production subsidy eliminates the monopolistic-markup distortion. Under that assumption, the absence of import tariffs implies that the Ramsey allocation coincides with the efficient allocation and is implemented by a look-through policy, or equivalently by PPI inflation stabilization.

This benchmark does not apply literally to the present model. Since fiscal policy is explicit in our model, the monopolistic-competition markup remains. Hence, even when import tariffs are absent, $\tau_{M,t} = 0$, setting $\Pi_{H,t} = 1$ is not generally Ramsey optimal. Positive import tariffs provide an additional reason for departing from strict PPI inflation stabilization, but they are not the only reason. The $\Pi_{H,t}$ FONC captures this point: the planner does not mechanically set domestic inflation to zero, but trades off the marginal cost of price dispersion under Calvo pricing against the marginal benefits of using domestic inflation to address the remaining markup distortion, fiscal distortions, import-tariff distortions, and, when relevant, the nominal-interest-rate constraint. Hence, the optimal domestic inflation rate is generally state-contingent and, under commitment, history-dependent.

The tariff-related departure from strict PPI stabilization operates in the present model through the fiscal-tax channel. An import tariff is not only a relative-price shock; it also raises tariff revenue, improves the primary balance, and reduces the labor income tax required by the fiscal rule. The induced tax cut raises the natural level of output and lowers real marginal cost. Consequently, the Ramsey planner does not choose $\Pi_{H,t}$ by mechanically offsetting the direct CPI effect of the tariff. It chooses domestic inflation jointly with the nominal interest rate after internalizing the price-dispersion cost, the remaining markup distortion, the fiscal-tax channel, the Euler equation, and the ZLB constraint.

The condition for i_t is the Kuhn–Tucker condition for the ZLB. If the notional nominal interest rate is positive, the ZLB multiplier is zero and the nominal interest rate implements the desired intertemporal allocation. If the notional nominal interest rate is non-positive, the nominal interest rate is constrained at zero and $\lambda_{i,t}$ measures the shadow cost of the ZLB. The lagged multiplier terms in the $\Pi_{H,t}$ condition reinforce the role of commitment: current policy must take into account the shadow values of constraints that were relevant for earlier price-setting and intertemporal-allocation decisions.

Overall, the FONCs imply that Ramsey policy jointly manages four margins: the real allocation (C_t, N_t), the open-economy relative price S_t, nominal rigidity and the ZLB $(\Pi_{H,t}, i_t)$, and fiscal implementation (SP_t, τ_t). This is why the constrained-efficient response can differ sharply from CPI inflation targeting. CPI inflation targeting treats the tariff shock mainly as a CPI-inflation shock. Ramsey policy instead internalizes the fiscal-tax channel and the history-dependent shadow costs of price setting and the ZLB.

4.3 Calibration

We calibrate the model in line with Monacelli [40]. We set β, ε, θ, υ, and η to 0.99, 3.8, 0.8, 0.3, and 1.5, respectively. This parameterization implies an annual steady-state interest rate of approximately 4 percent, a steady-state markup of 35 percent, an average price duration of five quarters, and a steady-state import share of 30 percent. We assume zero domestic inflation in steady state and set import and export tariffs to zero in steady state. Although Monacelli [40] does not specify the value of φ, we set it to 2.2, following Gali and Monacelli [33]. Tariff shocks follow AR(1) processes. Following Monacelli [40], we set the benchmark persistence of the import-tariff shock to 0.7. We then consider a high-persistence case in which the import-tariff persistence is raised to 0.8.

We set the fiscal-response parameter to $\phi_B = 0.02$, following Gali [32]. The benchmark value $\phi_B = 0.02$ lies near the lower end of the empirical estimates reported in the fiscal-reaction-function literature, while still satisfying the stability condition $\phi_B > 1/\beta - 1$. Bohn [22] estimates that the U.S. primary surplus-to-GDP ratio responds to the debt-to-GDP ratio with coefficients between 0.028 and 0.054 across samples; the estimates are 0.054 for 1916–1995 and 0.037 for 1948–1995. Abiad and Ostry [1] estimate coefficients between 0.04 and 0.09 for emerging market economies, with weaker responses at high debt levels captured by a negative spline above 50 percent of GDP. Ghosh et al. [34] estimate a nonlinear fiscal reaction function for advanced economies and report marginal responses of the primary balance to lagged debt of about 0.02–0.06 at moderate debt levels, while the response weakens at high debt levels. Checherita-Westphal and Zdarek [27] estimate euro-area fiscal reaction functions and find that the primary balance improves by about 0.03–0.05 for a one-percentage-point increase in the debt-to-GDP ratio. These empirical estimates should not be interpreted as direct estimates of the residual labor-income-tax adjustment in our model; they discipline only the surplus-debt feedback embedded in the Bohn-type rule.

We also compare the benchmark price-stickiness case, $\theta = 0.8$, with a low-stickiness case, $\theta = 0.7$.

4.4 Dynamics under Benchmark Persistence

4.4.1 Comparison with the Lump-sum Tax Model

We compare the dynamics of the baseline model with those of the lump-sum tax model, which corresponds to the environment in Monacelli [40]. Fig. 1 reports impulse responses of selected variables to a 20% increase in import tariffs. The figure omits the disaggregated consumption responses and focuses on the aggregate variables and policy margins that are central to the fiscal-tax channel. In Fig. 1, magenta solid lines and red solid lines show responses in the baseline and lump-sum tax models, respectively. In the lump-sum tax model, output and the output gap rise, while net exports improve (Panels 4, 7, and 12, Fig. 1). The nominal interest rate therefore rises to stabilize PPI inflation (Panels 1 and 2, Fig. 1).

In the baseline model, a 20 percent increase in import tariffs improves the primary balance (Panel 9, Fig. 1) and leads the government to reduce the labor income tax (Panel 8, Fig. 1). This tax cut raises the natural level of output. As a result, the output gap turns negative, whereas it is slightly positive in the lump-sum tax model (Panel 7, Fig. 1). The negative output gap puts downward pressure on PPI inflation. The labor income tax cut also lowers labor costs and thereby reinforces the decline in PPI inflation. Consequently, PPI inflation falls markedly, and the nominal interest rate declines to support inflation (Panels 1 and 2, Fig. 1). Although an import tariff is intended to support domestic output by discouraging imports, output falls substantially in the baseline model (Panel 4, Fig. 1). In this sense, an import tariff can be interpreted as a form of beggar-thyself policy, in the sense of Tille [48]; see also Tille [49] for a related open-economy transmission mechanism.

The pairing of a tariff increase and a tax cut in the IRFs should be interpreted as the fiscal implication of the government budget constraint, not as a literal earmarking of tariff revenues to a particular tax instrument. This implication is consistent with recent U.S. policy experience. In 2025, large tariff increases were followed in short order by the One Big Beautiful Bill Act. The Internal Revenue Service describes the Act as significantly changing federal taxes, credits, and deductions [37]. At the same time, CBO [28] estimated that tariff increases implemented during January–August 2025 would reduce primary deficits by $3.3 trillion over 2025–2035 if the higher tariffs persisted. Reuters reports that S&P treated tariff revenues as a fiscal offset, expecting tariff revenue to offset the fiscal impact of the tax-cut and spending bill [46]. Our model abstracts from the political process and from the detailed composition of the U.S. tax package, but the recent U.S. episode illustrates that tariff increases and tax reductions can be fiscally linked in practice.

It is important to interpret the labor-income-tax response as a change in a tax rate, not as a quarterly flow rate to be annualized. For example, a response of -0.06 means that the labor income tax rate is 6 percentage points below its steady-state value. If the steady-state labor income tax rate were 20 percent, such a response would correspond to a decline to 14 percent, not to an annualized 24 percent tax cut.

The comparison highlights the role of the implementation margins. Once tariff revenues affect distortionary labor income taxation, the Ramsey planner implements the desired allocation through a different combination of the nominal interest rate, the nominal exchange rate, the primary balance, and the labor income tax. The fiscal treatment of tariff revenues therefore changes the policy path required to support the economy after the tariff shock.

4.4.2 Tightening Bias under CPI Inflation Targeting

Monetary policy is often formulated in terms of stabilizing a CPI measure of inflation. As Monacelli [40] emphasizes, however, CPI inflation targeting can generate a tightening bias after an import tariff shock. A tariff raises the import-price component of CPI inflation. To offset this direct effect and keep CPI inflation constant, monetary policy must engineer a decline in PPI inflation. Because producer prices are sticky, achieving such deflation requires a contraction in economic activity. It is therefore useful to compare CPI inflation targeting with the constrained-efficient policy.

Fig. 2 compares impulse responses to a 20% increase in import tariffs under Ramsey optimal policy and CPI inflation targeting. Magenta solid lines, magenta dashed lines, and blue dashed lines show responses under Ramsey optimal policy in the baseline model, under CPI inflation targeting in the baseline model, and under CPI inflation targeting in the lump-sum tax model, respectively. Regardless of the model, CPI inflation targeting induces monetary tightening, in sharp contrast to Ramsey optimal policy in the baseline model (Panel 1, Fig. 2). Since the nominal interest rate rises under Ramsey optimal policy in the lump-sum tax model, the tightening bias is more severe in the baseline model. Under CPI inflation targeting, PPI inflation must fall to offset the direct upward pressure on CPI inflation generated by higher import tariffs (Panel 2, Fig. 2). Achieving this fall in PPI inflation requires a contraction in aggregate demand. Output, the output gap, and aggregate consumption are therefore lower under CPI inflation targeting than under Ramsey optimal policy (Panels 4, 7, and 11, Fig. 2). The monetary tightening also generates a stronger appreciation of the *ex-tariff* relative price of imports through an appreciation of the nominal exchange rate (Panels 5 and 6, Fig. 2). The existence of the tightening bias is not new; our contribution is to show that it becomes substantially stronger when tariff revenues induce a labor income tax cut.

4.5 Dynamics under High Persistence

We next examine how the persistence of tariff shocks affects dynamics under Ramsey optimal policy. Fig. 3 reports impulse responses to a 20 percent increase in import tariffs in the high-persistence case, where the AR(1) coefficient is set to 0.8 rather than 0.7. In Fig. 3, magenta solid lines, red solid lines, and green solid lines show responses in the baseline model under the benchmark parameterization, in the baseline model under high persistence, and in the lump-sum tax model under the benchmark parameterization, respectively.

In the lump-sum tax model, the responses to a 20 percent increase in import tariffs are close to those under the benchmark persistence of 0.7, with no major qualitative differences. In the baseline model, however, the nominal interest rate binds at the ZLB under high persistence (Panel 1, Fig. 3). Higher persistence makes the tariff increase more durable, which in turn prolongs the labor income tax cut (Panel 8, Fig. 3). The persistent tax cut raises the natural level of output for longer, so the negative output gap is also more persistent (Panel 7, Fig. 3). This persistent negative output gap, together with the direct effect of lower labor costs on marginal costs, generates a pronounced decline in PPI inflation (Panel 2, Fig. 3). Because the allocation is computed under commitment, the ZLB-constrained policy path is history-dependent and has a forward-guidance-like component. We do not model central-bank communication explicitly; the robust implication is that the tariff shock calls for an unconventional monetary-policy response. Under high persistence, a 20 percent tariff increase therefore produces a ZLB-constrained commitment policy.

Throughout the paper we set the subjective discount factor β to 0.99. Many studies of the ZLB instead set $\beta = 0.995$. While $\beta = 0.995$ implies an annual steady-state interest rate of about 2 percent, $\beta = 0.99$ implies a rate of about 4 percent. Thus, even when the steady-state nominal interest rate is relatively far from zero, a large tariff shock can require unconventional monetary policy.

The appreciation of the *ex-tariff* relative price of imports is weaker under Ramsey optimal policy because the ZLB prevents the nominal interest rate from falling below zero (Panel 5, Fig. 3). The ZLB therefore partly supports output, or prevents a further decline in the output gap, through the expenditure-switching channel.

4.6 Dynamics under Low Stickiness

We finally examine how lower price stickiness affects dynamics under Ramsey optimal policy. Fig. 4 reports impulse responses to a 20 percent increase in import tariffs when price stickiness is set to 0.7 rather than 0.8. In Fig. 4, magenta solid lines, red solid lines, and green solid lines show responses in the baseline model under the benchmark parameterization, in the baseline model under low stickiness, and in the lump-sum tax model under low stickiness, respectively.

As price stickiness decreases, the PPI adjusts more closely to the optimal reset price chosen by firms. After an increase in import tariffs, downward pressure on PPI inflation is therefore stronger in the low-stickiness case, because the increase in the natural level of output depresses the output gap more sharply (Panels 2 and 7, Fig. 4). The nominal interest rate falls in response to the tariff shock and binds at the ZLB because deflationary pressure is stronger under low stickiness (Panel 1, Fig. 4). As in the high-persistence case, the tariff shock produces a ZLB-constrained commitment policy.

These results show that, once the government issues debt and levies a labor income tax, the optimal response to an increase in import tariffs is monetary easing, and the tightening bias associated with CPI inflation targeting is stronger than in Monacelli [40]. Most importantly, a ZLB-constrained commitment policy arises under Ramsey optimal policy in the high-persistence and low-stickiness cases. Monetary accommodation is therefore more difficult than in the lump-sum tax model. Introducing import tariffs is not a beggar-thy-neighbor policy, but a beggar-thyself policy.

Appendix E checks the robustness of these small open economy results to a larger fiscal-response parameter within the empirical range discussed in Sec. 4.3. Fig. 14 reports the nominal-interest-rate responses for the benchmark, high-persistency, and low-stickiness cases when $\phi_B = 0.03$, rather than the baseline value $\phi_B = 0.02$. Since $\phi_B = 0.03$ lies in the middle part of the empirical estimates from Bohn-type fiscal reaction functions, this exercise checks whether the small open economy results survive under a more empirically central value of the surplus-debt feedback parameter. The larger fiscal-feedback parameter attenuates the interest-rate response in the benchmark case, but the nominal interest rate still reaches the ZLB under high tariff persistency and under lower price stickiness. Thus, the small open economy ZLB results are not driven solely by the lower benchmark value of ϕ_B.

5 Constrained Efficient Policy in a Two-Country Economy Model

The small open economy model is useful for isolating the fiscal-tax channel, but it abstracts from international general-equilibrium feedback. This abstraction is restrictive for two reasons. First, a tariff imposed by a large economy affects foreign demand, foreign inflation, and foreign monetary policy, and those foreign responses feed back into the tariff-imposing country. Second, country size determines the incidence of the ZLB: a tariff can require unconventional monetary policy domestically even when the foreign spillover is small, while a sufficiently large tariff-imposing country can transmit the ZLB pressure abroad. The two-country model is designed to separate these domestic and global margins.

We extend the analysis to a two-country New Keynesian model based on Benigno and Benigno [17]. The world economy consists of countries H and F. The population on the segment $[0, 1-\upsilon)$ belongs to country H, while the population on the segment $[1-\upsilon, 1]$ belongs to country F. Thus, a larger value of υ corresponds to a smaller country H and a larger country F. The remaining assumptions are identical to those in the small open economy model. Appendix D provides the details.

We assume that the policy planners in the two countries do not cooperate. Each planner maximizes the utility of the representative household in its own country. The constrained-efficient problem in country H consists of choosing the allocation $\{C_t, N_t, \Pi_H, \mathcal{Z}_{p,t}, \mathcal{K}_{p,t}, SP_t, \tau_t\}$ to solve $\max_{C_t, N_t, \Pi_H, \tilde{p}_{H,t}, SP_t, \tau_t, i_t} \sum_{t=0}^{\infty} \beta^t \mathrm{E}_t \left(\log C_t - \frac{1}{1+\varphi} N_t^{1+\varphi} \right)$. The *ex-tariff* relative price is eliminated by using the international risk-sharing condition. The constrained-efficient problem in country F is defined analogously. The ZLB constraint applies in both countries. The complementarity slackness condition is given by Eq.(22) and by its counterpart in country F.

The parameterization in the two-country model is the same as in the small open economy model. We consider three values of υ. The benchmark symmetric case sets $\upsilon = 0.50$. We also set $\upsilon = 0.73$, so that country H accounts for 27 percent of the world economy, close to the U.S. share of world GDP.[1] Finally, $\upsilon = 0.99$ makes country H a very small and highly open economy. The sequence of experiments proceeds as follows. We first show that a 20 percent Home import-tariff shock can make the ZLB bind in both countries when the countries are symmetric. We then reduce the size of country H to show how the ZLB becomes primarily domestic. Finally, in Fig. 8, we vary both the tariff size and country size to show that the return of the ZLB is not a knife-edge result of the 20 percent tariff experiment.

5.1 Dynamics under Benchmark Increase in the Import Tariff

Figs. 5 and 6 show IRFs to a 20% increase in the import tariff in country H. In Figs. 5 and 6, magenta solid lines and green solid lines show responses in countries H and F, respectively.

5.1.1 Same-Size Countries

When the two countries are symmetric in size, a 20 percent increase in the import tariff in country H makes the nominal interest rate bind at the ZLB in both countries (Panel 1, Fig. 5). This is the central difference from the small open economy model. In the small open economy model, foreign demand is taken as given, so the tariff shock affects the Home economy mainly through domestic fiscal and relative-price wedges. In the two-country model, by contrast, the same shock changes the world allocation: the contractionary pressure in country H is transmitted to country F, and the response of country F feeds back into country H. As a result, the tariff shock does not merely require unconventional monetary policy in the tariff-imposing country. It pushes the whole two-country economy into a constrained Ramsey allocation in which unconventional monetary policy becomes necessary worldwide.

The Home-country mechanism is the fiscal-tax channel. An increase in the import tariff raises tariff revenue, improves the primary balance, and reduces the labor income tax required by the fiscal rule (Panels 8 and 9, Fig. 5). The induced labor-income-tax cut raises the natural level of output. Since actual output does not immediately follow the higher natural level under sticky prices, the Home output gap falls (Panel 7, Fig. 5). At the same time, the tax cut lowers firms' real marginal costs. These two forces generate downward pressure on Home PPI inflation (Panel 2, Fig. 5). The Home Ramsey planner would like to lower the nominal interest rate to accommodate the higher natural level of output and stabilize the price-setting distortion, but the desired notional rate falls below zero. Hence, the Home nominal interest rate is constrained by the ZLB (Panel 1, Fig. 5).

The response of country F should be interpreted as an accommodative Ramsey response to the fall in demand for Foreign goods caused by the Home tariff. It is not accurate to say that Foreign PPI inflation rises simply because the Foreign output gap rises. The causality runs through the policy path chosen by the Foreign Ramsey planner. The Home tariff reduces Home demand for Foreign goods and thereby creates downward pressure on Foreign activity. To counteract this pressure, the Foreign planner lowers the nominal interest rate to the ZLB and commits to an accommodative future policy path (Panel 1, Fig. 5). This history-dependent, time-axis component of the commitment solution puts upward pressure on the Foreign output gap (Panel 7, Fig. 5). Under Calvo price setting, the resulting increase in current and expected demand raises Foreign

[1] The U.S. share of world nominal GDP was approximately 27 percent in 2025, based on the IMF's *World Economic Outlook* [36].

PPI inflation (Panel 2, Fig. 5). The policy is therefore not a mechanical response to an exogenous increase in Foreign inflation; the increase in Foreign PPI inflation is part of the Ramsey implementation of the desired allocation under sticky prices and the ZLB.

The same accommodative policy also works through the real-interest-rate channel. The decline in the Foreign nominal interest rate, together with the induced increase in current and expected CPI inflation (Panel 3, Fig. 5), lowers the Foreign real interest rate (Panel 10, Fig. 5). This lower real interest rate supports Foreign consumption and output (Panels 4 and 11, Fig. 5). At the same time, the Foreign monetary expansion operates through the exchange-rate channel. The depreciation of the Foreign nominal exchange rate puts downward pressure on the ex-tariff relative price of imports, S_t (Panels 5 and 6, Fig. 5). This movement in S_t generates an expenditure-switching effect toward Foreign goods and helps sustain demand for Foreign output. In this sense, the rise in Foreign PPI inflation, the increase in Foreign CPI inflation, the decline in the Foreign real interest rate, and the depreciation-induced fall in S_t are mutually reinforcing elements of the same constrained Ramsey policy.

The binding ZLB in country F is therefore not puzzling even though Foreign PPI inflation rises. The Foreign planner is not trying to suppress the increase in PPI inflation as a Taylor rule would. Instead, it uses the lowest feasible nominal interest rate, together with the commitment to future accommodation, to raise the output gap, increase PPI and CPI inflation, reduce the real interest rate, and improve the relative price of Foreign goods. The nominal interest rate required to implement this accommodative allocation is below zero, so the actual Foreign nominal interest rate is constrained at the ZLB (Panel 1, Fig. 5). Thus, the rise in Foreign PPI inflation and the binding Foreign ZLB are joint implications of the same constrained Ramsey response to the international spillover from country H.

This mechanism also explains why the two-country model strengthens the ZLB result. A unilateral import tariff in country H first generates fiscal-tax accommodation and deflationary pressure in country H. It then propagates to country F, where the Ramsey response raises the output gap and PPI inflation while driving the notional nominal interest rate below zero. The resulting Foreign response feeds back into country H through trade and relative-price channels. Hence, a tariff imposed by one large country can make unconventional monetary policy a worldwide necessity, even when the tariff shock originates only in country H.

5.1.2 A U.S.-Size Country H

We next consider the case in which country H is an economic power rather than one of two symmetric economies. Specifically, we set $\upsilon = 0.73$, so that country H accounts for $1 - \upsilon = 0.27$ of the world economy. This calibration is intended to capture a tariff-imposing country whose size is close to the U.S. share of world GDP. Fig. 6 reports the responses to a 20 percent increase in the import tariff in country H.

The main result is that the ZLB still binds in the tariff-imposing country, even though country H is smaller than the rest of the world. In country H, the nominal interest rate falls to the ZLB on impact and remains constrained for several periods before rising above the steady state (Panel 1, Fig. 6). The mechanism is the same fiscal-tax channel as in the symmetric case. The import-tariff increase raises tariff revenue and improves the primary balance on impact (Panel 9, Fig. 6). The fiscal rule then allows the government to reduce the labor income tax (Panel 8, Fig. 6). This tax cut raises the natural level of output and lowers firms' real marginal costs. Since actual output cannot immediately adjust to the higher natural level under sticky prices, the Home output gap falls (Panel 7, Fig. 6), and Home PPI inflation declines on impact (Panel 2, Fig. 6). The direct import-price effect still raises Home CPI inflation at the time of the shock, but this effect is followed by a decline in CPI inflation as the disinflationary pressure from PPI inflation dominates (Panel 3, Fig. 6). The Home Ramsey planner would like to implement stronger monetary accommodation, but the required notional nominal interest rate is negative. Hence, unconventional monetary policy is required in country H.

The responses of country F show the international spillover from a large Home-country tariff, but the asymmetry in country size makes the foreign response less extreme than in the symmetric case. The Home tariff reduces the demand for Foreign goods and generates downward pressure on Foreign activity. The Foreign Ramsey planner responds by lowering the nominal interest rate, but the decline is not large enough to make the Foreign ZLB bind (Panel 1, Fig. 6). Thus, unlike the symmetric case in Fig. 5, the benchmark tariff shock does not force unconventional monetary policy worldwide. It does, however, require monetary accommodation abroad.

The Foreign accommodation works through the same policy margins as in the symmetric case, although with smaller magnitude. The lower Foreign nominal interest rate reduces the Foreign real interest rate (Panel 10, Fig. 6), supporting Foreign consumption and output (Panels 11 and 4, Fig. 6). The exchange-rate response also lowers the *ex-tariff* relative price of imports, S_t, making Foreign goods cheaper relative to Home goods (Panels 5 and 6, Fig. 6). This movement generates an expenditure-switching effect toward Foreign goods and helps sustain demand for Foreign output. As a result, Foreign net exports rise, while Home net exports fall (Panel 12, Fig. 6).

Foreign PPI inflation rises on impact (Panel 2, Fig. 6). This increase should not be read as a reason for monetary tightening. Rather, it is part of the constrained-efficient response that supports Foreign demand in the face of the Home tariff shock. The Foreign planner lowers the nominal interest rate, puts upward pressure on Foreign demand, and allows PPI inflation to rise under Calvo pricing. The resulting increase in Foreign PPI inflation is therefore the price-setting counterpart of the accommodative Ramsey response, not an independent inflationary disturbance.

These results sharpen the interpretation of the two-country mechanism. When the tariff-imposing country is of U.S. size, a 20 percent import-tariff shock is large enough to make the ZLB bind in the Home economy. The rest of the world is affected through trade, relative prices, and international risk sharing, but its own nominal interest rate does not hit the ZLB. Thus, the worldwide propagation mechanism remains present, but the need for unconventional monetary policy is concentrated in the tariff-imposing economic power. This contrasts with the symmetric case, where both countries are pushed into the ZLB (Panel 1, Fig. 5).

5.1.3 A Small Country H

We next examine whether the incidence of the ZLB depends on the size of the tariff-imposing country. We set $\upsilon = 0.99$, so that country H accounts for only one percent of the world economy, and consider a 20 percent increase in the import tariff in country H. This experiment isolates the domestic ZLB margin. Country H is very small and highly exposed to goods produced in country F, while country F is almost the entire world economy. If a tariff imposed by country H still brings country H to the ZLB in this case, the result cannot be attributed to large global spillovers. It must instead reflect the strength of the domestic fiscal-tax and relative-price channels in a highly open economy.

Fig. 7 reports the results. The Home nominal interest rate immediately reaches the ZLB and remains constrained for several periods, whereas the Foreign nominal interest rate is essentially unchanged (Panel 1, Fig. 7). Since the figure reports deviations from the steady-state nominal interest rate, the ZLB corresponds to a deviation of approximately -0.0101, not to the horizontal zero line. The Home response therefore represents a genuine ZLB episode. After lift-off, the Home nominal interest rate rises above its steady-state value. This post-lift-off increase is not a tightening bias. It is the state-contingent normalization implied by the commitment solution after the planner has been constrained by the ZLB in the initial periods.

The domestic mechanism is the fiscal-tax channel. The import-tariff increase raises tariff revenue and improves the Home primary balance on impact (Panel 9, Fig. 7). Under the Bohn-type fiscal rule, the improvement in the primary balance is associated with a persistent decline in the Home labor income tax rate (Panel 8, Fig. 7). The tax cut lowers firms' real marginal costs and changes the natural allocation. Home PPI inflation falls sharply in the first periods despite the positive response of the output gap (Panels 2 and 7, Fig. 7). The direct tariff effect raises Home CPI inflation on impact, but this effect is short-lived; CPI inflation then falls below steady state as domestic disinflationary pressure dominates (Panel 3, Fig. 7). The Ramsey planner would like to implement a nominal interest rate below zero in order to accommodate these forces, but the ZLB prevents it from doing so (Panel 1, Fig. 7).

The real side of the Home economy reflects the same constrained adjustment. Home output falls on impact and then rises temporarily above steady state, while Home consumption declines persistently and net exports deteriorate (Panels 4, 11, and 12, Fig. 7). The economy therefore does not behave as if the tariff were a conventional expansionary protectionist policy. The tariff raises revenue and triggers a tax cut, but the associated relative-price and intertemporal adjustments are large enough to require a ZLB-constrained commitment policy. The positive output-gap response after the initial period should therefore be interpreted together with the tax cut and the fall in marginal costs, not as evidence that monetary tightening would be appropriate.

The Foreign responses confirm that the ZLB episode is domestic rather than global. Since country H is only one percent of the world economy, the effects on country F are negligible. Foreign PPI inflation, output, the labor income tax rate, the primary balance, consumption, and net exports remain close to steady state, and the Foreign nominal interest rate does not approach the ZLB (Fig. 7). Hence, a very small tariff-imposing country can require unconventional monetary policy at home, but it does not create a worldwide need for unconventional monetary policy.

This experiment clarifies the role of country size. Sufficiently large tariff shocks can bring back the ZLB domestically through the fiscal-tax and relative-price channels even under benchmark tariff persistence and benchmark price stickiness. However, for the ZLB pressure to be transmitted abroad, the tariff-imposing country must be sufficiently large. This is why both countries reach the ZLB in the symmetric case (Panel 1, Fig. 5), whereas only country H reaches the ZLB when the tariff-imposing country accounts for one percent of the world economy (Panel 1, Fig. 7).

5.2 Tariff Size, Country Size, and the Return of the ZLB

We now examine how the return of the ZLB depends jointly on the size of the tariff shock and on the size of the tariff-imposing country. This experiment is central for the quantitative interpretation of the paper. The preceding figures show that a 20 percent tariff shock can bind the ZLB in the two-country economy. Fig. 8 and Table 1 show that this result is not tied to one tariff size and that the incidence of the ZLB varies systematically with country size. Fig. 8 reports the nominal-interest-rate responses in countries H and F to increases in the import tariff in country H of 20 percent, 15 percent, 10 percent, and 5 percent. The 5 percent case is reported in the additional Home and Foreign nominal-interest-rate panels (Panels 6 and 7, Fig. 8). Table 1 summarizes the lower-bound incidence across these experiments. The magenta, blue, and green lines correspond to $\upsilon = 0.50$, $\upsilon = 0.73$, and $\upsilon = 0.99$, respectively. Since country H has population share $1 - \upsilon$, a larger value of υ corresponds to a smaller and more open tariff-imposing country. The responses are reported as absolute deviations from the steady-state nominal interest rate. Given $\beta = 0.99$, the steady-state quarterly nominal interest rate is $1/\beta - 1 \simeq 0.0101$. Hence, in Fig. 8, the ZLB corresponds to a deviation of approximately -0.0101, not to the horizontal zero line.

Table 1: ZLB Incidence under Unilateral Home Import Tariffs

Tariff shock	$\upsilon = 0.50$ Same-size countries	$\upsilon = 0.73$ U.S.-size H	$\upsilon = 0.99$ Small H
20%	H, F	H	H
15%	H, F	H	H
10%	–	H	H
5%	–	–	H

Notes: The table summarizes Fig. 8. The entry H (F) means that the nominal interest rate in country H (F) reaches the ZLB. The entry H, F means that both countries reach the ZLB. A dash means that neither country clearly reaches the ZLB. Because Fig. 8 reports deviations from the steady-state nominal interest rate, the ZLB corresponds to a deviation of approximately $-(1/\beta - 1)$.

The Home responses in Fig. 8, together with the entries in Table 1, show that the domestic lower-bound force strengthens as country H becomes smaller and more open. For 20 percent and 15 percent tariff shocks, the Home rate reaches the ZLB for all three country-size configurations. The ZLB episode is short when the two countries are symmetric, but it becomes longer as υ rises. When $\upsilon = 0.99$, country H is very small and highly exposed to Foreign goods. In that case, the Home rate remains at the ZLB for several periods and then rises substantially above its steady state. When the tariff shock is reduced to 10 percent, the Home rate still reaches the ZLB when country H is U.S.-size or sufficiently small and open, whereas the symmetric-country case displays only a milder decline. When the tariff shock is reduced further to 5 percent, the ZLB no longer binds in the symmetric case or in the U.S.-size case, but it still binds when $\upsilon = 0.99$ (Panel 6, Fig. 8).

These responses show that the ZLB result is a threshold phenomenon rather than a mechanical implication of any tariff increase. The magnitude of the tariff shock matters, but country size matters as well. In the present calibration, a smaller country H is more exposed to imported goods from country F. A tariff increase therefore has a larger effect on the Home allocation through the relative-price channel and through the fiscal-tax channel. The tariff raises revenue, improves the primary balance, and induces a reduction in the labor income tax under the Bohn-type rule. The resulting increase in the natural level of output and decline in firms' real marginal costs create downward pressure on PPI inflation. The Home Ramsey planner would like to reduce the nominal interest rate sufficiently to accommodate this higher natural level of output, but the required notional rate can become negative. When it does, the actual rate is constrained at the ZLB.

The post-ZLB rise in the Home nominal interest rate should not be interpreted as a tightening bias. It is instead a feature of the commitment solution after the initial ZLB constraint ceases to bind. During the first periods, the planner cannot implement the desired negative nominal interest rate. Once the constraint is relaxed, the Ramsey allocation requires a future interest-rate path that satisfies the Euler equation and the price-setting optimality conditions while returning the economy gradually to steady state. This is why the Home rate can rise above its steady-state level after lift-off, especially when the initial ZLB constraint is severe. The relevant policy implication is not that tariffs call for monetary tightening, but that tariffs can require a ZLB-constrained commitment policy followed by a state-contingent normalization of the nominal interest rate.

The Foreign responses in Fig. 8 and Table 1 clarify the international dimension. The Foreign nominal interest rate falls when the tariff-imposing country is large enough, but the size of the spillover depends strongly on υ. In the symmetric case, the Foreign rate also reaches the ZLB for the 20 percent and 15 percent shocks, so those cases generate a global lower-bound episode. When $\upsilon = 0.73$, so that country H accounts for 27 percent of the world economy, the Foreign rate falls noticeably but remains above the ZLB for all tariff sizes shown. When $\upsilon = 0.99$, the response of the Foreign rate is essentially zero, including under the 5 percent tariff shock (Panel 7, Fig. 8). Thus, a tariff shock can bring back the ZLB domestically even when the tariff-imposing country is small, but it generates a global ZLB episode only when the tariff-imposing country is sufficiently large.

Fig. 8 and Table 1 separate two margins of the return of the ZLB. The first is the domestic margin: tariff shocks can push the tariff-imposing country to the ZLB through the fiscal-tax channel and the relative-price channel, even under the benchmark tariff persistence and benchmark price stickiness. This margin is robust to smaller tariff shocks when the tariff-imposing country is sufficiently exposed to foreign goods; in the unilateral experiment it survives even under a 5 percent tariff shock when $\upsilon = 0.99$. The second is the global margin: the ZLB is transmitted abroad only when the tariff-imposing country is large enough for its contractionary and fiscal-tax effects to generate sizable international spillovers. The table makes clear that reducing the tariff shock from 20 percent to 10 percent eliminates the global ZLB in this calibration, and reducing it to 5 percent eliminates the global ZLB entirely, but it does not eliminate the domestic ZLB for the smallest and most open tariff-imposing economy. The return of the ZLB is therefore not a knife-edge implication of a single tariff size. It depends systematically on the interaction among tariff size, country size, openness, and the endogenous fiscal response to tariff revenues.

Appendix E also reports the corresponding robustness exercise for unilateral Home import-tariff shocks. Fig. 15 plots the Home and Foreign nominal-interest-rate responses for alternative tariff sizes and country sizes when $\phi_B = 0.03$. The threshold pattern documented in Fig. 8 is preserved: the Home ZLB is more likely to bind when the tariff shock is larger and when country H is smaller and more open, while the spillover to country F remains limited when country H is very small. This confirms that the unilateral two-country result is not an artifact of the baseline value $\phi_B = 0.02$.

5.3 Dynamics in a Small Country Hit by Foreign Import Tariffs

We finally consider how a small country is affected by a foreign import-tariff shock. We set $\upsilon = 0.99$, so that country H accounts for only $1 - \upsilon = 0.01$ of the world economy, while country F accounts for the remaining 99 percent. In this experiment, the import tariff is raised in country F, not in country H. Since country F imposes the tariff on goods imported from country H, the shock is a foreign import-tariff shock from the perspective of the small country H. Equivalently, it is an export-demand shock for country H. This exercise is therefore the two-country counterpart of the export-tariff experiment in Monacelli [40], but with a government budget constraint and a ZLB constraint in both countries.

Fig. 9 reports impulse responses to a 20 percent increase in the import tariff in country F. The magenta solid lines and green solid lines show responses in countries H and F, respectively. Since country H is very small, country F's tariff on Home goods has negligible aggregate effects on country F itself. The responses of country F's nominal interest rate, PPI inflation, output, labor income tax rate, primary balance, consumption, and net exports are all close to zero (Fig. 9). In particular, the ZLB does not bind in country F (Panel 1, Fig. 9). Thus, unlike the symmetric Home-tariff experiment in Fig. 5, a tariff imposed by the large country on imports from a very small country does not generate a global ZLB episode.

The effects on the small country H are much larger. Country F's import tariff raises the price of Home goods in the Foreign market and depresses Foreign demand for Home exports. The Home nominal interest rate immediately reaches the ZLB and remains constrained for most of the transition (Panel 1, Fig. 9). Since the figure is plotted as deviations from steady state, the flat response at approximately -0.0101 corresponds to a zero nominal interest rate. The unconstrained Ramsey policy would call for a negative Home nominal interest rate, but the ZLB prevents this adjustment.

The real allocation in country H shows the consequences of this foreign-tariff shock. Home output falls on impact, but then rises temporarily above steady state as the ZLB-constrained commitment path supports demand (Panel 4, Fig. 9). Home consumption increases slightly on impact and gradually returns to steady state, while Home net exports improve persistently (Panels 11 and 12, Fig. 9). The improvement in net exports should not be read as evidence that the foreign tariff is beneficial. It reflects the equilibrium adjustment of domestic absorption, relative prices, and the exchange rate in a very small open economy. The Home output gap is sharply negative and then closes gradually (Panel 7, Fig. 9), indicating that the foreign tariff creates a substantial stabilization problem for the Home Ramsey planner.

The price responses are also different from the Home import-tariff case. Home PPI inflation rises on impact and then gradually returns to steady state, while Home CPI inflation is close to zero and slightly below steady state for most of the transition (Panels 2 and 3, Fig. 9). This pattern reflects the fact that country H does not receive the tariff revenue. The direct Home fiscal-tax channel generated by Home tariff revenues is absent. Instead, the foreign tariff affects country H through export demand, relative prices, the exchange rate, and the endogenous fiscal adjustment implied by the Bohn-type rule. The ZLB-constrained commitment path then shapes the price-setting response under Calvo pricing.

The Home fiscal variables adjust endogenously even though the tariff revenue accrues to country F. The Home primary balance rises and remains above steady state for several periods before returning gradually (Panel 9, Fig. 9). The Home labor income tax rate initially rises, then falls below steady state during the transition, and eventually returns to steady state (Panel 8, Fig. 9). These movements are induced by the interaction among the foreign-demand shock, output and price dynamics, and the Bohn-type fiscal rule. They are not the direct revenue effect emphasized in the Home import-tariff experiments.

Fig. 9 therefore clarifies the role of the direction of the tariff shock. When country H imposes an import tariff, the domestic fiscal-tax channel is direct: tariff revenues improve the Home primary balance and reduce the Home labor income tax rate. When country F imposes an import tariff on Home goods, country H is instead hit through an external-demand channel. Nevertheless, the small country can still be pushed to the ZLB. Hence, the return of the ZLB is not confined to tariff-imposing countries. A small open economy can also require a ZLB-constrained commitment policy when it is hit by a foreign tariff on its exports, even though the large tariff-imposing country remains essentially unaffected at the aggregate level.

5.4 Reciprocal Tariffs and the Global ZLB

The preceding subsections considered unilateral tariff shocks. Country H either raises its own import tariff, or it is hit by an import tariff imposed by country F on Home goods. We now turn to reciprocal tariffs. The Trump administration's move toward reciprocal tariffs makes simultaneous tariff increases by trading partners a natural policy experiment. In the same policy environment, the administration also enacted the One Big Beautiful Bill, which the White House described as increasing workers' take-home pay through tax cuts [52]. We use this policy combination as a motivation for studying how reciprocal tariff revenues interact with endogenous labor-income-tax adjustment. The model does not impose a legal earmarking of tariff revenues to tax cuts; rather, it treats tariff revenues as part of the consolidated government budget constraint and lets the labor income tax rate adjust residually under the fiscal rule. It is therefore useful to ask whether the ZLB result survives when both countries raise import tariffs at the same time.

The reciprocal-tariff experiment differs from the unilateral experiments in two respects. First, the fiscal-tax channel operates in both countries. Each government receives tariff revenues, the required primary balance is pinned down by its Bohn-type rule, and the residual labor income tax rate adjusts to satisfy its government budget constraint. Second, the relative-price and exchange-rate effects depend on country size. When the two countries are symmetric, the nominal exchange rate has no role in reallocating the adjustment across countries. When country sizes differ, however, the smaller and more open economy is more strongly exposed to the tariff shock, while the larger economy absorbs a smaller aggregate disturbance. The question is therefore whether reciprocal tariffs generate a genuinely global ZLB episode, or whether the ZLB force remains concentrated in the smaller and more open country.

5.4.1 Same-Size Countries

Fig. 10 reports the responses to a 20 percent reciprocal increase in import tariffs when the two countries are of the same size. The main result is that the nominal interest rate reaches the ZLB in both countries. Since the figure is plotted as deviations from steady state, the flat response at approximately -0.0101 corresponds to a zero nominal interest rate. Both central banks would like to implement a negative notional rate in the early phase of the transition, but the ZLB prevents this adjustment (Panel 1, Fig. 10).

The symmetric structure of the experiment is important for interpreting the transmission mechanism. Since both countries raise import tariffs simultaneously and are of the same size, the nominal exchange rate remains essentially unchanged (Panel 6, Fig. 10). Thus, the ZLB episode in Fig. 10 is not driven by a large exchange-rate movement or by a unilateral expenditure-switching effect. Instead, it reflects the common fiscal-tax and relative-price effects generated by reciprocal tariffs.

In both countries, the direct import-price effect raises CPI inflation on impact (Panel 3, Fig. 10). At the same time, tariff revenues improve the primary balance on impact and allow a reduction in the labor income tax under the fiscal rule (Panels 8 and 9, Fig. 10). The tax cut raises the natural level of output and lowers firms' real marginal costs. With sticky prices, actual output cannot immediately replicate the movement in the natural allocation, so the output gap initially falls and then temporarily turns positive as the ZLB-constrained commitment policy supports demand (Panel 7, Fig. 10). Domestic PPI inflation therefore falls on impact, rises temporarily during the accommodative phase, and then returns gradually to steady state (Panel 2, Fig. 10).

The real-interest-rate and absorption responses are consistent with this constrained Ramsey policy. The initial rise in CPI inflation is not met by monetary tightening. Instead, both nominal interest rates remain at the lower bound, and the subsequent path of CPI inflation lowers the real interest rate during the transition (Panel 10, Fig. 10). Consumption and output recover after their initial declines, while net exports return gradually toward steady state (Panels 4, 11, and 12, Fig. 10). Hence, reciprocal tariffs between same-size countries generate a global ZLB episode: the two economies face the same stabilization problem, and neither country can shift the adjustment to the other through the nominal exchange rate.

5.4.2 A U.S.-Size Country H

We next consider reciprocal tariffs when country H is a U.S.-size economy. As before, we set $\upsilon = 0.73$, so that country H accounts for $1 - \upsilon = 0.27$ of the world economy. Fig. 11 reports the responses to a 20 percent reciprocal increase in import tariffs.

The Home nominal interest rate again reaches the ZLB and remains constrained for several periods (Panel 1, Fig. 11). The early decline in the Home rate reflects the same fiscal-tax channel as in the unilateral Home-tariff experiment. Home tariff revenues improve the primary balance, and the labor income tax falls sharply under the fiscal rule (Panels 8 and 9, Fig. 11). The tax cut raises the natural level of output and reduces real marginal cost. As a result, Home PPI inflation falls on impact, the Home output gap declines sharply, and the constrained-efficient policy calls for monetary accommodation (Panels 2 and 7, Fig. 11). The direct tariff effect nevertheless raises Home CPI inflation on impact (Panel 3, Fig. 11), which again illustrates why stabilizing CPI inflation would point in the wrong direction relative to the Ramsey allocation.

The reciprocal nature of the experiment generates an additional Foreign response. Country F also receives tariff revenues and reduces its labor income tax (Panel 8, Fig. 11). However, because country F is much larger than country H, the aggregate effect of its tariff on Home goods is smaller than the effect of Home's tariff on Foreign goods from the perspective of country H. The Foreign responses of output, PPI inflation, consumption, and the primary balance are therefore much smaller than the Home responses (Panels 2, 4, 9, and 11, Fig. 11). The Foreign nominal interest rate also falls and is constrained at the lower bound for a shorter period than the Home rate, but the Foreign ZLB episode is less persistent (Panel 1, Fig. 11).

Country-size asymmetry also makes the exchange-rate and relative-price margins active. Unlike the same-size case, the nominal exchange rate moves during the transition, and the *ex-tariff* relative price of imports changes substantially (Panels 5 and 6, Fig. 11). These movements reallocate demand across countries and amplify the adjustment in the smaller and more open Home economy. Home consumption falls sharply and Home net exports initially deteriorate, while the Foreign responses are more muted (Panels 11 and 12, Fig. 11).

Fig. 11 therefore modifies, but does not overturn, the global-ZLB conclusion from the symmetric case. Reciprocal tariffs involving a U.S.-size country can make the ZLB bind in both countries, but the incidence is asymmetric. The smaller and more open Home economy faces a larger and more persistent ZLB constraint, whereas the larger Foreign economy experiences a shorter and milder lower-bound episode. Thus, reciprocal tariffs can be global in their monetary-policy implications even when the countries are not the same size, but the burden of the adjustment is concentrated in the more open economy.

5.4.3 A Small Country H

We now set $\upsilon = 0.99$, so that country H accounts for only one percent of the world economy. Fig. 12 reports the responses to a 20 percent reciprocal increase in import tariffs. This experiment is useful because it separates the domestic effect on a very small and open economy from the spillover to the rest of the world.

The effect on country H is large. The Home nominal interest rate reaches the ZLB in the initial phase of the transition (Panel 1, Fig. 12). After the constraint ceases to bind, the Home rate rises substantially above its steady-state level before returning gradually. This post-lift-off increase should not be read as evidence that the tariff shock calls for an immediate monetary tightening. It is a feature of the commitment solution after an initial lower-bound episode: once the planner is no longer constrained by the ZLB, the future interest-rate path must satisfy the Euler equation and the Calvo price-setting conditions while unwinding the earlier constrained accommodation.

The Home real allocation is also much more volatile than in the larger economies. Home CPI inflation rises sharply on impact because imported goods are important in the consumption basket of a very small open economy (Panel 3, Fig. 12). Home output and consumption fall initially, while the Home output gap becomes strongly positive during the transition (Panels 4, 7, and 11, Fig. 12). Home PPI inflation is initially below steady state but then rises persistently above steady state as the constrained commitment policy and the relative-price adjustment pass through to domestic price setting (Panel 2, Fig. 12). The Home net-export response is correspondingly large and changes sign during the transition (Panel 12, Fig. 12).

The fiscal variables show that the reciprocal tariff remains a fiscal shock for the small country. Home tariff revenues generate a large improvement in the primary balance on impact (Panel 9, Fig. 12). The labor income tax response is non-monotone: it rises slightly on impact, then falls below steady state before returning gradually (Panel 8, Fig. 12). This pattern reflects the interaction among tariff revenues, the Bohn-type fiscal rule, the sharp movement in domestic absorption, and the price-setting dynamics generated by the ZLB-constrained Ramsey policy.

By contrast, the effect on country F is negligible. Since country H accounts for only one percent of the world economy, country F's exposure to Home goods is too small to generate a sizable aggregate response. The Foreign nominal interest rate, PPI inflation, output, tax rate, primary balance, consumption, and net exports remain close to steady state (Fig. 12). In particular, the Foreign ZLB does not bind (Panel 1, Fig. 12). Thus, reciprocal tariffs involving a very small country do not generate a global ZLB episode. They generate a severe domestic stabilization problem for the small and open economy, with only negligible spillovers to the rest of the world.

5.4.4 Tariff Size, Country Size, and the Return of the ZLB

Fig. 13 summarizes how the nominal-interest-rate response under reciprocal tariffs depends on tariff size and country size. The figure reports 20 percent, 15 percent, 10 percent, and 5 percent reciprocal tariff shocks. The 5 percent case is reported in the additional Home and Foreign nominal-interest-rate panels (Panels 6 and 7, Fig. 13). The three lines correspond to $\upsilon = 0.50$, $\upsilon = 0.73$, and $\upsilon = 0.99$. Table 2 summarizes the ZLB incidence implied by these panels.

Table 2: ZLB Incidence under Reciprocal Tariffs

Tariff shock	$\upsilon = 0.50$ Same-size countries	$\upsilon = 0.73$ U.S.-size H	$\upsilon = 0.99$ Small H
20%	H, F	H, F	H
15%	H, F	H, F	H
10%	H, F	H	H
5%	–	H	H

Notes: The table summarizes Fig. 13. The entry H (F) means that the nominal interest rate in country H (F) reaches the ZLB. The entry H, F means that both countries reach the ZLB. A dash means that neither country clearly reaches the ZLB. Under reciprocal tariffs, both countries receive tariff revenues, but country size determines whether the lower-bound force remains domestic or becomes global.

The Home responses show that the domestic ZLB force is stronger when country H is smaller and more open. For 20 percent, 15 percent, and 10 percent reciprocal tariff shocks, the Home nominal interest rate reaches the ZLB in all three country-size configurations. The intensity of that incidence, however, differs sharply across country sizes: for a 20 percent reciprocal tariff shock, the post-lift-off increase is much larger when $\upsilon = 0.99$ than when $\upsilon = 0.50$ or $\upsilon = 0.73$ (Fig. 13). The same qualitative pattern appears for the 15 percent and 10 percent shocks. The 5 percent case sharpens the threshold interpretation. The Home ZLB does not bind in the symmetric case, but it binds when $\upsilon = 0.73$ and when $\upsilon = 0.99$ (Panel 6, Fig. 13). Thus, reciprocal tariff escalation makes the Home lower-bound force more robust than in the unilateral experiment, where the 5 percent shock binds the Home ZLB only when $\upsilon = 0.99$.

The Foreign responses separate the global margin from the domestic margin. When the two countries are of the same size, the Foreign nominal interest rate behaves much like the Home rate and reaches the ZLB for the 20 percent, 15 percent, and 10 percent shocks, but not for the 5 percent shock. When $\upsilon = 0.73$, the Foreign rate reaches the ZLB for the 20 percent and 15 percent shocks, but the lower-bound episode is shorter and less severe than in the Home economy; for the 10 percent and 5 percent shocks, the lower-bound force remains domestic. When $\upsilon = 0.99$, the Foreign response is close to zero for all tariff sizes, including the 5 percent shock (Panel 7, Fig. 13). Thus, the spillover to country F depends primarily on the aggregate size of country H and on country F's exposure to Home goods.

Fig. 13 and Table 2 therefore identify two distinct implications of reciprocal tariffs. First, reciprocal tariffs make the domestic ZLB result robust: even when both countries raise tariffs, the smaller and more open country can be pushed to the ZLB through the interaction of tariff revenues, distortionary taxation, relative prices, and sticky prices. This robustness does not rely solely on the benchmark 20 percent tariff shock; the qualitative country-size pattern survives under the 15 percent and 10 percent shocks, and the Home ZLB still binds under a 5 percent reciprocal tariff shock when $\upsilon = 0.73$ or $\upsilon = 0.99$. Second, reciprocal tariffs generate a global ZLB episode only when both countries are sufficiently important to each other in general equilibrium. The table shows that the global ZLB appears for the 20 percent, 15 percent, and 10 percent shocks in the symmetric case and for the 20 percent and 15 percent shocks in the U.S.-size case, but disappears for the 5 percent shock in all country-size configurations and for all tariff sizes when H is very small. The return of the ZLB under reciprocal tariffs is therefore governed jointly by tariff size and country size, not by tariff size alone.

The reciprocal-tariff results can be summarized as follows. In the same-size case, the Home and Foreign nominal interest rates both reach the ZLB for sufficiently large reciprocal tariff shocks, so reciprocal tariffs can generate a global ZLB episode (Fig. 10 and Table 2). In the U.S.-size case, both nominal interest rates can be constrained for sufficiently large tariff shocks, but the Home lower-bound episode is larger and more persistent than the Foreign one, so the global ZLB is asymmetric (Fig. 11). In the small-country case, the Home ZLB force is severe while the Foreign response is negligible, so the ZLB episode is essentially domestic (Fig. 12). Finally, the alternative-tariff-size experiment shows that these conclusions vary systematically with both tariff size and country size, rather than being an artifact of the benchmark 20 percent shock (Fig. 13 and Table 2).

The threshold property is useful for interpreting the recent U.S. experience. The model does not imply that every tariff increase must send nominal interest rates to zero. Recent policy estimates place the U.S. average effective tariff rate in the high single digits to low double digits, depending on whether the measure is based on announced statutory rates, import substitution, exemptions, or actual duty collections. For example, the Budget Lab at Yale [26] estimates that the U.S. average effective tariff rate was 2.4 percent before the 2025 tariff announcements, about 10 percent in June and July, and likely 11–12 percent in August. Amiti et al. [2] similarly report that the average tariff rate on U.S. imports rose from 2.6 percent to 13 percent over 2025, while emphasizing that the actual duty rate can be lower than the statutory rate because of exemptions and import substitution. Estimates based more directly on collections are somewhat lower: Penn Wharton Budget Model [43] estimates that the effective tariff rate rose from 2.3 percent in January 2025 to 8.9 percent in February 2026. Richmond Fed scenario calculations also place the average effective tariff rate in the same broad range, starting from a 2024 benchmark of 2.2 percent and rising to 7.1, 10.4, or 12.4 percent under alternative 2025 tariff scenarios [45]. Rogoff [44], in discussing the recent U.S. tariff episode, refers to estimates in the 10–12 percent range while suggesting that the realized effective increase may be closer to 6–8 percent. These estimates are consistent with the threshold pattern in Figs. 8 and 13 and Tables 1 and 2: moderate tariff increases need not generate a ZLB episode in all country-size configurations, even though sufficiently large or sufficiently asymmetric tariff shocks can do so. Hence, the absence of an actual U.S. ZLB episode in the recent tariff environment should not be read as evidence against the mechanism. It is consistent with the model's implication that the return of the ZLB depends on effective tariff size, country size, openness, and whether tariff escalation is unilateral or reciprocal.

Because the fiscal-tax channel is governed by the surplus-debt feedback parameter, Appendix E also reports the corresponding robustness exercise for reciprocal tariff shocks. Fig. 16 plots the Home and Foreign nominal-interest-rate responses under reciprocal tariff increases when $\phi_B = 0.03$. The threshold pattern documented in Fig. 13 is preserved: reciprocal tariffs continue to make the Home ZLB more likely to bind when country H is smaller and more open, while a global ZLB episode arises only when both countries are sufficiently exposed to each other and the tariff shock is large enough. Together with Figs. 14 and 15, this shows that the main ZLB mechanism is not driven solely by the lower benchmark value $\phi_B = 0.02$.

6 Conclusion

This paper has studied the optimal monetary-policy response to import tariffs when tariff revenues interact with the government budget constraint. In a lump-sum tax model, a tariff shock mainly works through relative prices and expenditure switching. In our model, by contrast, the tariff also changes public revenue. Under a Bohn-type fiscal rule, the primary-balance target is pinned down by outstanding public debt. The labor income tax then adjusts residually to satisfy the government budget constraint, so tariff revenues mechanically reduce the tax rate required to implement the rule. This fiscal-tax channel raises the natural level of output and lowers firms' real marginal costs. With sticky prices, the output gap and domestic producer-price inflation fall, and the constrained-efficient nominal interest rate declines.

The small open economy model clarifies the mechanism. Relative to the lump-sum tax model, the labor-income-tax adjustment reverses the sign of the optimal interest-rate response and makes monetary easing the constrained-efficient response to an import-tariff shock. CPI inflation targeting has the opposite implication. By attempting to stabilize the CPI component directly affected by the tariff, it induces monetary tightening precisely when the Ramsey allocation calls for accommodation. This yields a tightening bias that is stronger than in a lump-sum tax environment.

The two-country model delivers the main quantitative message. International general-equilibrium feedback strengthens the ZLB force. Under benchmark tariff persistence and benchmark price stickiness, a Home import-tariff shock can push the tariff-imposing country to the ZLB. The incidence of the ZLB depends systematically on tariff size and country size. A smaller and more open tariff-imposing country is more likely to hit the ZLB domestically, because the tariff has a larger effect on its allocation through the relative-price and fiscal-tax channels. At the same time, the spillover to the Foreign nominal interest rate is sizable only when the tariff-imposing country is sufficiently large. Thus, the model distinguishes between a domestic ZLB episode and a global ZLB episode.

The reciprocal-tariff experiments extend this message. When both countries raise import tariffs at the same time, the fiscal-tax channel operates in both countries. In the symmetric case, sufficiently large reciprocal tariff shocks can push both nominal interest rates to the ZLB. With country-size asymmetry, however, the incidence of the ZLB becomes uneven. A U.S.-size Home economy can generate a ZLB episode in both countries for larger tariff shocks, but the Home lower-bound episode is more persistent. When Home is very small, the domestic response is large while the Foreign response is nearly zero. The 5 percent tariff experiments sharpen the interpretation: a unilateral 5 percent tariff shock binds the Home ZLB only when $\upsilon = 0.99$, whereas a reciprocal 5 percent tariff shock binds the Home ZLB when $\upsilon = 0.73$ or $\upsilon = 0.99$. Reciprocal tariffs therefore strengthen the domestic lower-bound force, but they generate a global ZLB only when countries are sufficiently exposed to each other and the tariff shock is large enough. The recent U.S. combination of reciprocal-tariff policy and tax-cut legislation motivates this fiscal closure, while the model's mechanism rests on the consolidated government budget constraint rather than on a literal legal earmarking of tariff revenues to tax cuts.

The main implication is that sufficiently large or internationally amplified tariffs can bring back unconventional monetary policy even when the steady-state nominal interest rate is positive.

This result does not rely solely on unusually persistent tariff shocks, unusually low price stickiness, or a single benchmark 20 percent tariff experiment, and it does not imply that every tariff increase generates a ZLB episode. It follows from the interaction among tariff revenues, residual labor-income-tax adjustment, debt stabilization, and open-economy general-equilibrium feedback. The analysis therefore adds a fiscal dimension to the literature on tariffs and monetary policy: how tariff revenues are absorbed by the government budget constraint is central for determining whether tariffs call for monetary tightening, conventional monetary easing, or a ZLB-constrained commitment policy under both unilateral and reciprocal tariff regimes.

Appendices

A Details on Natural Level of Output

In the flexible price equilibrium, Eq.(20) is given by:

$$Y_t^n = (1-\upsilon)\left[(1-\upsilon)+\upsilon\left(1+\tau_{M,t}\right)^{1-\eta}\left(S_t^n\right)^{1-\eta}\right]^{\frac{\eta}{1-\eta}} C_t^n + \gamma\left(\frac{S_t^n}{1+\tau_{X,t}}\right)^{\eta} + G_t, \tag{A.1}$$

where C_t^n and S_t^n are the consumption and the *ex-tariff* price of imported goods relative to Home produced goods.

In the flexible price equilibrium, Eq.(5) is given by:

$$\mathcal{M}^{-1} = \left(Y_t^n\right)^{\varphi} C_t^n \frac{\left[(1-\upsilon)+\upsilon\left(1+\tau_{M,t}\right)^{1-\eta}\left(S_t^n\right)^{1-\eta}\right]^{\frac{1}{1-\eta}}}{A_t^{1+\varphi}\left(1-\tau_t^n\right)},$$

which can be rewritten as:

$$C_t^n = \mathcal{M}^{-1}\frac{A_t^{1+\varphi}\left(1-\tau_t^n\right)}{\left(Y_t^n\right)^{\varphi}\left[(1-\upsilon)+\upsilon\left(1+\tau_{M,t}\right)^{1-\eta}\left(S_t^n\right)^{1-\eta}\right]^{\frac{1}{1-\eta}}}. \tag{A.2}$$

In the flexible price equilibrium, Eq.(20) is given by:

$$C_t^n = \frac{S_t^n}{\left[(1-\upsilon)+\upsilon\left(1+\tau_{M,t}\right)^{1-\eta}\left(S_t^n\right)^{1-\eta}\right]^{\frac{1}{1-\eta}}}.$$

Plugging the previous expression into Eq.(A.2) yields:

$$S_t^n = \mathcal{M}^{-1}\frac{A_t^{1+\varphi}\left(1-\tau_t^n\right)}{\left(Y_t^n\right)^{\varphi} Y_t^*}. \tag{A.3}$$

Plugging Eqs.(A.2) and (A.3) into Eq.(A.1) yields:

$$\begin{aligned} Y_t^n \;=\; & \frac{(1-\upsilon) A_t^{1+\varphi}\left(1-\tau_t^n\right)}{\left\{(1-\upsilon)+\upsilon\left(1+\tau_{M,t}\right)^{1-\eta}\left[\frac{A_t^{1+\varphi}\left(1-\tau_t^n\right)}{\mathcal{M}\left(Y_t^n\right)^{\varphi}}\right]^{1-\eta}\right\}\mathcal{M}\left(Y_t^n\right)^{\varphi}} \\ & + \gamma\left[\frac{A_t^{1+\varphi}\left(1-\tau_t^n\right)}{\mathcal{M}\left(Y_t^n\right)^{\varphi}\left(1+\tau_{X,t}\right)}\right]^{\eta} + G_t, \end{aligned} \tag{A.4}$$

In the flexible price equilibrium, Eq.(3) is given by:

$$SP_t^n = \phi_B \mathcal{B}_{t-1}^n, \tag{A.5}$$

where SP_t^n and $\mathcal{B}_t^n$ denote SP_t and $\mathcal{B}_t$ in the flexible price equilibrium.

In the flexible price equilibrium, Eq.(1) is given by:

$$\mathcal{B}_t^n = \left(\frac{1}{\beta} \frac{C_t^n}{C_{t-1}^n} - \phi_B \right) \mathcal{B}_{t-1}^n,$$

where we use Eq.(12). Plugging Eqs.(A.2) and (A.3) into the previous expression yields:

$$\mathcal{B}_t^n = \left\{ \frac{1}{\beta} \left[\frac{(1-\upsilon) + \frac{\upsilon (1+\tau_{M,t-1})^{1-\eta} A_{t-1}^{(1+\varphi)(1-\eta)} \left(1-\tau_{t-1}^n\right)^{1-\eta}}{\mathcal{M}^{1-\eta} \left(Y_{t-1}^n\right)^{\varphi(1-\eta)}}}{(1-\upsilon) + \frac{\upsilon (1+\tau_{M,t})^{1-\eta} A_t^{(1+\varphi)(1-\eta)} \left(1-\tau_t^n\right)^{1-\eta}}{\mathcal{M}^{1-\eta} \left(Y_t^n\right)^{\varphi(1-\eta)}}} \right]^{\frac{1}{1-\eta}} \frac{\left(Y_{t-1}^n\right)^{\varphi} A_t^{1+\varphi} \left(1-\tau_t^n\right)}{\left(Y_t^n\right)^{\varphi} A_{t-1}^{1+\varphi} \left(1-\tau_{t-1}^n\right)} - \phi_B \right\} \mathcal{B}_{t-1}^n \tag{A.6}$$

In the flexible price equilibrium, Eq.(2) is given by:

$$\begin{aligned} SP_t^n \quad = \quad & \frac{Y_t^n \tau_t^n}{\mathcal{M} \left\{ (1+\upsilon) + \upsilon \left[\frac{(1+\tau_{M,t}) A_t^{1+\varphi} \left(1-\tau_t^n\right)}{\mathcal{M} \left(Y_t^n\right)^{\varphi}} \right]^{1-\eta} \right\}^{\frac{1}{1-\eta}}} \\ & + \upsilon \frac{\tau_{M,t}}{(1+\tau_{M,t})^{\eta}} \frac{\left[\frac{A_t^{1+\varphi} (1-\tau_t^n)}{\mathcal{M} \left(Y_t^n\right)^{\varphi}} \right]^{2-\eta}}{\left\{ (1-\upsilon) + \upsilon \left[\frac{(1+\tau_{M,t}) A_t^{1+\varphi} \left(1-\tau_t^n\right)}{\mathcal{M} \left(Y_t^n\right)^{\varphi}} \right]^{1-\eta} \right\}^{\frac{2-\eta}{1-\eta}}} \\ & - \left\{ (1-\upsilon) + \upsilon \left[\frac{(1+\tau_{M,t}) A_t^{1+\varphi} (1-\tau_t^n)}{\mathcal{M} \left(Y_t^n\right)^{\varphi}} \right]^{1-\eta} \right\}^{-\frac{1}{1-\eta}} G_t, \end{aligned} \tag{A.7}$$

where we use Eqs.(A.2) and (A.3) and $N_t^n = \frac{Y_t^n}{A_t}$ resulting from Eq.(15) and N_t^n denotes N_t in the flexible price equilibrium. The system consisting of Eqs.(A.4) to (A.7) determines Y_t^n as well as τ_t^n, SP_t^n and $\mathcal{B}_t^n$.

B FONCs for the Social Planner

B.1 Constrained Efficient Policy

The Lagrangian is given by:

$$\begin{aligned} \mathcal{L}_t \quad \equiv \quad & \mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\log C_t - \frac{1}{1+\varphi} N_t^{1+\varphi} \right) \\ & + \mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \lambda_{p,t} \left\{ 1 - \theta \Pi_{H,t}^{\varepsilon-1} - (1-\theta) \tilde{p}_{H,t}^{1-\varepsilon} \right\} \\ & + \mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \lambda_{y,t} \left[N_t - (1-\upsilon) S_t^{\eta} C_t^{1-\eta} - \upsilon \left(\frac{S_t}{1+\tau_{X,t}} \right)^{\eta} Y_t^* - G_t \right] \\ & + \mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \lambda_{r,t} \left\{ C_t - \frac{S_t}{\left[(1-\upsilon) + \upsilon (1+\tau_{M,t})^{1-\eta} S_t^{1-\eta} \right]^{\frac{1}{1-\eta}}} C_t^* \right\} \end{aligned}$$

$$+\mathrm{E}_0\sum_{t=0}^{\infty}\beta^t\lambda_{sp,t}\left[(1-\tau_t)\,SP_t-\tau_t C_t N_t^{1+\varphi}-\upsilon\,(1-\tau_t)\,(1+\tau_{M,t})^{-\eta}\,\tau_{M,t}C_t^{-(\eta-2)}\right]$$
$$+\mathrm{E}_0\sum_{t=0}^{\infty}\beta^t\lambda_{b,t}\left\{SP_{t+1}-\left(\frac{1}{\beta}\frac{C_t}{C_{t-1}}-\phi_B\right)SP_t-\left(\frac{1}{\beta}\frac{C_t}{C_{t-1}}-1\right)\left[\frac{\beta\,(1+\phi_B)-1}{\beta}\right]\mathcal{B}\right\}$$
$$+\mathrm{E}_0\sum_{t=0}^{\infty}\beta^t\lambda_{i,t}\left\{\frac{1}{\beta}\frac{\left[(1-\upsilon)+\upsilon\,(1+\tau_{M,t+1})^{1-\eta}\,S_{t+1}^{1-\eta}\right]^{\frac{1}{1-\eta}}}{\left[(1-\upsilon)+\upsilon\,(1+\tau_{M,t})^{1-\eta}\,S_t^{1-\eta}\right]^{\frac{1}{1-\eta}}}\frac{C_{t+1}}{C_t}\Pi_{H,t+1}-(1+i_t)\right\}$$

The FONCs are given by:

$$\begin{aligned}
(C_t)\quad:\quad & \frac{1}{C_t}-\lambda_{y,t}\,(1-\upsilon)\,S_t^{\eta}\,(1-\eta)\,C_t^{-\eta}+\lambda_{r,t}\\
&+\lambda_{sp,t}\left[-\tau_t N_t^{1+\varphi}+\upsilon\,(1-\tau_t)\,(1+\tau_{M,t})^{-\eta}\,\tau_{M,t}\,(\eta-2)\,C_t^{-(\eta-1)}\right]\\
&-\lambda_{b,t}\frac{1}{\beta}\frac{1}{C_{t-1}}\left(SP_t+\frac{\beta\,(1+\phi_B)-1}{\beta}\mathcal{B}\right)+\lambda_{b,t+1}\frac{C_{t+1}}{C_t^2}\left(SP_{t+1}+\frac{\beta\,(1+\phi_B)-1}{\beta}\mathcal{B}\right)\\
&-(1-\theta)\,(1-\varepsilon)\sum_{j=0}^{\infty}\beta^{-j}\lambda_{p,t-j}\tilde{p}_{H,t-j}^{-\varepsilon}\tilde{p}'_{H,t-j}\,(C_t)-\lambda_{i,t}\frac{1}{\beta}\frac{\mathcal{G}\,(S_{t+1},\tau_{M,t+1})}{\mathcal{G}\,(S_t,\tau_{M,t})}\frac{C_{t+1}}{C_t^2}\Pi_{H,t+1}\\
&+\lambda_{i,t-1}\beta^{-2}\frac{\mathcal{G}\,(S_t,\tau_{M,t})}{\mathcal{G}\,(S_{t-1},\tau_{M,t-1})}\frac{1}{C_{t-1}}\Pi_{H,t}=0 \qquad\qquad (\mathrm{B}.1)\\
(N_t)\quad:\quad & -N_t^{\varphi}+\lambda_{y,t}-\lambda_{sp,t}\tau_t C_t\,(1+\varphi)\,N_t^{\varphi}\\
&-(1-\theta)\,(1-\varepsilon)\sum_{j=0}^{\infty}\beta^{-j}\lambda_{p,t-j}\tilde{p}_{H,t-j}^{-\varepsilon}\tilde{p}'_{H,t-j}\,(N_t)=0, \qquad\qquad (\mathrm{B}.2)\\
(S_t)\quad:\quad & \lambda_{y,t}\left[-(1-\upsilon)\,\eta S_t^{\eta-1}C_t^{1-\eta}-\upsilon\eta\left(\frac{S_t}{1+\tau_{X,t}}\right)^{\eta-1}\frac{1}{1+\tau_{X,t}}Y_t^{*}\right]\\
&-\lambda_{r,t}C_t^{*}\frac{\chi_t-\upsilon\,(1+\tau_{M,t})^{1-\eta}\,(\mathcal{G}\,(S_t,\tau_{M,t}))^{\eta}\,S_t^{1-\eta}}{(\mathcal{G}\,(S_t,\tau_{M,t}))^2}\\
&-(1-\theta)\,(1-\varepsilon)\sum_{j=0}^{\infty}\beta^{-j}\lambda_{p,t-j}\tilde{p}_{H,t-j}^{-\varepsilon}\tilde{p}'_{H,t-j}\,(S_t)\\
&-\lambda_{i,t}\frac{1}{\beta}\frac{\mathcal{G}\,(S_{t+1},\tau_{M,t+1})}{\mathcal{G}\,(S_t,\tau_{M,t})}\frac{\upsilon\,(1+\tau_{M,t})^{1-\eta}\,S_t^{-\eta}}{(1-\upsilon)+\upsilon\,(1+\tau_{M,t})^{1-\eta}\,S_t^{1-\eta}}\frac{C_{t+1}}{C_t}\Pi_{H,t+1}\\
&+\lambda_{i,t-1}\beta^{-2}\frac{\mathcal{G}\,(S_t,\tau_{M,t})}{\mathcal{G}\,(S_{t-1},\tau_{M,t-1})}\frac{\upsilon\,(1+\tau_{M,t+1})^{1-\eta}\,S_t^{2-\eta}}{(1-\upsilon)+\upsilon\,(1+\tau_{M,t})^{1-\eta}\,S_t^{1-\eta}}\frac{C_t}{C_{t-1}}\Pi_{H,t}=0, \qquad\qquad (\mathrm{B}.3)\\
(\Pi_{H,t})\quad:\quad & -\theta\,(\varepsilon-1)\,\lambda_{p,t}\Pi_{H,t}^{\varepsilon-2}-(1-\theta)\,(1-\varepsilon)\sum_{j=0}^{\infty}\beta^{-j}\lambda_{p,t-j}\tilde{p}_{H,t-j}^{-\varepsilon}\tilde{p}'_{H,t-j}\,(\Pi_{H,t})\\
&+\lambda_{i,t-1}\beta^{-2}\frac{\mathcal{G}\,(S_t,\tau_{M,t})}{\mathcal{G}\,(S_{t-1},\tau_{M,t-1})}\frac{C_t}{C_{t-1}}=0, \qquad\qquad (\mathrm{B}.4)\\
(SP_t)\quad:\quad & \lambda_{sp,t}\,(1-\tau_t)-\lambda_{b,t}\left(\frac{1}{\beta}\frac{C_t}{C_{t-1}}-\phi_B\right)+\beta^{-1}\lambda_{b,t-1}=0, \qquad\qquad (\mathrm{B}.5)\\
(\tau_t)\quad:\quad & \lambda_{sp,t}\left[-SP_t-C_tN_t^{1+\varphi}+\upsilon\,(1+\tau_{M,t})^{-\eta}\,\tau_{M,t}C_t^{-(\eta-2)}\right]\\
&-(1-\theta)\,(1-\varepsilon)\sum_{j=0}^{\infty}\beta^{-j}\lambda_{p,t-j}\tilde{p}_{H,t-j}^{-\varepsilon}\tilde{p}'_{H,t-j}\,(\tau_t)=0, \qquad\qquad (\mathrm{B}.6)\\
(i_t)\quad:\quad & i_t\lambda_{i,t}=0\quad;i_t\geq 0\quad;\lambda_{i,t}\geq 0, \qquad\qquad (\mathrm{B}.7)
\end{aligned}$$

with $\tilde{p}'_{H,t}\,(V_t)\equiv\frac{\partial\tilde{p}_{H,t}}{\partial V_t}=\mathcal{M}\frac{\mathcal{Z}'_{p,t}(V_t)\mathcal{K}_{p,t}-\mathcal{K}'_{p,t}(V_t)\mathcal{Z}_{p,t}}{(\mathcal{K}_{p,t})^2}$, $\mathcal{Z}'_{p,t}\equiv\frac{\partial\mathcal{Z}_{p,t}}{\partial V_t}$ and $\mathcal{K}'_{p,t}\equiv\frac{\partial\mathcal{K}_{p,t}}{\partial V_t}$ for arbitrary variable V_t.

C Lump-sum Transfer Model

In the lump-sum transfer model, the primary balance is transferred to households in a lump-sum fashion, and the government does not issue debt. The government budget constraint is given by:

$$TR_t = SP_t$$

instead of Eq.(1), where TR_t denotes lump-sum transfer. The fiscal policy rule in Eq.(3) is not applicable. Then, the sequence of the budget constraint for households is given by:

$$P_t C_t + \mathrm{E}_t\left(\nu_{t,t+1} D_{t+1}\right) = D_t + W_t\left(1-\tau_t\right) N_t + P_t PR_t + P_t TR_t, \tag{C.1}$$

instead of Eq.(10). Here, the tax rate for labor income τ_t is exogenous.

Households maximize Eq.(8) subject to Eq.(C.1). Optimality conditions are given by Eqs.(11) and (12). International risk-sharing condition is given by Eq.(14). The price-setting behavior is given by Eq.(16) and (19).

The key difference in the lump-sum transfer model appears in the natural level of output.

D A Two-Country Economy Model

D.1 Households

The utility function is given by:

$$\mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t U\left(C_t^j, N_t^j\right), \tag{D.1}$$

with $U\left(C_t^j, N_t^j\right) \equiv \log C_t^j - \frac{1}{1+\varphi}\left(N_t^j\right)^{1+\varphi}$. Country F variables are denoted by a star.

The consumption index is given by:

$$C_t^j \equiv \left[(1-\upsilon)^{\frac{1}{\eta}}\left(C_{H,t}^j\right)^{\frac{\eta-1}{\eta}} + \upsilon^{\frac{1}{\eta}}\left(C_{F,t}^j\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{D.2}$$

The CPI in country H is defined by:

$$P_t \equiv \left[(1-\upsilon) P_{H,t}^{1-\eta} + \upsilon \tilde{P}_{F,t}^{1-\eta}\right]^{\frac{1}{1-\eta}}.$$

The CPI in country F is defined analogously.

Substituting the optimal allocations for generic goods and for bundles of goods produced in both countries into the households' flow budget constraint yields:

$$P_t C_t^j + \mathrm{E}_t\left(\xi_{t,t+1} D_{t+1}^j\right) \leq D_t^j + W_t\left(1-\tau_t\right) N_t^j + P_t PR_t^j.$$

Households' intratemporal and intertemporal optimality conditions are given by:

$$U_{c,t}\frac{W_t\left(1-\tau_t\right)}{P_t} = -U_n, \tag{D.3}$$

$$\beta \mathrm{E}_t\left(\frac{P_t}{P_{t+1}}\frac{U_{c,t+1}}{U_{c,t}}\right) = \xi_{t,t+1}, \tag{D.4}$$

The optimality conditions in country F are given analogously.

Combining Eq.(D.4) with its Foreign counterpart, the UIP $1+i_t^* \equiv \mathrm{E}_t\left[(1+i_t)\left(\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}\right)^{-1}\right]$ and imposing the initial condition yields an international risk-sharing condition identical to Eq.(14).

D.2 Domestic Firms and Price Setting

Firm technology in country H is given by Eq.(15), and the counterpart in country F is defined analogously. The firms' optimality condition in country H is given by Eq.(16), while the counterpart in country F is defined analogously.

D.3 Government

The government budget constraint in country H is given by Eq.(1), while its counterpart in country F is defined analogously. The primary balance in country H is given by Eq.(2), and the Foreign counterpart is defined analogously. The fiscal policy rule in country H is given by Eq.(3), while the counterpart in country F is defined analogously.

D.4 Market Clearing

Market-clearing conditions in countries H and F are given by:

$$Y_t = \left[\mathcal{G}\left(S_t, \tau_{M,t}\right)\right]^{\eta}\left[(1-\upsilon)\, C_t + \upsilon\left(1+\tau_{M,t}^*\right)^{-\eta}\left(E_t^r\right)^{\eta} C_t^*\right] + G_t, \tag{D.5}$$

$$Y_t^* = \left[\mathcal{G}^*\left(S_t, \tau_{M,t}^*\right)\right]^{\eta}\left[(1-\upsilon)\left(1+\tau_{M,t}\right)^{-\eta}\left(E_t^r\right)^{-\eta} C_t + \upsilon C_t^*\right] + G_t^*. \tag{D.6}$$

E Robustness to the Fiscal-Response Parameter

This appendix examines the robustness of the nominal-interest-rate responses to a larger surplus-debt feedback parameter. The benchmark calibration sets $\phi_B = 0.02$. Here we set $\phi_B = 0.03$, which is close to the upper boundary of the determinate region in the two-country benchmark model. A larger value of ϕ_B strengthens the required primary-surplus response to outstanding debt and therefore changes the residual labor-income-tax adjustment induced by tariff revenues.

Fig. 14 reports the small open economy results. Relative to the benchmark calibration, the decline in the nominal interest rate is attenuated in the benchmark-persistency case. However, the nominal interest rate still reaches the ZLB under high tariff persistency and under lower price stickiness. Hence, the small open economy result is not driven solely by the baseline value $\phi_B = 0.02$.

Fig. 15 reports the two-country results for a unilateral import-tariff shock in country H. The threshold pattern documented in the main text remains present. The ZLB is more likely to bind in country H when the tariff shock is larger and when country H is smaller and more open. The spillover to country F remains limited when country H is very small.

Fig. 16 reports the corresponding results for reciprocal tariff increases. Reciprocal tariffs strengthen the ZLB pressure relative to unilateral tariff increases. Even with $\phi_B = 0.03$, the ZLB can bind under relatively small tariff shocks when the countries are sufficiently exposed to each other. These results indicate that the ZLB mechanism is not an artifact of the benchmark value $\phi_B = 0.02$.

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Figure 1: Impulse Responses to a 20% Rise in Import Tariffs under the Ramsey (Constrained-Efficient) Optimal Allocation in the Benchmark Parameterization: Comparison with the Lump-sum Tax Model

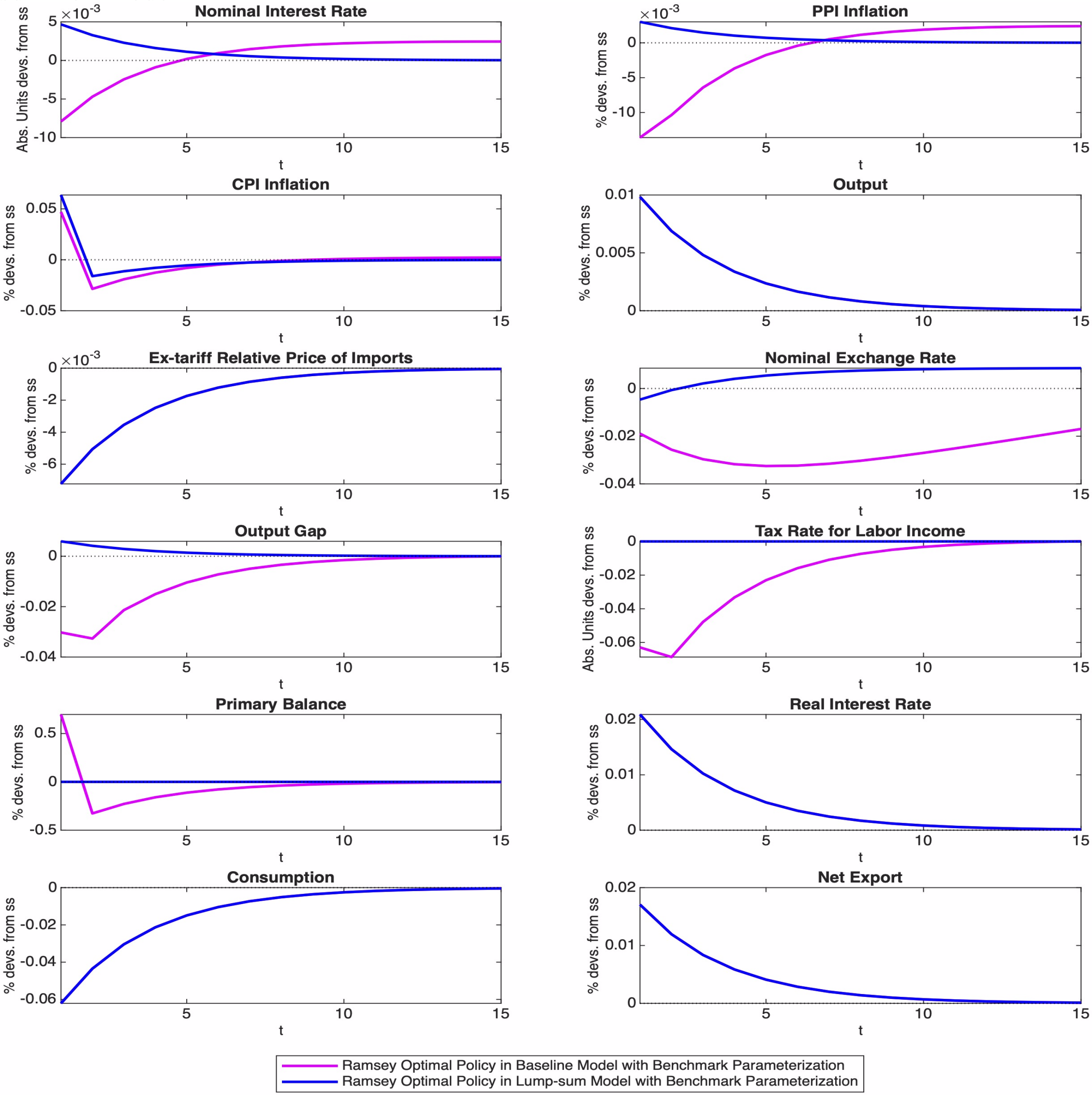

Figure 2: Impulse Responses to a 20% Rise in Import Tariffs under the Ramsey (Constrained-Efficient) Optimal Allocation in the Benchmark Parameterization: Tightening Bias under CPI Inflation Targeting

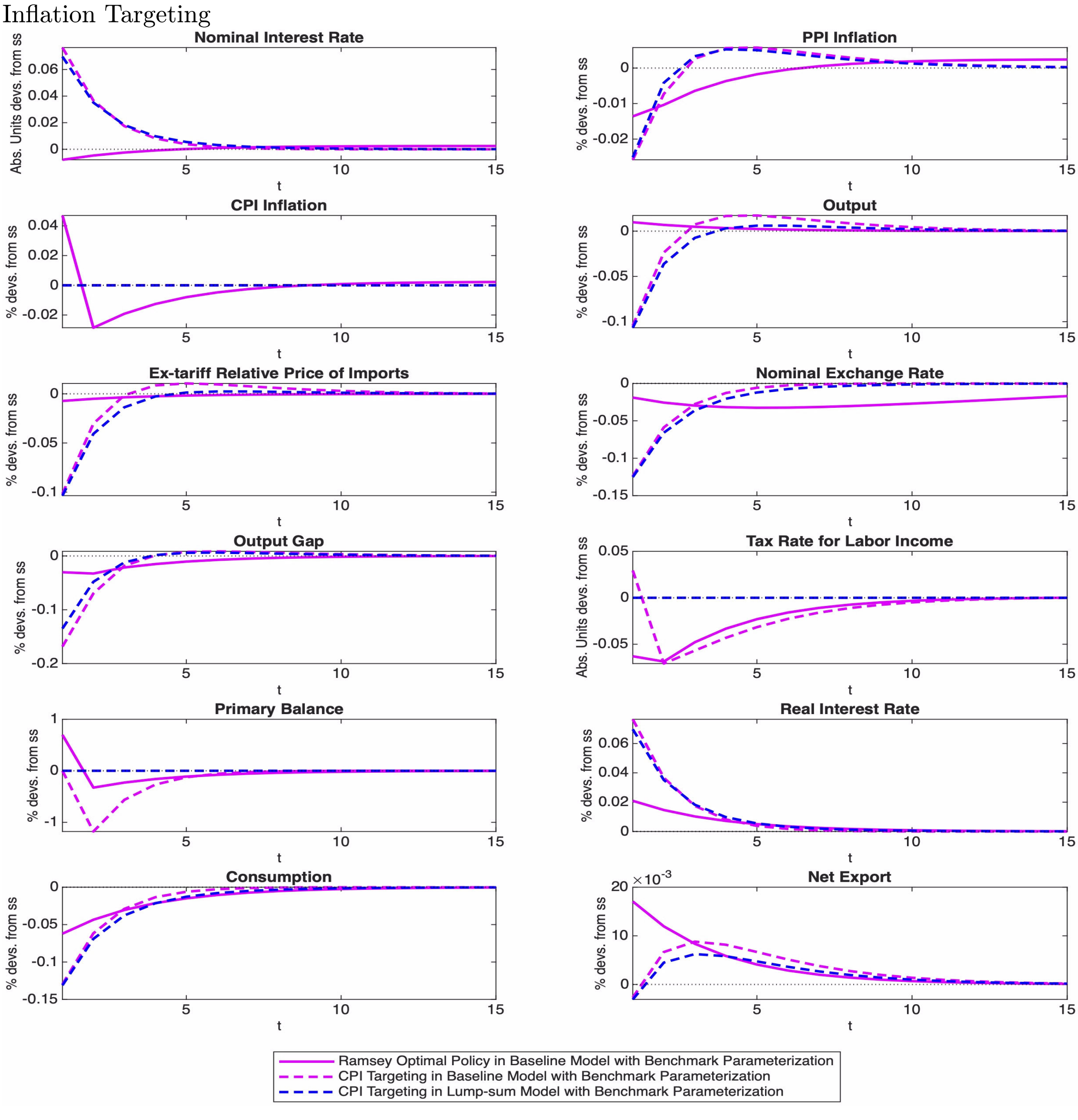

Figure 3: Impulse Responses to a 20% Rise in Import Tariffs under the Ramsey (Constrained-Efficient) Optimal Allocation in the High Persistence: Comparison with the Lump-sum Tax Model

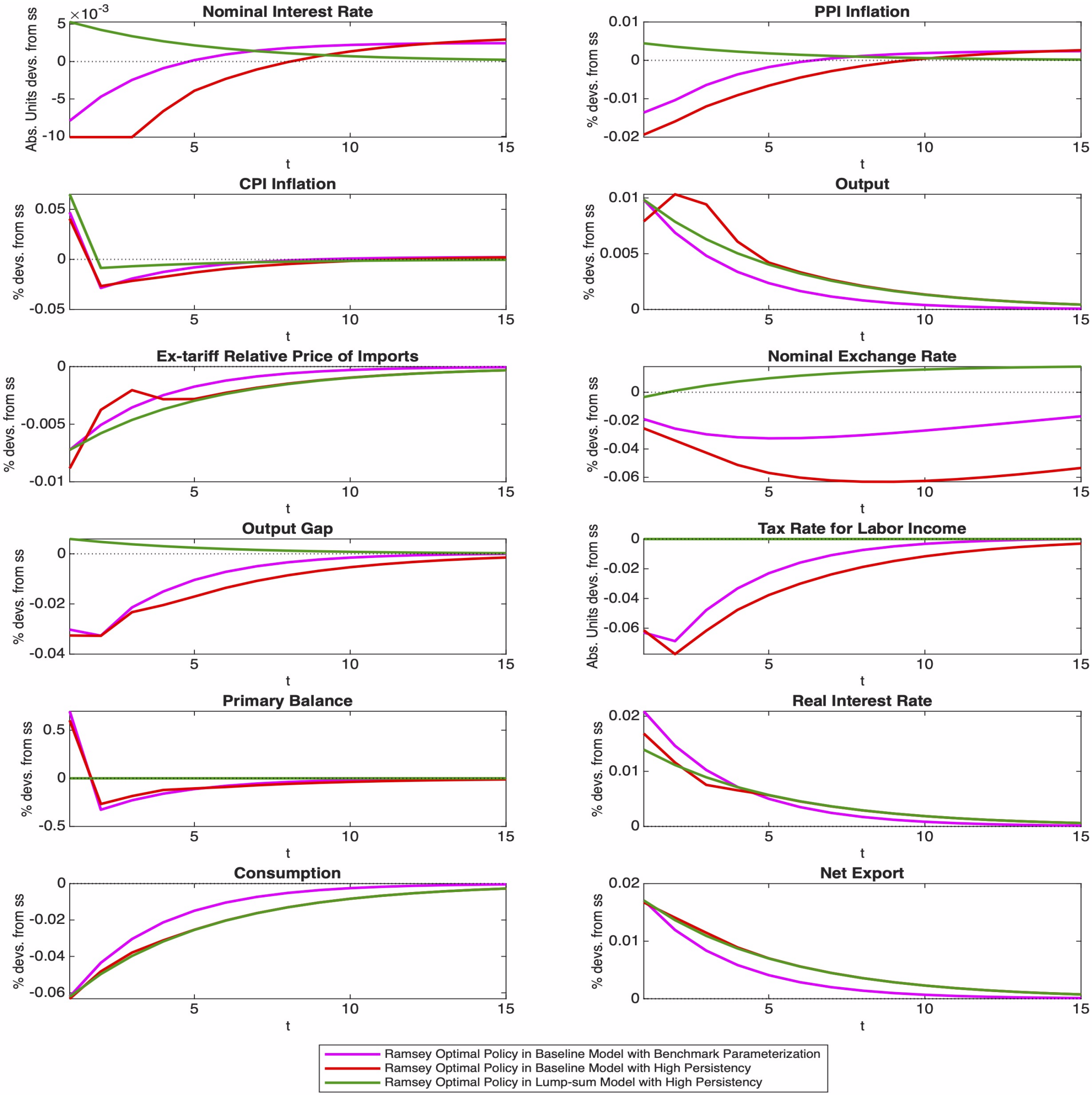

Figure 4: Impulse Responses to a 20% Rise in Import Tariffs under the Ramsey (Constrained-Efficient) Optimal Allocation in the Low Stickiness: Comparison with the Lump-sum Tax Model

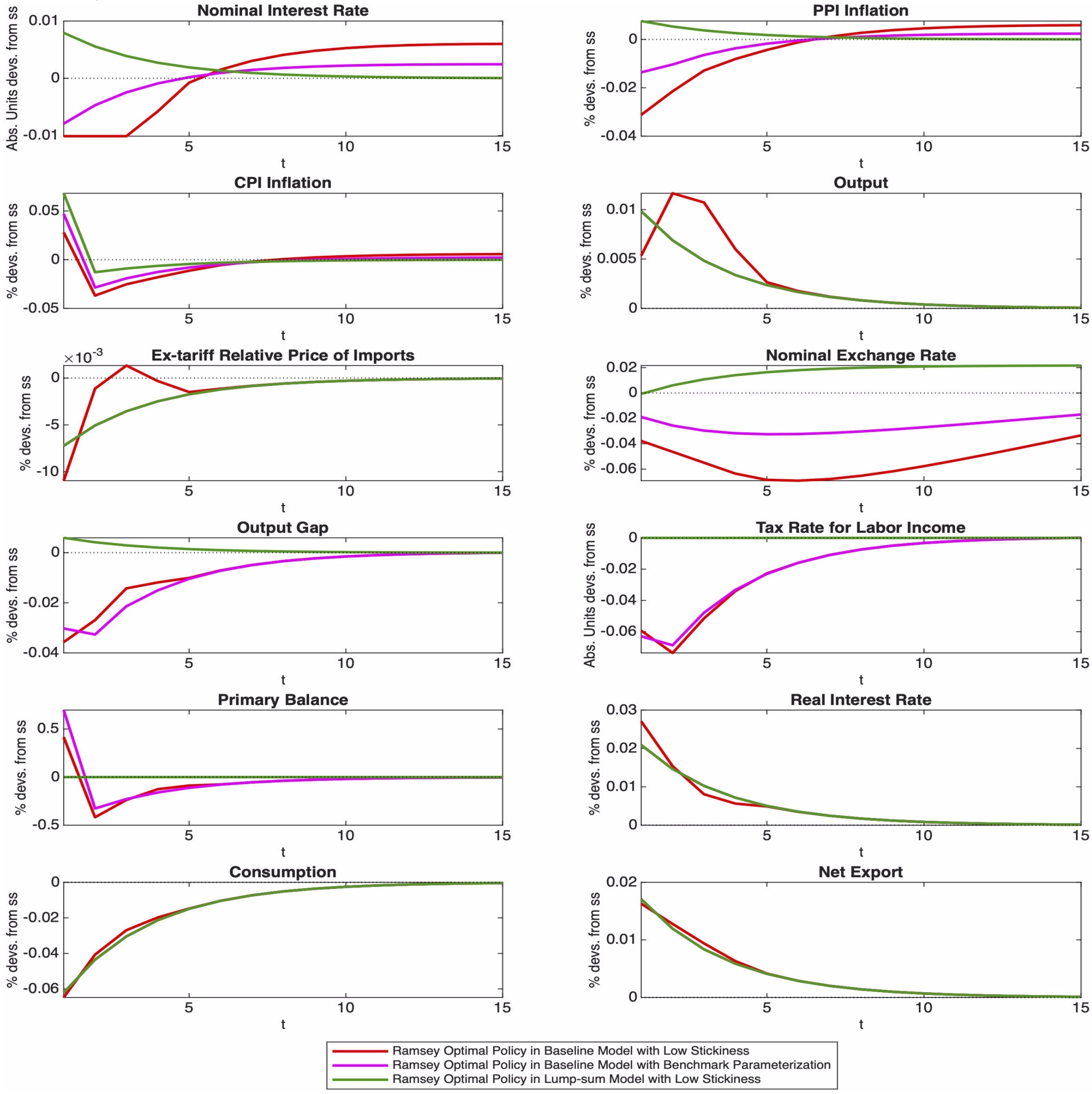

Figure 5: Impulse Responses to a Benchmark 20% Increase in the Import Tariff under the Ramsey (Constrained-Efficient) Optimal Allocation in Country H: The Case of Same-Size Countries

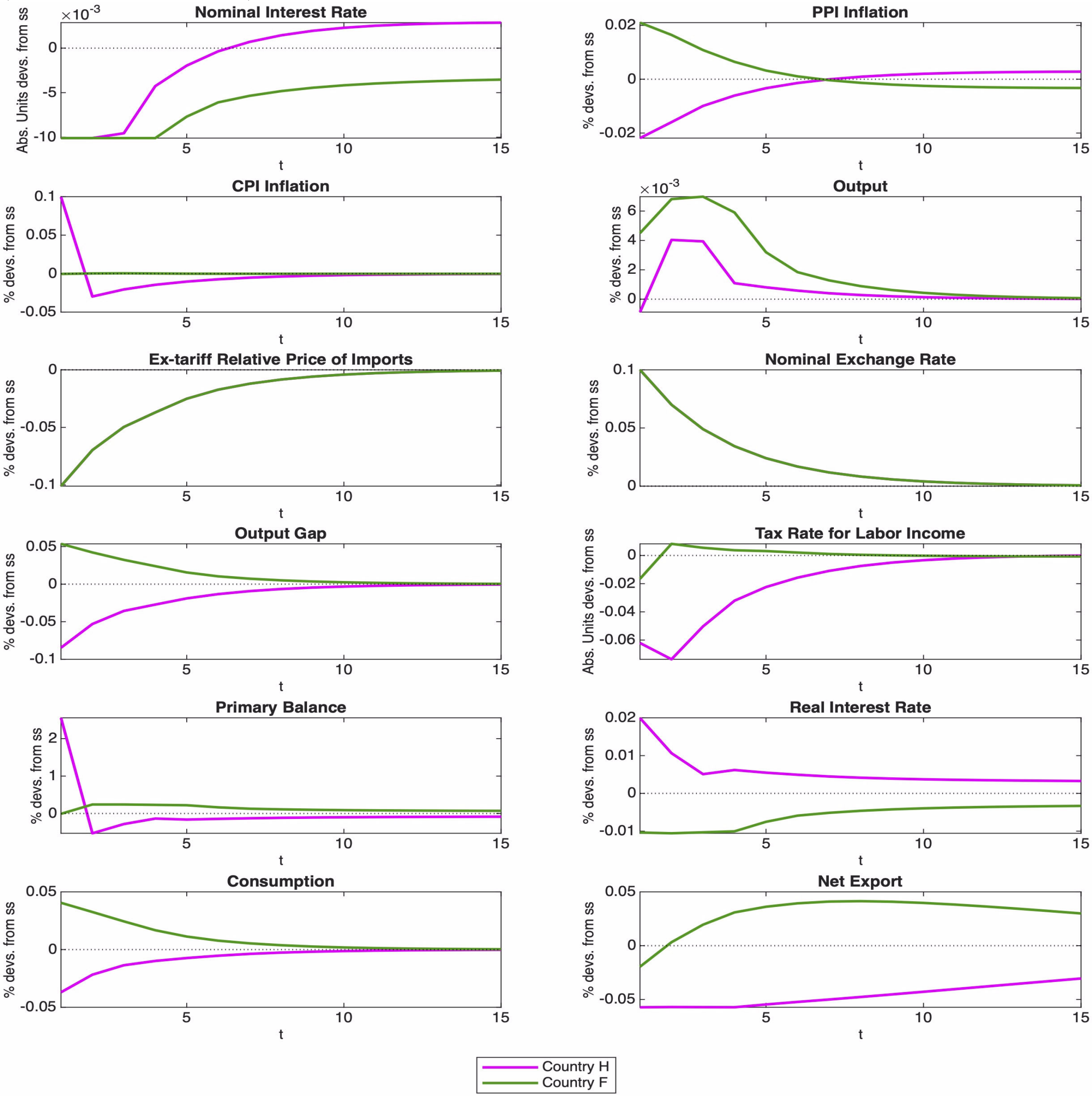

Figure 6: Impulse Responses to a Benchmark 20% Increase in the Import Tariff under the Ramsey (Constrained-Efficient) Optimal Allocation in Country H: The Case of a U.S.-GDP-Size Country

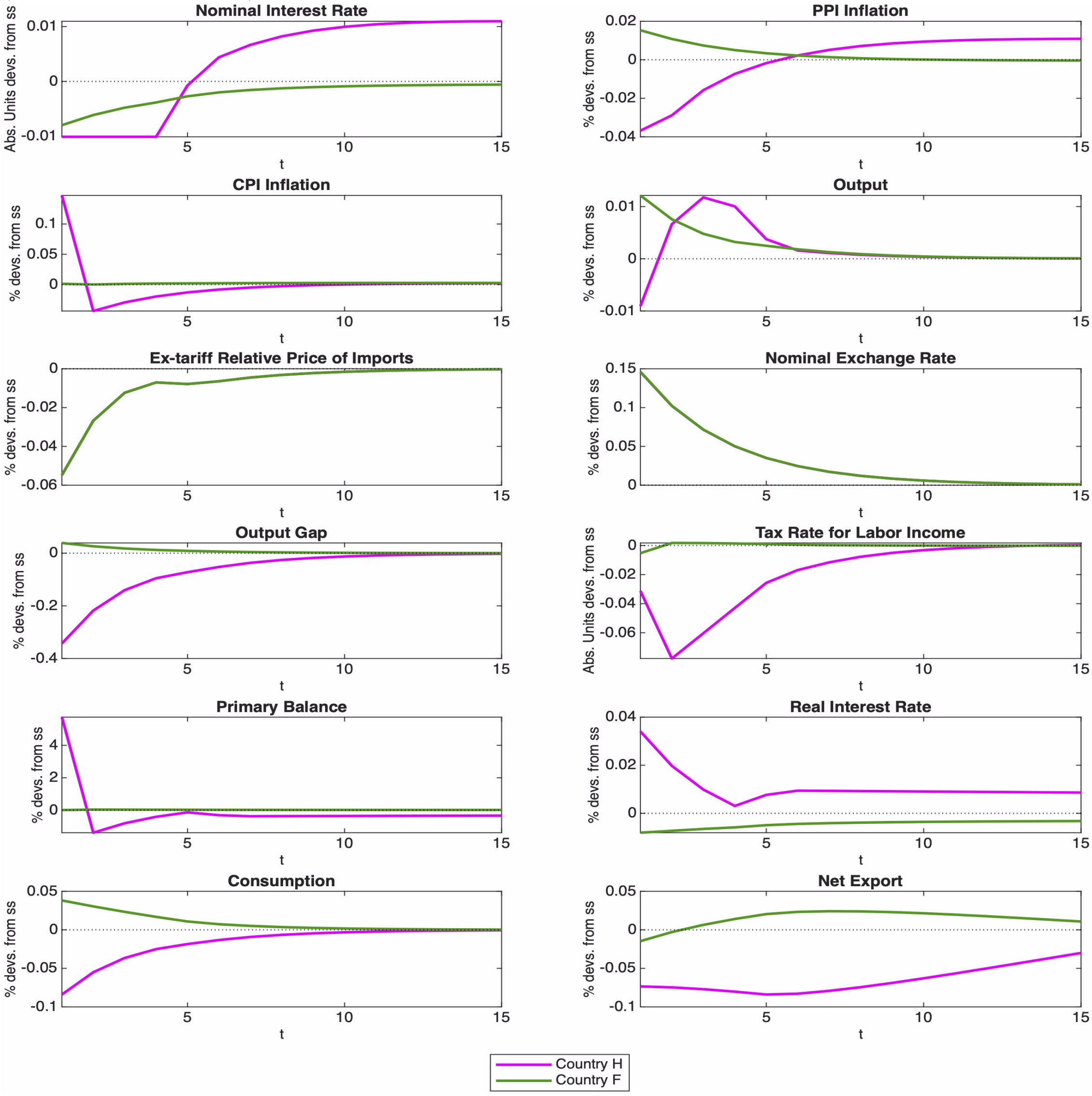

Figure 7: Impulse Responses to a 20% Increase in the Import Tariff in Country H under the Ramsey (Constrained-Efficient) Optimal Allocation: The Case of a Small Tariff-Imposing Country

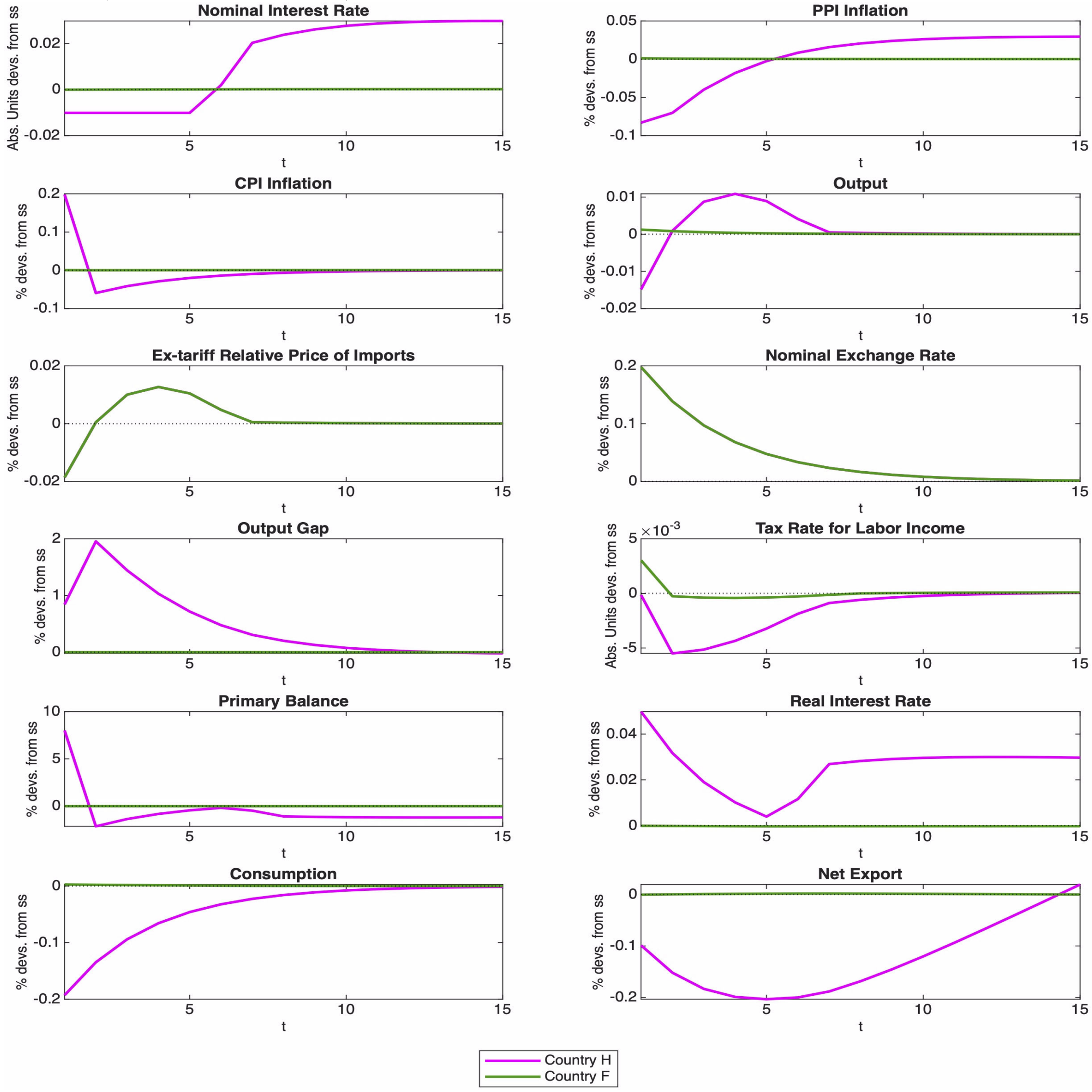

Figure 8: Impulse Responses of the Nominal Interest Rate to Increases in the Import Tariff in Country H under the Ramsey (Constrained-Efficient) Optimal Allocation: Alternative Tariff Sizes and Country Sizes. Panels 6 and 7 report the Home and Foreign nominal-interest-rate responses to a 5% tariff increase.

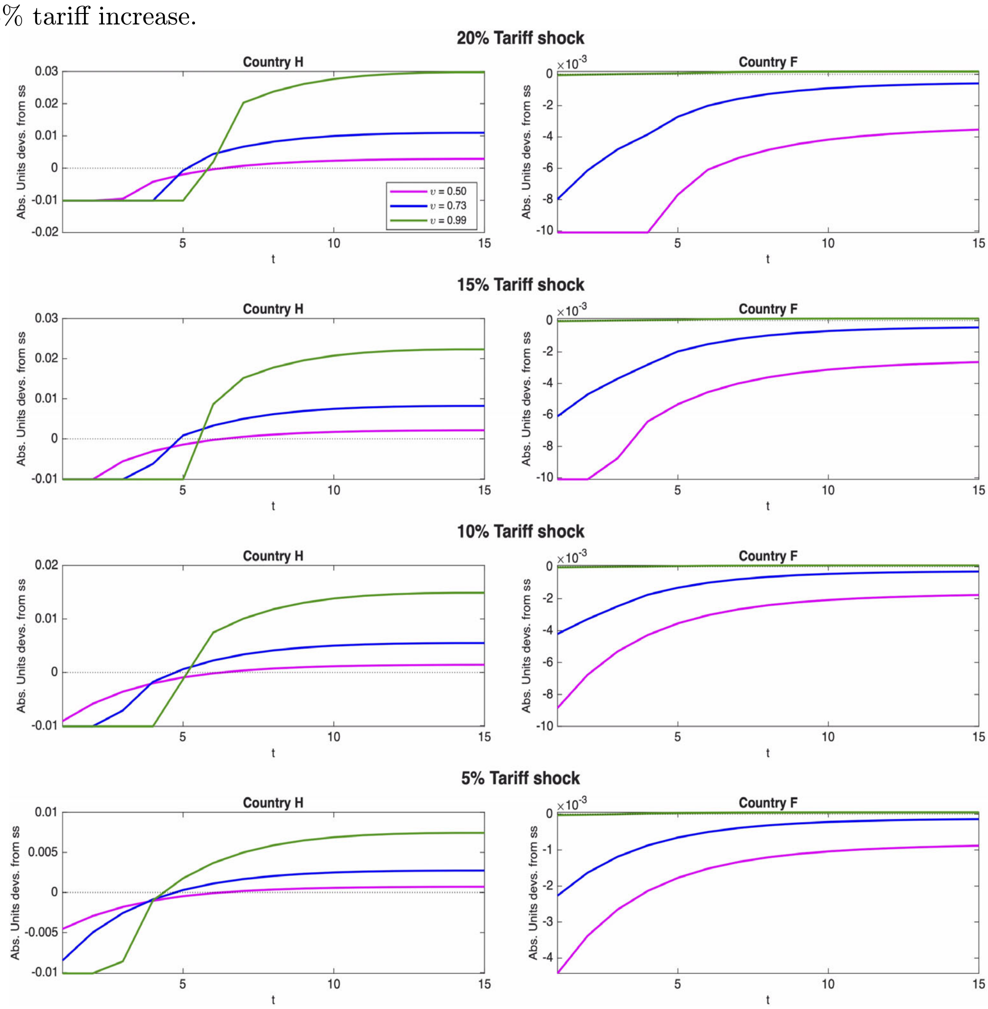

Figure 9: Impulse Responses to a 20% Increase in the Import Tariff in Country F under the Ramsey (Constrained-Efficient) Optimal Allocation: The Case of a Small Country H Hit by Foreign Import Tariffs

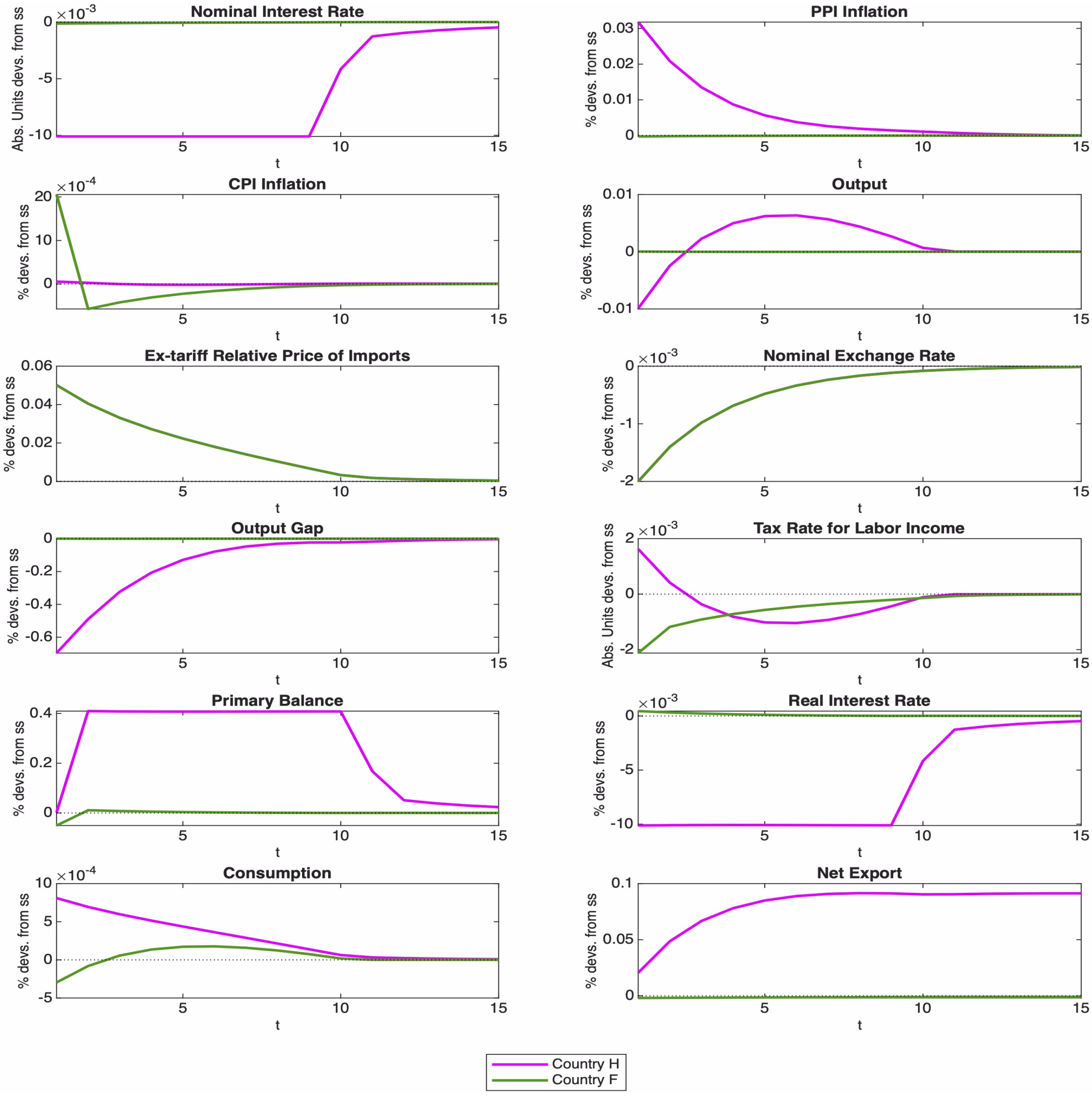

Figure 10: Impulse Responses to a 20% Reciprocal Increase in Import Tariffs under the Ramsey (Constrained-Efficient) Optimal Allocation: The Case of Same-Size Countries

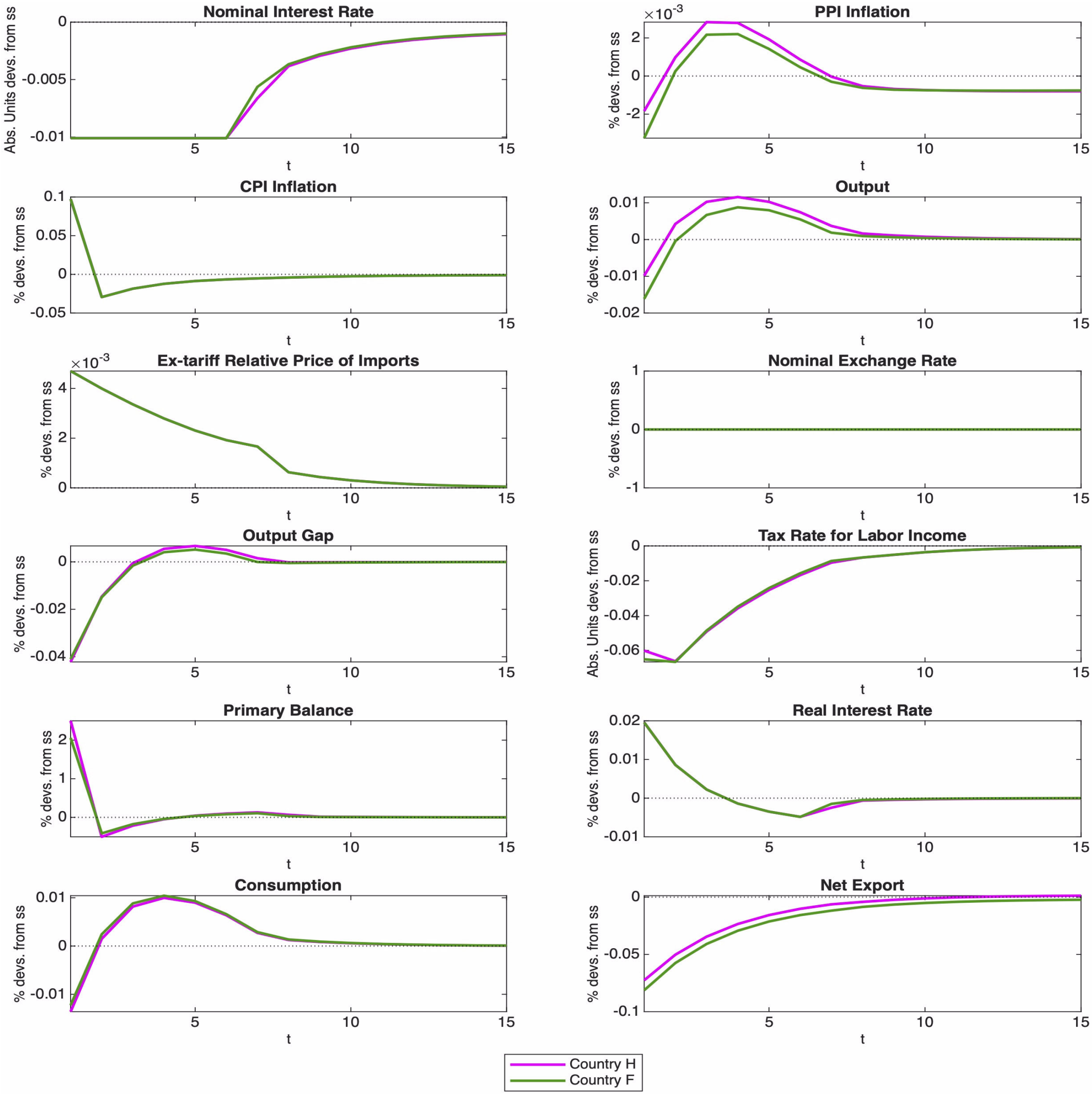

Figure 11: Impulse Responses to a 20% Reciprocal Increase in Import Tariffs under the Ramsey (Constrained-Efficient) Optimal Allocation: The Case of a U.S.-GDP-Size Country H

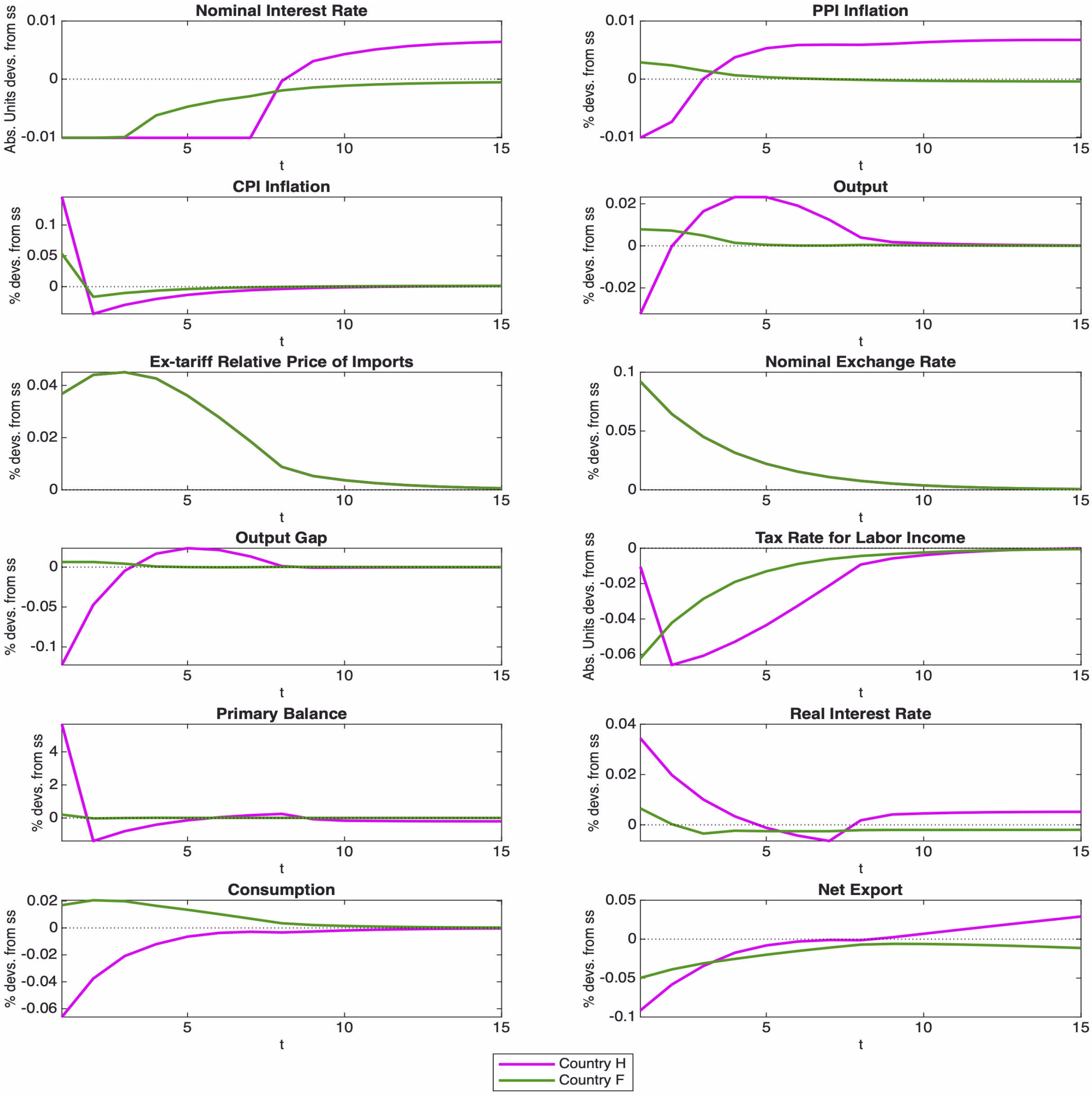

Figure 12: Impulse Responses to a 20% Reciprocal Increase in Import Tariffs under the Ramsey (Constrained-Efficient) Optimal Allocation: The Case of a Small Country H

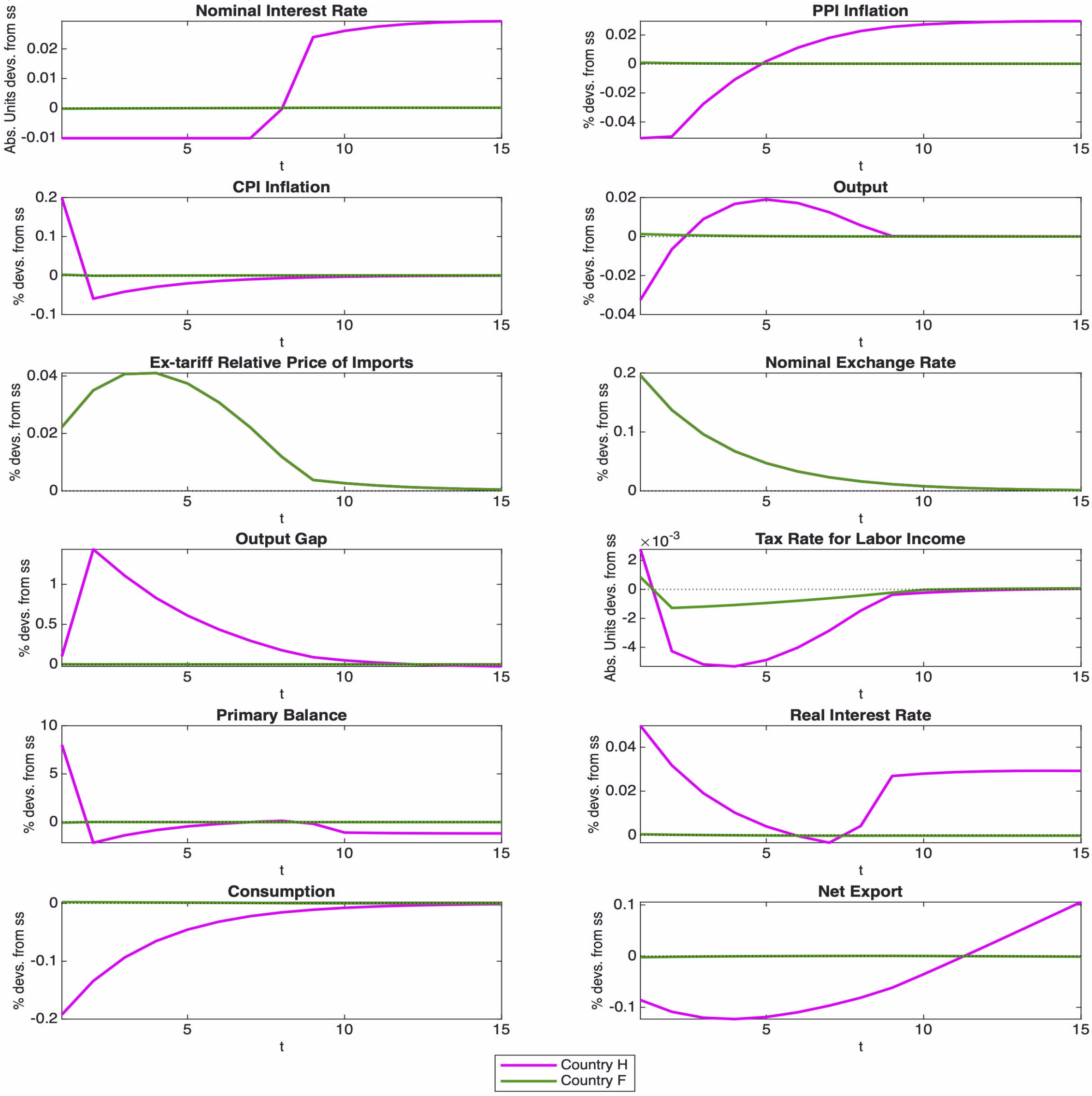

Figure 13: Impulse Responses of the Nominal Interest Rate to Reciprocal Tariff Increases under the Ramsey (Constrained-Efficient) Optimal Allocation: Alternative Tariff Sizes and Country Sizes. Panels 6 and 7 report the Home and Foreign nominal-interest-rate responses to a 5% reciprocal tariff increase.

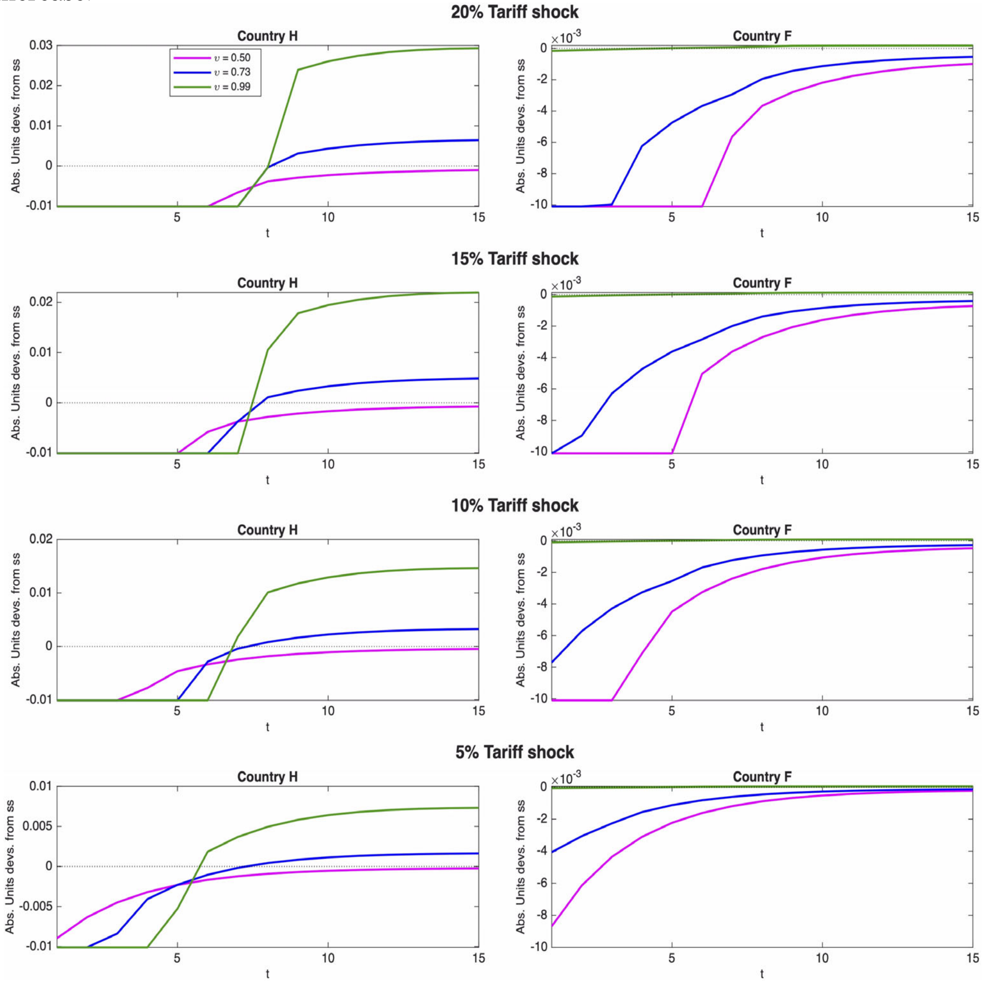

Figure 14: Robustness to the Fiscal-Response Parameter: Impulse Responses of the Nominal Interest Rate in the Small Open Economy Model with $\phi_B = 0.03$

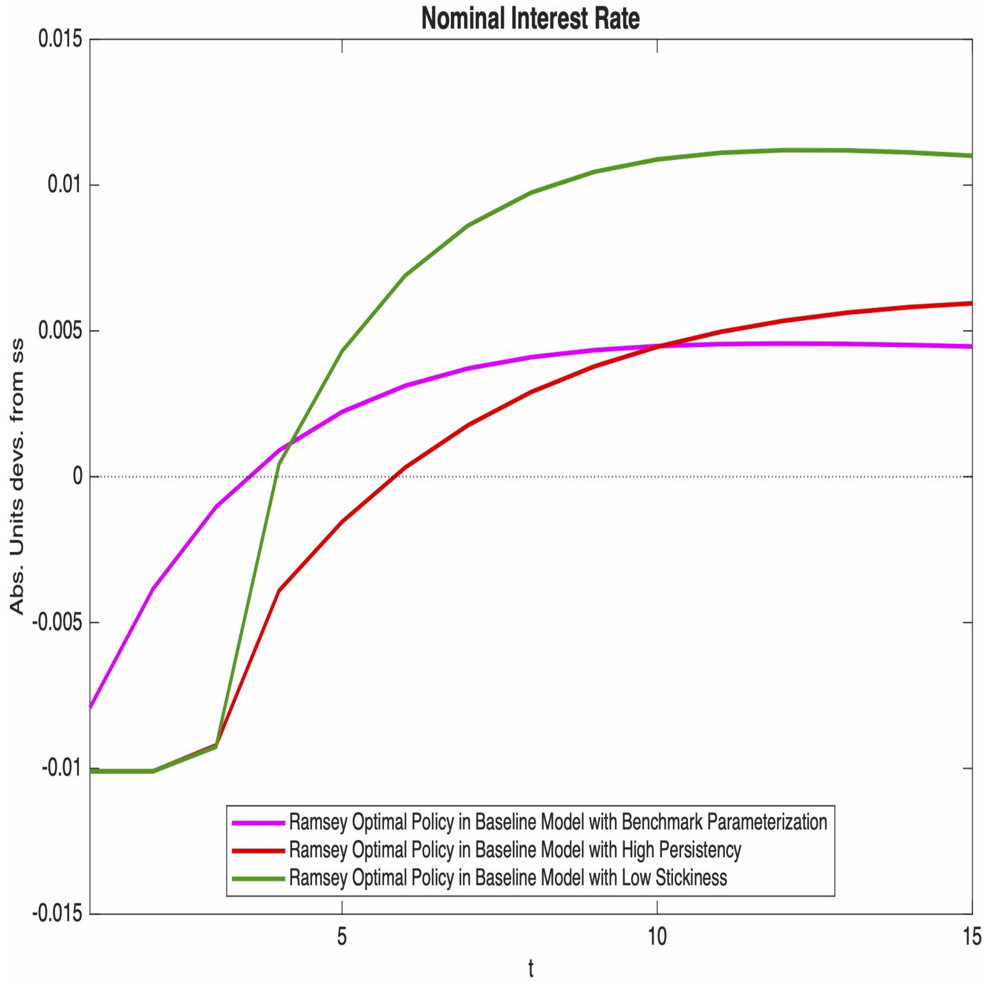

Figure 15: Robustness to the Fiscal-Response Parameter: Impulse Responses of the Nominal Interest Rate to Import Tariff Increases in Country H in the Two-Country Model with $\phi_B = 0.03$

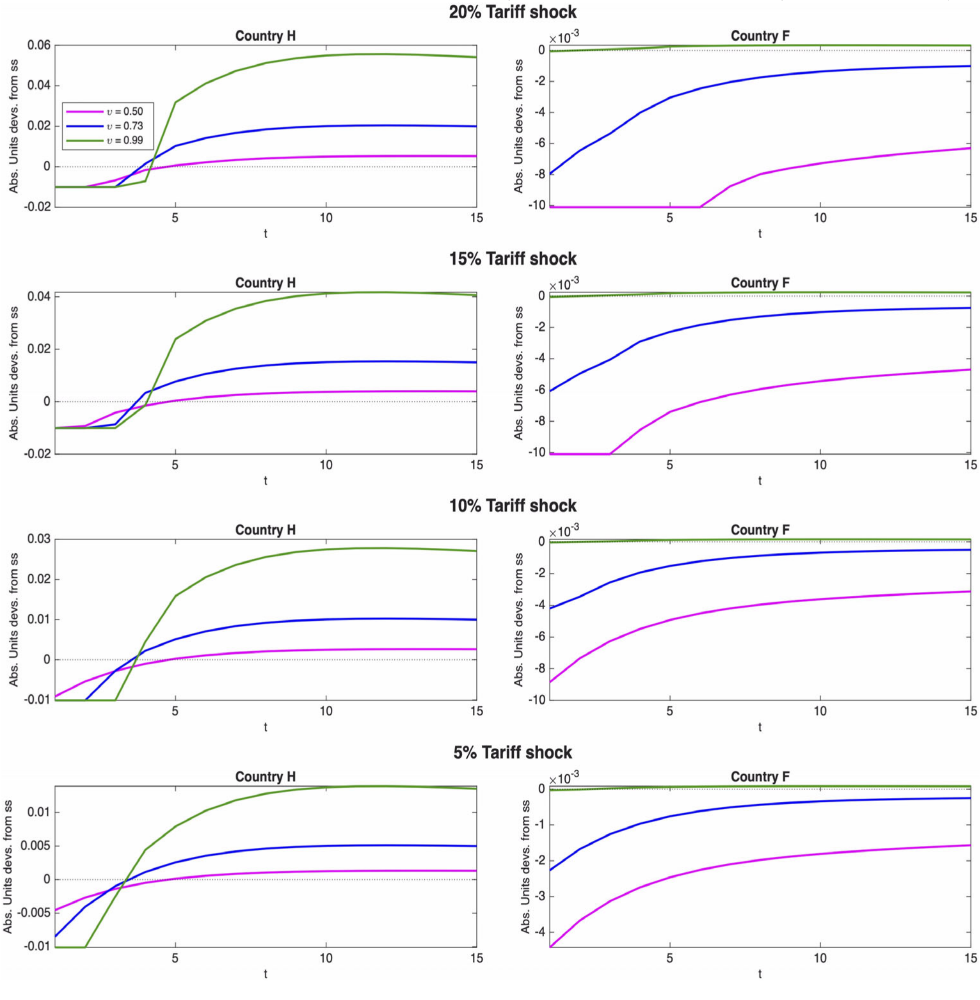

Figure 16: Robustness to the Fiscal-Response Parameter: Impulse Responses of the Nominal Interest Rate to Reciprocal Tariff Increases in the Two-Country Model with $\phi_B = 0.03$