The Macroeconomic Effects of Trade Tariffs: Revisiting the Lerner Symmetry Result*

Jesper Lindé
Sveriges Riksbank and CEPR

Andrea Pescatori
IMF

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Abstract

We study the robustness of the Lerner symmetry result in an open economy New Keynesian model with price rigidities. While the Lerner symmetry result, i.e. the absence of allocative and trade-flow effects of an equally-sized change in import tariff and export subsidy, holds up approximately for a number of alternative assumptions, we obtain quantitatively important long-term deviations under complete international asset markets. Direct pass-through of tariffs and subsidies to prices and slow exchange rate adjustment can also generate significant short-term deviations from Lerner. Deviations from symmetry, however, do not necessarily imply an impact on global output and are often limited to a redistribution of production and consumption across countries. Finally, we quantify the macroeconomic costs of a trade war and find that they can be substantial, with permanently lower income and trade volumes. However, a fully symmetric retaliation to an unilaterally imposed border adjustment tax can prevent any sizable adverse real or nominal effects.

JEL Classification: E52, E58

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1. Introduction

Recent U.S. tax reform proposals (see e.g. Auerbach et al., 2017, and Ryan and Brady, 2017) have renewed the interest in understanding the macroeconomic effects of commercial policies. The suggested proposals implicitly include a border adjustment of corporate income taxes (BAT henceforth) that allows firms to subtract export revenues from their taxable profits but not import costs. Under quite general conditions, a BAT is equivalent to a combination of an import tariff and export subsidy of the same rate.[1] This means that is possible to assess the macroeconomic implications of a BAT reform by studying the macroeconomic effects of trade policies. The traditional views on the effects of a BAT adjustment in the academic literature can be broadly grouped into two camps: one sees the BAT akin to a protectionist measure able to stimulate output under nominal rigidities (Keynesian view); the other one, instead, contends the macroeconomic neutrality of BAT by highlighting the role of the exchange rate adjustment (Mundellian view).[2]

A long standing result in the trade literature underpins the view that BATs have allocative neutrality. In a seminal paper, Lerner (1936) established the equivalence between import and export tariffs: in a deterministic environment, an import tariff coupled with an equally-sized export subsidy leads the real and nominal exchange rate to fully offset the price distortions induced by the trade policy and leaves the real equilibrium allocation unaffected (often referred to as the Lerner symmetry theorem).[3] This result has also been proved to

[1] See Erceg et al (2017) for a discussion of the equivalence between BAT and import-export tariffs.

[2] The Mundellian and Keynesian views are usually mentioned in relation to the effects of trade policies more broadly. For instance, Krugman (1982) writes "*The Keynesian revolution of the 1930s opened a Pandora's box of justifications for tariffs and quotas. [...] The result was a temporary respectability for commercial policy. [...] [However] if the exchange rate were allowed to float freely, tariffs and quotas might not promote employment; they might even have a perverse effect.*" In what follows, we take the liberty to label the view that a BAT is neutral for the real economy as the Mundellian view.

[3] The Lerner theorem was originally derived in a simple static neoclassical economy with two countries and two final goods and no other distortions.

hold in more general contexts with multiple intermediate goods (see McKinnon, 1966, and Grossman, 1980) and under monopoly pricing (Eaton et al., 1983) — while Razin and Svensson (1983) and recent work by Erceg, Prestipino and Raffo (2017) show that the change in trade policy must be perceived as permanent for the theorem to hold.

The recent macroeconomic literature, however, has paid little attention to the effects of changes in tariffs in empirically validated macroeconomic models. Hence, except for a couple of recent papers (discussed in further detail below), the quantitative macroeconomic effects of tariffs have not been studied at length.[4] In this paper, we reassess the generality of the Lerner symmetry result and quantify deviations from it in a fully-fledged open economy New Keynesian DSGE model with capital and Keynesian households. The model assumes that the relocation of production technology is not feasible and that consumers are immobile between countries — two conditions that Costinot and Werning (2017) demonstrate are necessary for the Lerner symmetry result.[5] We use the model to study the role of alternative firm-pricing behavior, exchange rate determination mechanisms, and asset market assumptions. We also assess a universal BAT adoption and trade wars.

Distinct from Costinot and Werning (2017), our goal is mainly quantitative and we highlight the role of trade policy uncertainty by studying the implications of complete markets. Our paper also complements Barbiero et al. (2018) and Erceg et al. (2017) who focus on the incomplete market case in model environments without capital and liquidity constrained households.[6] Barattieri et al (2017), instead, focuses on protectionist tariffs empirically and

[4] Eichengreen (1981, 1983) was the first to use a dynamic rational expectation framework to study trade policies and found a temporary boost (but long-term decline) in output from the introduction of import tariffs.

[5] Moreover, we assume that trade is balanced in the steady state. This assumption per se is innocuous when the conditions for Ricardian equivalence hold (see Costinot and Werning, 2017). In a non-Ricardian setup a trade deficit is a sufficient condition to break up the Lerner symmetry, however, for a calibration to the US economy the deviation is probably still quantitatively small.

[6] Neither Barbiero et al (2017) nor Erceg et al (2017) setups allow for endogenous capital accumulation

in a small open economy a la Melitz-Ghironi (Ghironi and Melitz, 2007).

Under incomplete markets and no valuation effects (foreign asset and liabilities are exclusively in terms of foreign-currency bonds), we find that the Lerner symmetry result is very robust in the long-term since the equilibrium real exchange rate eventually fully offsets the price distortions introduced by the BAT. Valuation effects can cause long-run deviations from Lerner symmetry. Nonetheless, the quantitative difference from the benchmark no-valuation-effect case is likely to be modest as the transfer to the rest of the world is small relative to home wealth (albeit large as a fraction of annual GDP).[7]

In the short-term, however, Lerner symmetry breaks down when frictions prevent the real exchange rate to fully adjust immediately. It is useful to distinguish between frictions that prevent price adjustment and those that prevent nominal exchange rate adjustment. Under perfectly flexible exchange rates, sticky prices and wages per se do not break the Lerner symmetry as long as the pass-through from the exchange rate and tariffs to import prices is the same across exporters — an assumption that finds empirical support in Feenstra (1989).[8] So even if import prices are subject to local currency pricing (LCP), and export prices are subject to producer currency pricing (PCP), a permanent and unanticipated BAT reform will not have any effect on the real equilibrium regardless of nominal and real rigidities, home bias in investment and/or consumption, different import intensity for investment and consumption, or sectorial differences in these rigidities.

Since a combination of LCP in the import sector and PCP in the export sector can be thought of as dollar-invoicing, it follows that dollar invoicing does not automatically break

and non-ricardian consumers. Their focus is on the role of other assumptions such as foreign asset holdings, currency invoicing, and partial and temporary implementation of the BAT.

[7] Barbiero et al (2018) finds that valuation effects from asset holdings in US dollar break the Lerner symmetry and amplify the positive home output response to a temporary BAT reform.

[8] Feenstra (1989) does not reject the null hypothesis that long-run pass-through of tariffs and exchange rates are identical for the Japanese automotive industry.

the Lerner symmetry, in contrast to the findings in Amiti et al. (2017) and Barbiero et al. (2017).[9] The reason why Lerner fails in their dominant currency pricing (DCP) setting is that the export subsidy have a full and immediate pass-through to export prices whereas exchange rate movements are only passed on gradually. We also find Lerner symmetry breaks down when we assume that the exchange rate pass-through differs from tariff pass-through in either of the import and export sectors under dollar invoicing. Specifically, when tariffs are passed on to prices more quickly than exchange rate movements, the exchange rate overshoots and the home country output expands while global trade and output are unaffected. The effects are more modest when only import tariffs are passed quickly to prices, but global trade and output still decline as exporters increase their margins but cut production in response to lower demand.

Moreover, unless good prices are fully flexible in both countries, the nominal exchange rate determination mechanism will play a key role. The main intuition behind the symmetry result is that the exchange rate response is driven solely by an adjustment in the long-term equilibrium exchange rate. This represents a pure change in expectations which does not require any movement in cross-country interest rate differentials (and, thus, consumption-saving decisions for the two countries are unaffected). If the trade policy is anticipated, however, the exchange rate strengthens too early leading to an initial decline in home output, though with a quantitatively minor impact. Gradual adjustment of the exchange rate, on the other hand, induces a sustained expenditure switch towards home products, which leads to an increase in home output and a drop in output abroad. At the extreme, we show that a nominal currency peg may lead to a significant fall in foreign output and a substantial

[9] By dollar invoicing, we mean that tradable goods are priced in U.S. dollar regardless of their destination.

decline in global trade and output in our sticky price framework since foreign monetary policy cannot respond to domestic conditions.

While alternative pricing arrangements and slow nominal exchange rate adjustment only generate transient deviations from Lerner symmetry, complete international asset markets (i.e., a set of Arrow-Debreu securities contingent on tariffs exist) cause the symmetry result to break in the long-term. In this case, an appreciation of the home currency (e.g., the U.S. dollar) following a BAT shock triggers payoffs from the contingent contracts (i.e., a redistribution) from the U.S. to the rest of the world, similar to a portfolio effect. This implies that the real exchange rate appreciates by a smaller extent (relative to the BAT rate shock) and cannot fully offset the price distortions induced by the trade policy.[10] Global trade and output are still unaffected but production shifts to the home country while consumption is shifted abroad.[11] In terms of magnitudes, the effects are rather large: under our benchmark calibration which roughly reflects trade flows and relative sizes of the U.S. and the Euro Area, a home economy (e.g., U.S.) 10 percent BAT shock leads to a one percent increase (drop) in home (foreign) output and two percent decline (rise) in home (foreign) consumption while the real exchange rate appreciates by 6 percent. Importantly, for the complete markets assumption to be relevant it is sufficient that only a small mass of households has access to a complete set of state contingent claims. Even though the largest share of the population may be hand-to-mouth consumers and do not participate in financial markets, the symmetry will break down, see Kollmann (2011, 2015) for further discussion.

Finally, a fully symmetric retaliation that implies an analogous border adjustment tax

[10] Notice that payoffs are specified in nominal (not physical) terms. Hence, because purchasing power parity does not hold, asset markets do not imply full consumption insurance.

[11] Dellas and Stockman (1986) and Barari and Lapan (1993) were among the first papers that showed how traditional trade theory results could be overturned under complete international asset markets.

in the foreign country is completely neutral. This result is quite robust since it does not rely on exchange rate movements. However, if the retaliation is performed solely through higher import tariffs to offset the export subsidy and match the increase in the tariff in the home economy, then global trade and output will be negatively affected. When the model is calibrated to reflect trade flows and relative sizes of the U.S. and the rest of the world, it implies that a 10 percent rise in import tariffs in both the U.S. and the rest of the world block leads to a 1 percent fall in world trade and a 1/2 percent fall in world GDP. A key assumption in this calculation is that the other countries do not increase any tariffs vis a vis each other — they only impose tariffs vis a vis the U.S. Had they also imposed tariffs vis a vis each other, the adverse consequences would be notably larger. As an example, when the model is calibrated to reflect the relative sizes of the U.S. and the Euro area, the same-sized increase in import tariffs leads to a 2 percent fall in trade and 1 percent fall in overall GDP for given degree of openness of the U.S. economy. The larger impact reflects that the degree of openness in the foreign block is effectively larger in this calibration, so import tariffs affect a larger share of consumption and investment goods. The negative global effects of tariffs are in line with recent empirical evidence (Barattieri et al., 2017). Assuming a mean-reverting process for tariffs (as in Erceg et al. 2017, for example) would lead to a world-wide increase in tariffs stimulating global output, which appears counterfactual (see e.g. Barattieri et al., 2018). Hence, throughout the paper we retain the assumption that future changes in trade policy are unpredictable.

As noted by Ostry and Rose (1992), the theoretical effect of tariffs on output is usually ambiguous. However, in our model, we obtain a negative effect of transient and permanent hikes in import tariffs on output in both countries, which seems in line with recent empirical evidence. For example, in a panel VAR on fifteen small open economies with floating exchange rates, Barattieri et al (2018) obtains a sizeable negative short-run output effect of temporary positive tariffs shock whereas inflation rises.

The remaining of the paper is organized as follows. Section 2 discusses the introduction of tariffs in a New Keynesian model and Section 3 presents the benchmark Lerner results. In Section 4, we discuss permanent and transient deviations from the symmetry result. The macroeconomic costs of trade wars are discussed in Section 5. Finally, Section 6 concludes.

2. Import Tariffs and Export Subsidies in a Sticky Price Framework

In this section, we introduce custom duties (i.e., import and export tariffs) in a sticky price framework under producer and local currency pricing, describe the fiscal implications and define the relevant terms of trade. We then offer a brief overview of the workhorse two-country New Keynesian model we use in the simulations.

2.1. Introduction of Import Tariffs and Export Subsidies

The home economy imports (exports) bundles of goods and services for both consumption and investment purposes from (to) the foreign economy (foreign economy's variables are marked by "*"). Both goods intended for consumption and investment goods are tradable and home bias in preferences favors domestic over foreign produced goods. As the degree of stickiness is assumed to be the same in both sectors, and the tariffs and subsidies are levied on both goods, we do not distinguish between them below.

Under flexible import prices, the law-of-one-price (gross of custom duties) holds[12]

$$P_{M,t} = S_t P^*_{X,t} \frac{1 + \tau_{M,t}}{1 + \tau^*_{X,t}}, \tag{1}$$

where $P_{M,t}$ is the final import price index in domestic currency, S_t is the nominal exchange rate (home per foreign currency), $P^*_{X,t} = P^*_{D,t}$ is the export price index which equals the price index of domestically produced goods abroad, $P^*_{D,t}$, both expressed in foreign currency. $\tau_{M,t}$ is the uniform import tariff levied by the home economy, and $\tau^*_{X,t}$ is a uniform export subsidy (or tax if negative) levied by the foreign economy.[13] An analogous equation to eq. (1) holds for the foreign economy.

Two alternative pricing assumptions are usually adopted in the open-economy literature as a source of nominal rigidities: producer currency pricing (PCP henceforth) and local currency pricing (LCP henceforth).[14] LCP assumes pricing to market and invoicing in local currency reflecting firms' price-setting behavior where markets are segmented and export prices are possibly rigid in the currency of the export market (see e.g. Betts and Devereux, 2000, and Devereux and Engel, 2003). In this environment changes in custom duties and the exchange rate will only gradually transmit to the price of imported goods and services. Eq. (1) implies that δ_t, the percent deviations from the law of one price for the home economy can be written as

$$\delta_t \simeq -p_{M,t} + s_t + p^*_{X,t} + \tau_{M,t} - \tau^*_{X,t}, \tag{2}$$

[12] The arbitrage condition behind the law-of-one-price holds for producers since consumers are assumed to be immobile across countries.

[13] Throughout the paper we define the exchange rate as the amount of units of the domestic currency that is required to purchase one unit of the foreign currency. Hence, a reduction in the exchange rate means an appreciation of the home currency.

[14] Moreover, distribution costs are often introduced to account for a high pass-through from exchange rate to import prices but a low pass-through from import prices to consumer prices (Burstein, Eichenbaum, and Rebelo 2006 and Corsetti et al 2005). Our main qualitative results, however, are not affected by an explicit introduction of a distribution sector.

which can be rearranged in terms of first differences (where $\pi_t = \Delta p_t$) as

$$\Delta\delta_t = -\pi_{M,t} + \Delta s_t + \pi^*_{X,t} + \Delta\tau_{M,t} - \Delta\tau^*_{X,t}. \tag{3}$$

Import price inflation, $\pi_{M,t}$, is, in turn, determined by a standard Phillips curve

$$\pi_{M,t} = \tfrac{\beta}{1+\iota_M}\mathrm{E}_t\pi_{M,t+1} + \tfrac{\iota_M}{1+\iota_M}\pi_{M,t-1} + \kappa_M\left(mc^*_t + \delta_t\right), \tag{4}$$

where mc^*_t denotes (steady state log-deviations of) real marginal costs in the foreign economy, ι_M is indexation to past inflation among the non re-setting firms, and β the discount factor. Eq. (4) implies that import prices only adjust gradually to changes in import tariffs, at a speed determined by $\kappa_M = (1-\xi_M)(1-\beta\xi_M)/\xi_M$, where ξ_M is the probability that an import firm is not allowed to reset its price. Notice that even if prices are flexible in the import sector (so that κ_M is arbitrarily large), we can still have deviations from LOP (δ_t differs from nil) as flexible import prices only ensure that $mc^*_t + \delta_t = 0$, i.e., since we have the market segmentation LCP, different degrees of price stickiness between the home and foreign market induce a deviation from the LOP.

In the foreign economy, the corresponding equations are

$$\begin{aligned}
\Delta\delta^*_t &= -\pi^*_{M,t} - \Delta s_t + \pi_{X,t} + \Delta\tau^*_{M,t} - \Delta\tau_{X,t}, && (5)\\
\pi^*_{M,t} &= \tfrac{\beta}{1+\iota_M}\mathrm{E}_t\pi^*_{M,t+1} + \tfrac{\iota_M}{1+\iota_M}\pi^*_{M,t-1} + \kappa_M\left(mc_t + \delta^*_t\right). && (6)
\end{aligned}$$

Under PCP, export prices are set (and are sticky) in the domestic currency of the exporter and moves one-for-one with changes in the nominal exchange rate (see Obstfeld and Rogoff, 2000, and Corsetti and Pesenti, 1998) so that eq. (1) implies that[15]

$$\pi_{M,t} = \Delta s_t + \pi^*_{D,t} + \Delta\tau_{M,t} - \Delta\tau^*_{X,t}. \tag{7}$$

[15] Equivalently, PCP implies replacing eq. (4) with $\Delta\delta_t = 0$ which, combined with eq. (3), gives eq. (7)

Notice that PCP does not imply that import prices are flexible, as export price inflation $\pi^*_{D,t}$ may respond only gradually to foreign real marginal costs mc^*_t. To impose flexible import prices, i.e. $mc^*_t = 0$, we need to assume flexible domestic prices. Even so, eq. (7) implies that the effects of import tariffs on $\pi_{M,t}$ are substantially more front-loaded under PCP.

In our context, evidence of a high pass-through from VAT to prices (Carbonnier 2007, 2013, and Freund and Gagnon, 2017) advocates for adopting PCP in our analysis. Nevertheless, as there is strong empirical support for LCP (for example Engle and Rogers, 2001), we will maintain this framework as benchmark throughout the paper. Note, however, that the main aspects of our results are invariant to the LCP assumption. To show this, online Appendix B reports results for PCP.

The terms of trade is the ratio of import to export prices net of import tariffs:

$$ToT_t = \frac{1+\tau^*_{M,t}}{1+\tau_{M,t}} \frac{P_{M,t}}{S_t P^*_{M,t}}, \tag{8}$$

where $P_{M,t}/(1+\tau_{M,t})$ is the price paid (by the home country) for imports and $S_t P^*_{M,t}/(1+\tau^*_{M,t})$ is the price charged (by the home country) for its exports (expressed in home currency). When the LOP holds we have $ToT_t = \frac{1+\tau^*_{M,t}}{1+\tau_{M,t}} \frac{P_{M,t}}{S_t P^*_{M,t}} = \frac{P_{M,t}}{P_{X,t}} \frac{1+\tau_{X,t}}{1+\tau_{M,t}}$.

If the pass-through from tariffs to prices is low, ceteris paribus, the terms of trade appreciates after a tariff shock. Vice versa, if the USD appreciates but export prices are sticky in foreign currency then the terms of trade depreciates. When the exchange rate does not fully offset an increase in the tariff the term of trade appreciates.[16]

[16] As Obstfeld and Rogoff (2000) noted, a sticky price framework in which imports are invoiced in the importing country's currency (LCP) implies that, keeping trade tariffs constant, unexpected currency appreciations are associated with deteriorations of the terms of trade contrary to what happens under PCP.

The trade balance depends on the terms of trade in eq. (8) as follows

$$\frac{TB_t}{P_t Y_t} = \frac{S_t P^*_{M,t}/P_t}{1+\tau^*_{M,t}} \frac{X_t}{Y_t} - \frac{P_{M,t}/P_t}{1+\tau_{M,t}} \frac{M_t}{Y_t} = \frac{P_{M,t}/P_t}{1+\tau_{M,t}} [ToT_t^{-1} \frac{X_t}{Y_t} - \frac{M_t}{Y_t}]. \quad (9)$$

Notice that import tariffs (but not export subsidies) introduce a wedge between home (foreign) import expenditure and foreign (home) exporter revenues in the trade balance.

The net effect of custom duties on the home primary surplus is given by

$$\tau_{M,t} \frac{P_{M,t}}{1+\tau_{M,t}} M_t - \tau_{X,t} \frac{S_t P^*_{M,t}}{1+\tau^*_{M,t}} X_t. \quad (10)$$

In a log-linear approximation around a steady state where trade is balanced and tariffs are zero there are no first-order effects from BATs to public finances (i.e., there is a symmetric and opposite effect from equally-sized import tariff and export subsidy on government revenues and expenses).[17] In a Ricardian environment, balanced trade is neither necessary nor sufficient for Lerner symmetry to hold, but trade deficits can trigger deviations from Lerner symmetry under distortionary taxes and liquidity constrained consumers. We avoid these sources of non-neutrality by assuming that the endogenous fiscal instrument that varies to satisfy the government budget constraint is a lump-sum tax paid by optimizing households (see online Appendix A for further details).

2.2. Model Overview

We use a large-scale two country model with endogenous capital and labor that closely follows Erceg, Guerrieri and Gust (2006) and Erceg and Linde (2013). Each region is assumed to be equally large and the parameterizations of the model is completely symmetric. Abstracting from open economy features, the specification of each country block builds heavily

[17] The (log-linear) trade balance as share of GDP is given by $tb_t = -\overline{x}\widetilde{tot}_t + x_t - m_t$, where x and m are export and import shares of GDP (the bar denotes the steady state), while $\widetilde{tot}$ is the terms of trade in deviation from 1.

on the estimated models of Christiano, Eichenbaum and Evans (CEE, 2005) and Smets and Wouters (2003, 2007). Thus, the model features both sticky nominal wages and prices, habit persistence in consumption, investment adjustment costs, and a financial accelerator mechanism. In addition, the model is a two-agent (TANK) environment where some households consume their current after-tax income in a hand-to-mouth fashion.[18]

Within the open economy dimension, the benchmark model assumes local currency pricing, as previously described, and financial markets are incomplete as only a single non-state contingent "internationally traded" bond is available. The exchange rate is, thus, determined by the choice of foreign and domestic bond holdings, which boils down to an uncovered interest rate parity (UIP, henceforth) condition, where net foreign assets also enter to ensure stationary bond holdings. We study deviations from the UIP condition in Section 4. Foreign assets and liabilities are exclusively in terms of foreign-currency bonds.[19]

The trade share of the home economy is set to 14 percent of its GDP, roughly matching the U.S. trade share. This pins down the trade intensity of both consumption and investment for the home country under the additional assumption that the import intensity of consumption is equal to 3/4 of investment. For symmetry reasons, we assume that the home economy is equally sized as the foreign economy. Our balanced trade assumption then implies an equally sized trade share of the foreign economy. This calibration is suitable for studying the impact of tariffs and subsidies on trade and output for U.S. and the Euro Area, which are

[18] Galí, López-Salido and Vallés (2007) show that the inclusion of non-Ricardian households helps account for structural VAR evidence indicating that private consumption rises in response to higher government spending. Debortoli and Galí (2017) argues that dynamics in TANK models mimic key aspects of the so-called HANK models (Kaplan et al., 2016). We are interested in the extent to which TANK aspects may magnify or attenuate deviations from Lerner symmetry.

[19] It is only the gross assets position of foreigners in the United States that matters for the Lerner symmetry. Indeed, in the case of U.S. assets abroad, any change in their value caused by the trade policy (tariff cum export subsidy) will be exactly equated by a change in tax revenues that, in turn, can offset any wealth effect of the trade policy on households. In contrast, in the case of foreign assets in the United States, there are no transfers abroad to compensate foreign households for changes the value of their assets. (See Costinot and Werning 2017).

nearly equally sized currency unions, although it overstates the extent of trade between the U.S. and the Euro Area. Therefore, we also discuss the economic effects when we entertain a U.S. versus the rest of the world calibration of the model (which features the same trade intensity, but assumes that the U.S. only accounts for 23 percent of the world economy) in the section on trade wars (Section 5). As the assumption is that tariffs and subsidies are only imposed between (and not within) the two blocks, this calibration is more reasonable for the purpose of tracing out the global effects of a U.S. BAT reform if foreign countries solely retaliate versus the U.S. and not towards any other country.

In the benchmark model, monetary policy is assumed to follow a Taylor-style rule where the central bank reacts to CPI inflation, π_{Ct}, and the flex-price output gap x_t:

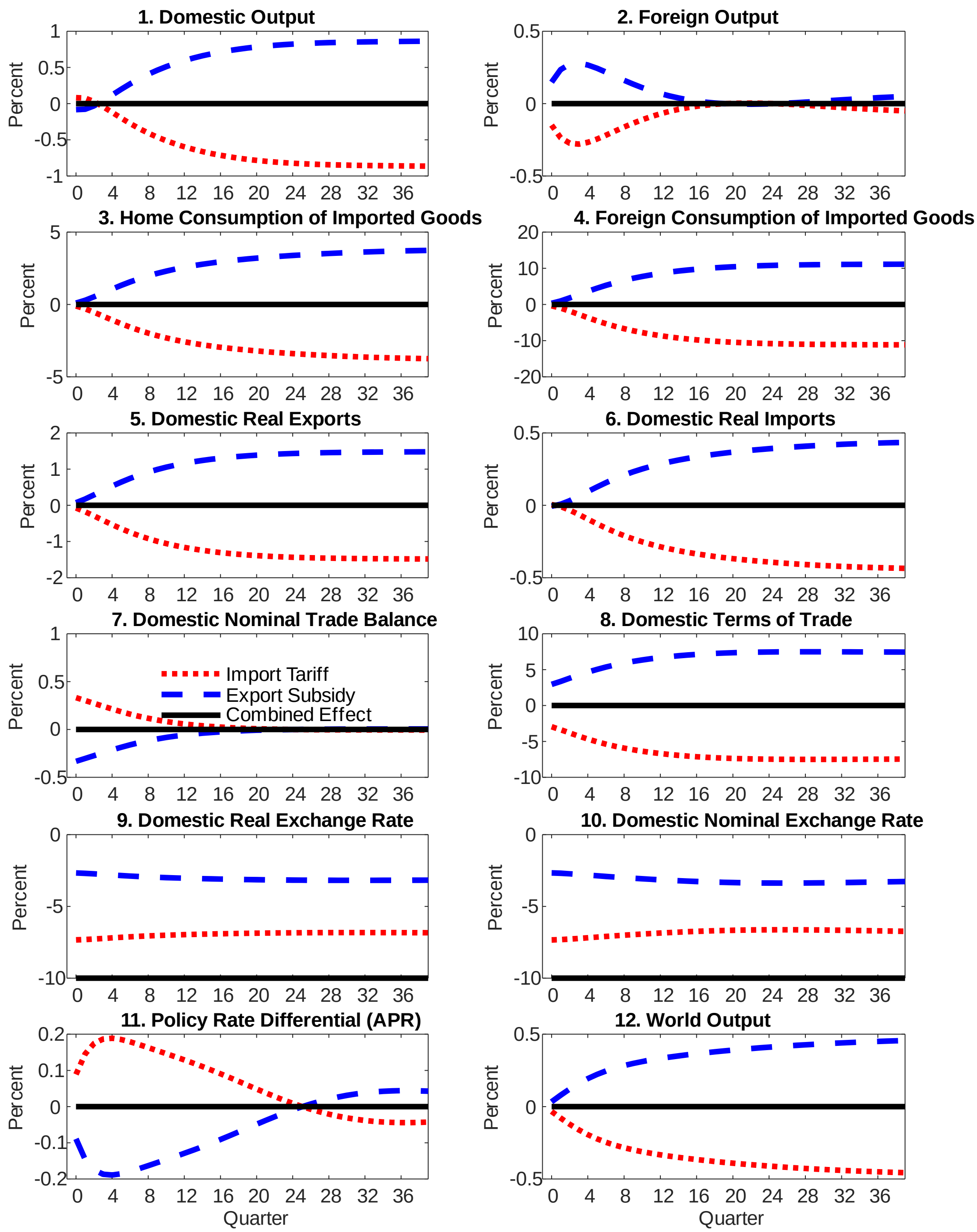
$$i_t = (1 - \gamma_i) \left[\gamma_\pi \pi_{Ct} + \gamma_x x_t + \gamma_{\Delta x} \Delta x_t\right] + \gamma_i i_{t-1}, \tag{11}$$

where an analogous rule holds for the foreign central bank. Thus, in line with stated practice in the U.S. and the Euro Area, neither of the central banks reacts to exchange rate movements in the benchmark model. Nevertheless, in Section 4 we study the consequences of nominal exchange rate pegs, in which case the Lerner equivalence breaks down. The online Appendix A provides further details on how the model is calibrated and solved.

3. The benchmark Case: Lerner Symmetry

Figure 1 reports the responses to (i) a permanent 10 percent hike in the home import tariff τ_{Mt} (see eqs. (2) to (4); dotted red line); (ii) a permanent 10 percent hike in the home export subsidy $\tau_{X,t}$ (dashed blue line); and (iii) their combined effects (i.e., the border adjustment tax: home import tariff $\tau_{M,t}$ and export subsidy $\tau_{X,t}$ move simultaneously; black solid line).

Figure 1: Effects of Permanent Import Tariffs and Export Subsidies.



The import tariff hike appreciates the home (real and nominal) exchange rate (Panel 9 and 10) as the domestic policy rate and the interest rate differential increase (Panel 11 and 12). Home real imports falls (Panel 6) while the home terms of trade appreciates (i.e., falls; Panel 8) with a delayed peak due to the LCP assumption. The terms of trade appreciation, in turn, induces a positive wealth effect on consumption but a drag on real net export (Panel 5 and 6) that implies a decline in output. The appreciation of the terms of trade is, however, sufficient to improve the nominal trade balance (Panel 7). The expenditure switch from imported to domestic consumption goods (Panel 3) occurs because the import tariff hike in the home country outweighs the appreciated exchange rate, so prices of imported goods rise somewhat for home consumers. However, for foreign households, consumption of imported goods (Panel 4) is eventually cut by over 10 percent as their import prices rise gradually due to the depreciated exchange rate.

Panel 2 shows that the adverse spillovers on foreign output are relatively muted and transient, as the depreciated terms of trade boost foreign real net exports. However, in the flex price-wage equilibrium of our model, presented in online Appendix B.1, foreign output rises on impact because their real net exports rise sharply, whereas domestic output declines by -0.5 percent on impact because the appreciated real exchange rate causes home net real exports to fall sharply.

Figure 1 also documents that a 10 percent hike in the export subsidy has completely opposite effects to those for the import tariff. The only exceptions are the nominal and real exchange rates (Panels 9 and 10), which appreciate slightly less than in the import tariff case. After the export subsidy shock, about one-third of the smaller nominal exchange rate appreciation is explained by the forward sum of the interest rate differential, which is negative instead of positive as in the import tariff case (Panel 11), while about two thirds of the larger exchange rate appreciation is explained by the equilibrium exchange rate.

To see this, note that under incomplete markets, the relation between the exchange rate and interest rates is governed by the (log-linear) UIP condition

$$i_t - i_t^* = \Delta \mathrm{E}_t s_{t+1} - \phi_b b_{f,t}, \tag{12}$$

where the net foreign assets as share of GDP, $b_{f,t}$, ensures stationarity of foreign bond holdings when $\phi_b > 0$ (Turnovsky, 1985). However, since ϕ_b is empirically estimated to be very small we can (approximately) neglect net foreign assets $b_{f,t}$. Solving eq. (12) forward we then obtain

$$s_t = -\sum_{j=0}^{\infty} \mathrm{E}_t(i_{t+j} - i_{t+j}^*) + \overline{s}_t, \tag{13}$$

where $\overline{s}_t = \lim_{j->\infty} \mathrm{E}_t s_{t+j}$ is the long-term (expected) *equilibrium exchange rate*. Changes in the nominal value of the currency can thus be determined solely by the equilibrium exchange rate without having to rely on movements in current or expected interest rate differentials. For the export subsidies and the import tariffs the total effect on $\overline{s}_t$ is always -10 percent.

The solid black line in Figure 1 shows that the combined effects of the import tariff and export subsidy shock exactly cancel out — i.e., the Lerner symmetry holds for a permanent and unanticipated BAT adjustment. Intuitively, the real and nominal exchange rate appreciation hits two birds with a stone offsetting both the effects of the import tariff (by effectively lowering the pre-tariff import price of the home economy by 10 percent) and the export subsidy (by increasing the effective export price by 10 percent).

Formally, by inspecting eqs. (3) and (5) it is easy to see how $\Delta s_t = \Delta\tau_{M,t} = \Delta\tau_{X,t}$ perfectly offsets both the import tariff and export subsidy while the UIP, eq. (13), allows the exchange rate to adjust instantaneously without having to alter households' consumption-saving decisions. Thus, neither $P_{M,t}$ nor $P^*_{M,t}$ need to adjust.

The Lerner symmetry theorem holds even if there are asymmetries in the degree of price stickiness in the home import and export sectors or across countries. It is also easy to show that the introduction of additional sectors (for example, a flexible price sector) does not alter the result. Moreover, amending the model with variable markups following Gust, Leduc and Sheets (2009) mitigates the effects of $\tau_{M,t}$ and $\tau_{X,t}$, but Lerner still holds up.

Another interesting case is all traded goods being invoiced in the home currency (e.g., in US dollars). Amiti, Itskhoki and Konings (2017) argues that this would break Lerner symmetry. We can examine this case within our model by assuming LCP in the home import sector (so that foreign exporters set their prices in the home currency) and PCP in the foreign import sector. In online Appendix B.3, we show that the Lerner theorem still holds, although the effects of the individual instruments ($\tau_{M,t}$ and $\tau_{X,t}$) differ relative to the benchmark calibration with LCP (i.e. invoicing in the currency of the importing country). The reason why Lerner holds is that the pass-through from the exchange rate and tariffs to prices are still the same across exporters. Had we instead followed Barbiero et al. (2017) and assumed DCP (dominant currency paradigm, see Casas et al., 2016), so that the final price to foreign importers (post export-subsidy price) was sticky in the home currency, then Lerner symmetry would break down because, by assumption, the (full) exchange rate pass-through would differ from the (incomplete) pass-through of the export subsidy. While the assumption that tariffs and exchange rate have the same pass-through to prices finds empirical support in Feenstra (1989), the more recent study by Mallick and Marques (2008) obtains more ambiguous results for India where the pass-through is not always the same depending on the industry.

4. Deviations from Lerner Symmetry

In this section, we examine a number of mechanisms which break the Lerner symmetry result. We organize the discussion of these mechanisms into channels that generate permanent and temporary deviations.[20]

4.1. Permanent Deviations: Complete Financial Markets

Complete international financial markets allow households to trade assets to insure against trade policy uncertainty by buying and selling financial assets that are contingent on tariffs. It has long been an important benchmark in the literature, and some empirical papers have also shown its ability to deliver empirical results that are similarly plausible to the ones under incomplete markets (Chari et al. 2002, and Rabanal and Tuesta, 2010). Importantly, our results in this section hold up as long as a fraction of households have access to a complete set of state contingent claims. Hence, the complete markets assumption may be much more realistic empirically than it might appear at first sight. This finds support by Kollmann (2011, 2015) who argues that this asset market structure captures key empirical regularities (such as high exchange rate and net foreign asset volatility, and the low correlation between relative consumption and the real exchange rate) much better than a market structure in which (i) all Ricardian agents trade an international bond (as in our previous analysis with incomplete markets); (ii) all agents have access and trade in complete markets (an extreme form of complete markets which we do not entertain in our baseline calibration).

[20] Furthermore, uncertainty about whether the tariffs will remain in place infinitively will also break the Lerner symmetry. But since this mechanism is discussed in detail by Erceg, Prestipino and Raffo (2017), we omit it in our exposition below.

Since markets are segmented (i.e., home and foreign consumers can face different prices for the same good), we assume that it is impossible to make state-contingent trades that allow payoffs in physical goods, instead payoffs are specified in nominal terms. In this case, optimal contracts ensure that the marginal utility from an additional unit of currency, $\Lambda_{C,t}/P_{t,}$ is proportional between home and foreign consumers in all states

$$Q_t = \Lambda^*_{C,t}/\Lambda_{C,t}, \tag{14}$$

where $Q_t = S_t P^*_{C,t}/P_{C,t}$ is the real exchange rate. Log-linearizing eq. (14), we have

$$\Delta q_t = \Delta\lambda^*_{C,t} - \Delta\lambda_{C,t}. \tag{15}$$

where $\Delta q_t = \Delta s_t + \pi^*_{C,t} - \pi_{C,t}$, $\lambda_{C,t} = d\Lambda_{C,t}/\Lambda_C$ and $\lambda^*_{C,t} = d\Lambda^*_{C,t}/\Lambda^*_C$.

The corresponding incomplete markets condition is given by

$$\Delta \mathrm{E}_t q_{t+1} = \Delta \mathrm{E}_t \lambda^*_{C,t+1} - \Delta \mathrm{E}_t \lambda_{C,t+1} + \phi_b b_{f,t}, \tag{16}$$

and differs fundamentally from eq. (15).[21]

As previously discussed, Lerner symmetry requires exchange rate movements to occur without altering households' consumption and saving decisions. This is feasible under incomplete markets because eq. (16) only holds with expectations; in which case a permanent and unanticipated movement in the exchange rate is not sufficient to violate eq. (16). Instead, under complete markets eq. (15) holds for all shock realizations, which means that any exchange rate movement triggers a relative change in household consumption and saving behavior. As a consequence, the Lerner symmetry will not hold.

[21] Equation (16) can be derived by rewriting eq. (12) in real terms as $i_t - \mathrm{E}_t\pi_{C,t+1} - \left(i^*_t - \mathrm{E}_t\pi^*_{C,t+1}\right) = \Delta \mathrm{E}_t q_{t+1} - \phi_b b_{f,t}$, and inserting the two consumption Euler equation $\Lambda_{C,t} = \beta \mathrm{E}_t \frac{(1+i_t)}{1+\pi_{C,t+1}} \Lambda_{C,t+1}$ and $\Lambda^*_{C,t} = \beta \mathrm{E}_t \frac{(1+i^*_t)}{1+\pi^*_{C,t+1}} \Lambda^*_{C,t+1}$.

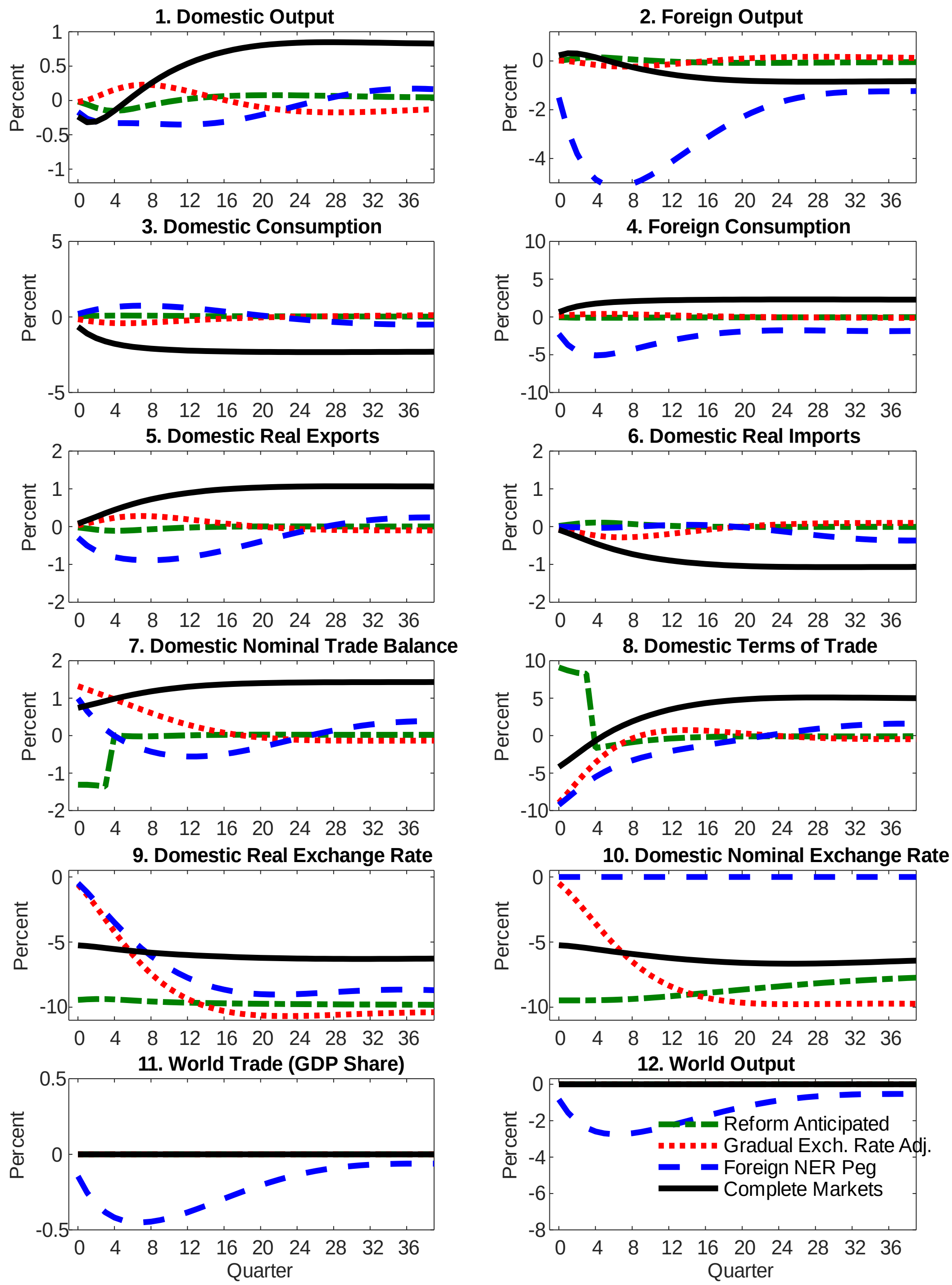
To gain further insights, it is useful to consider log utility of consumption, no habit persistence, equal sales taxes, and no hand-to-mouth consumers, in which case the complete markets condition of eq. (14) simplifies to

$$S_t P^*_{C,t} C^*_t = P_{C,t} C_t. \tag{17}$$

In this case, optimal contracts ensure that the dollar values of home and foreign consumption expenditures are equated. Consequently, an exchange rate movement leads to a transfer of resources across countries akin to a balance sheet's valuation effect. The fact that household consumption-saving decisions have to change under complete markets but not necessarily under incomplete markets might be surprising, since the complete markets assumption is supposedly a more efficient arrangement (and tariffs and subsidies are inefficient). However, as Stockman (1989) and Barari and Lapan (1993) point out, the welfare superiority of complete markets holds only under efficient shocks, but not for distortionary shocks we study here. Indeed, since contracts' payoffs are nominal (e.g., in US dollars rather than in consumption units), foreign households want to insure against a loss of the value of their own currency (vis-à-vis the home currency) while home consumers want to insure against higher consumption prices induced by the tariff; hence, a full insurance arrangement where consumption volumes are equated is not an equilibrium. As our workhorse model does not allow us to fully characterize the breakdown from Lerner equivalence under complete markets analytically, we use a simple static model in online Appendix C – which builds on the framework in Dellas and Stockman (1986) – to demonstrate that uncertainty about trade policy causes deviations from the equivalence result under complete markets.

However, these considerations tell us little about how large the deviations from Lerner are quantitatively. To asses this, the black solid line in Figure 2 shows the effects of a BAT

Figure 2: Deviations from Lerner Symmetry for Import Tariffs and Export Subsidies.



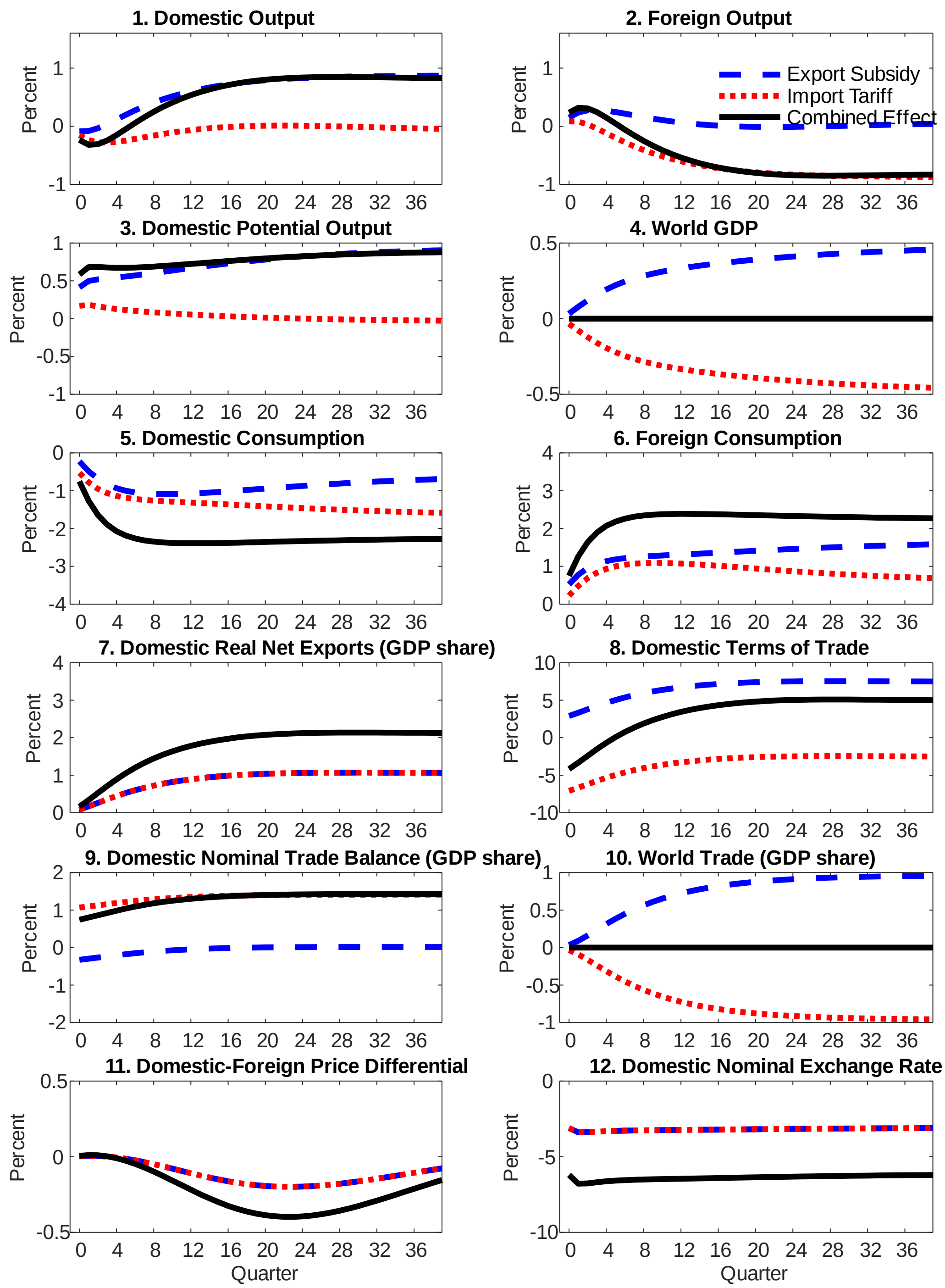
reform under complete markets. Initially, output contracts notably in the domestic economy (Panel 1) and expands in the foreign economy (Panel 2) before the impact on domestic output becomes positive and the benign effects on the foreign economy are reversed. Consistent with the model in Dellas and Stockman (1986), the effects on domestic (foreign) consumption (Panels 5 and 6) are unambiguously negative (positive), reflecting the associated real exchange rate appreciation of the domestic currency (Panel 12).

To examine the role of the two instruments, Figure 3 teases out their partial effects of the import tariff and export subsidy shocks. The import tariff τ_{Mt} shock has rather transient effects on actual and potential output, whereas the export subsidy $\tau_{X,t}$ has much more persistent positive effect on home output. Since the responses are symmetric in the foreign economy, it expands temporarily following the hike in the foreign export subsidy and contracts persistently following the hike in home import tariff (Panels 1 and 3).

World output contracts following an increase in the import tariff and expands by an identical amount for an increase in the export subsidy $\tau_{X,t}$ (Panel 4). In fact, the partial effect of the two instruments on world output is identical under both complete and incomplete markets (compare Panel 12 in Figure 1 and Panel 4 in Figure 3). So the alternative assumptions of exchange rate determination in asset markets only affect the split-up of the domestic and foreign production. This means that the BAT reform leaves world output unchanged also under complete markets.

We now turn to discuss the composition of GDP. In the home economy, the output expansion in the medium and longer terms is mainly driven by net exports (Panel 7) and is modestly supported by a slight rise in investment (not shown), while the fall in private consumption is only a partial offset. The home-to-foreign consumption ratio drops by about

Figure 3: Effects of a Permanent Import Tariff and Export Subsidy under Complete Asset Markets.

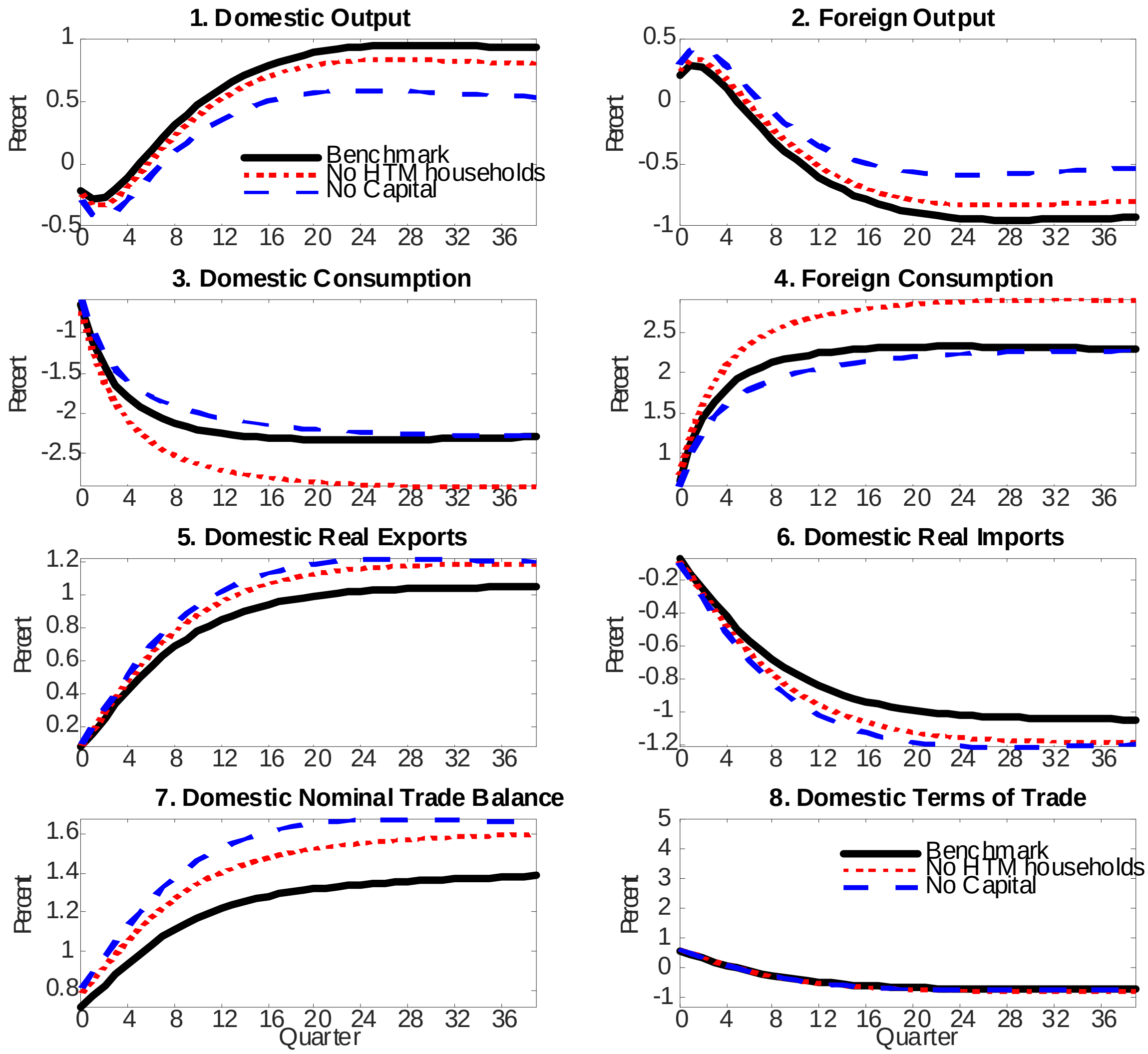


4 percent, which explains most of the movement in the real exchange rate (of about -5 percent, Panel 12) since nominal rigidities imply a slow movement in the inflation differential (Panel 11). If prices were less sticky, the consumption differential would nevertheless remain roughly the same, but the larger initial decline in the inflation differential would cause a larger initial appreciation of the nominal exchange rate and a smaller fall in output. In fact, the initial decline in home output is caused by price rigidities (compare black lines in Panels 1 and 3); if prices were fully flexible, home (foreign) output would rise (fall) immediately and would not be subject to a sign reversal over time.

Interestingly, we also see that home real net exports rise by an identical amount for both BAT shocks (Panel 7). However, because the domestic terms of trade depreciates (Panel 8), notably following the export subsidy $\tau_{X,t}$ hike, the domestic nominal trade balance as share of GDP, shown in Panel 9, does not improve for $\tau_{X,t}$. The trade balance only improves for the import tariff $\tau_{M,t}$ because the domestic terms of trade appreciates significantly, especially in the near-term. In Panel 10, we report the implications for World trade as share of GDP. World trade flows rise following a hike in $\tau_{X,t}$ but falls following a hike in $\tau_{M,t}$. This may seem inconsistent with the fact that net exports rise equally much for both instruments (Panel 7), but can be explained by the fact that the improvement in net exports following the tariff hike is driven by a decline in imports, whereas the hike in $\tau_{X,t}$ causes exports to rise. Even so, as was the case under incomplete markets, there are no effects on World trade when both $\tau_{M.t}$ and $\tau_{X,t}$ are changed simultaneously.

Finally, we briefly discuss the extent to which endogenous capital formation and TANK aspects quantitatively contribute to the deviations from Lerner symmetry under complete markets. This is important because neither Barbiero et al. (2017) nor Erceg et al. (2017) allow for capital and hand-to-mouth consumers in their analysis.

Figure 4: Impact of Capital and Keynesian Households Under Complete Markets.



In Figure 4, we show that quantitatively these two features are indeed key. The peak output effect is reduced from about 1 to 0.5 percent in the domestic economy when endogenous capital is excluded from the model (since there is no global impact, the attenuation is from -1 to -0.5 percent in the foreign economy). As seen from Panel 3, domestic consumption is little affected. Nonetheless, because the private consumption share is notably larger in the model without investment, the drag on output from the fall in consumption outweighs the more positive response of net exports (Panels 5 and 6), which attenuates the output response in the model without capital. When omitting the hand-to-mouth households, the peak domestic-output response is attenuated from about 1 to 0.7 percent (and similarly for the foreign economy with reverse sign). Interestingly, in this case the consumption response is elevated as seen from Panels 3 and 4. Even so, the output response is smaller because domestic net exports (Panels 5 and 6) and domestic investment (not shown) increase even more. To sum up, the findings in Figure 4 demonstrate that the combined Keynesian accelerator effects of capital and hand-to-mouth households are substantial.

4.2. Transient Deviations From Lerner Symmetry

We now return to the model with incomplete markets used to demonstrate Lerner symmetry in Section 3 and discuss mechanisms which lead to transient deviations from Lerner.

4.2.1. Implementation Lags

First, we repeat the benchmark experiment in Section 3 but assume that the BAT adjustment (changes in both $\tau_{M,t}$ and $\tau_{X,t}$) is announced one year before it is actually implemented. Figure 2 (green dash-dotted line) shows that the deviations from Lerner symmetry caused by implementation lags are modest (Figure 2, green dash-dotted line). The real and nominal exchange rates jump on announcement of the trade policy reform; but since the actual implementation is delayed 4 quarters, exports fall and imports rise somewhat, resulting in a peak decline of about 0.2 percent in domestic output after two years. Moreover, it is important to note that World GDP remains unchanged even in the short-term. With a 2 quarter delay between announcement and implementation, the peak decline in GDP is less than 0.1 percent, suggesting that short-term deviations from Lerner symmetry stemming from implementation lags should be modest.

4.2.2. Gradual Exchange Rate Adjustment

The results in the benchmark model are contingent on an immediate sizeable appreciation of the nominal and real exchange rates. The UIP condition embedded into the model facilitates this exchange rate adjustment. Nevertheless, there is ample empirical evidence against the standard UIP condition. VAR evidence suggests that the impulse response function for the real exchange rate (RER henceforth) after a shock to monetary policy is hump-shaped, with a peak effect after about 1 year (see, e.g., Eichenbaum and Evans, 1995, Faust and Rogers, 2003), whereas the standard UIP condition implies a peak followed immediately by quick mean reversion. Moreover, the standard UIP condition cannot account for the so-called "forward premium puzzle" (i.e., a currency whose interest rate is high tends to appreciate which implies that the risk premium must be negatively correlated with the expected exchange rate depreciation; see, e.g., Fama, 1984; Froot and Frankel, 1989, and Duarte and Stockman, 2005, and Bacchetta and van Wincoop, 2010).

In an attempt to account for these empirical shortcomings, we modify the UIP condition to allow for a negative correlation between the risk premium and the expected change in the exchange rate, following e.g. Engel (1996). Our modified UIP condition is given by

$$i_t - i_t^* = (1 - \phi_s) \, \mathrm{E}_t \Delta s_{t+1} - \phi_s \Delta s_t - \phi_b b_{f,t}, \tag{18}$$

and following Adolfson et al. (2008), we set $\phi_s = 0.6$ and refer to this case as "Gradual Exchange Rate Adjustment" since the modified UIP condition (18) only alters the *pace* at which the RER appreciation occurs.

The red dotted line in Figure 2 demonstrates that the deviations from Lerner symmetry are fairly modest even under gradual exchange rate adjustment. With slower appreciation of the home real and nominal exchange rates, domestic output expands by 0.3 percent after 2–3 years before receding to baseline (no change) after 5 years. The slower appreciation of the exchange rate boosts the home trade balance by over 1 percent of GDP (Panel 7) during the first year, and the domestic terms of trade (Panel 8) initially appreciates nearly 10 percent before receding back to nil when the exchange rate adjusts. Panel 9 shows that it takes about 3 and 5 years for the home RER and NER to appreciate 10 percent, respectively.

To sum up, gradual exchange rate adjustment only results in modest short-term deviations and does not have any effect on global trade and GDP.

4.2.3. Nominal Exchange Rate Pegs

We now turn to the effects of nominal exchange rate (NER, henceforth) pegs. To begin with, we assume that the foreign economy is pegging its nominal exchange rate vis a vis the domestic economy. In this case, the foreign central bank abandons the standard policy rule in eq. (11) in favor of the following one:

$$i_t^* = -\gamma_s \Delta S_t, \tag{19}$$

where γ_s is set arbitrarily large.[22]

If prices were fully flexible, a nominal exchange rate peg would not matter for equilibrium allocations, as the real exchange rate adjustment is brought about by movements in relative prices, and Lerner symmetry would still hold up. However, RER adjustment takes much longer with rigid prices, which triggers a breakdown in Lerner symmetry as shown by the blue dashed line in Figure 2. When the NER is fixed, an appreciation of the home RER must

[22] As a higher (lower) value of S means an appreciated (depreciated) currency from the perspective of the foreign economy, a minus sign in front of γ_s indicates that the policy rate will be lowered (raised) sufficiently to offset any movements in S_t in equilibrium.

be achieved through a relative price adjustment, i.e. higher prices in the home economy, or lower prices foreign economy, or combination of both. Since the domestic central bank acts to stabilize domestic inflation and the output gap, most of the RER adjustment occurs via a gradual and permanent fall in the foreign price level. Figure 2 shows that this adjustment has severe adverse economic consequences as world GDP gap shown in Panel 12 falls considerably in the short-term. This is due to both domestic (Panel 1) and, especially, foreign output gap (Panel 2) falling (output equals the output gap since both domestic and foreign potential output remain unchanged, see Panels 1 and 2 in Figure 1).[23]

The large contraction in the foreign output gap under a NER peg is remarkable. The main driver behind it is the inability of the foreign monetary authority to react to its domestic conditions. In order to maintain a fixed NER it has to maintain the same nominal interest rate as in the home economy; and the home central bank only cuts its policy rate at a measured pace since home CPI inflation (not shown) and output gap (Panel 1) fall modestly. The home nominal interest rate cut is not sufficient to achieve price stability in the foreign economy, and foreign inflation (not shown) falls significantly. This implies a substantial rise in the foreign real interest rate path which triggers the foreign output gap to contract with about -5 percent as shown by Panel 2. Lower foreign consumption (Panel 4) and investment (not shown) accounts for the fall in foreign output gap whereas higher foreign net exports attenuate the decline only modestly (Panels 5 and 6). While the drag on home real net exports induces a (modest) decline in home output, the home nominal trade balance

[23] In online Appendix B.4, we report results for an extended set of variables (including domestic and foreign CPI inflation) under a NER peg. We also discuss the responses to BAT reform for the hypothetical case when the home economy is pegging its NER (i.e. follows the rule $i_t = \gamma_s \Delta S_t$ where γ_s is set arbitrarily large) and the foreign economy is assumed to follow a standard Taylor-type rule (eq. A.26). In this alternative configuration, the effects are flipped in a symmetric way: the real exchange rate appreciation now occurs gradually via higher home prices and the home economy experiences a sharp boom in economic activity due to lower real interest rates (and associated rise in consumption and investment) despite a slight worsening of home real net exports.

improves (Panel 7) due to a strong terms of trade appreciation (Panel 8). The drop in domestic real exports is driven by our LCP assumptions (plus the permanent nature of the tariffs). If we relax the LCP assumption in the model, home real exports and GDP rise in line with the basic textbook Mundell-Fleming model.

4.2.4. Alternative Price Pass-Through Assumptions

We now turn to analyze alternative assumptions about pass-through of the tariffs and subsidies onto prices. While there are many possible options to consider, we focus on two alternatives that we think may be of particular interest. Yet, we appreciate that both cases are somewhat ad hoc.

The first case assumes that export firms fully pass both import tariffs and export subsidy $\tau_{M,t}$ and $\tau_{X,t}$ into import prices. The LOP (eq. 3) is modified to

$$\Delta\delta_t = -\pi_{M,t}^{Pre} + \Delta s_t + \pi_{X,t}^{*}. \tag{20}$$

The price Phillips curve (eq. 4) is unchanged and expressed as a pre-tariff price but the actual import price inflation constitutes

$$\pi_{M,t}^{Post} = \pi_{M,t}^{Pre} + \Delta\tau_{M,t} - \Delta\tau_{X,t}^{*}, \tag{21}$$

where $\pi_{M,t}^{Pre}$ is the home import price net of tariffs and subsidies charged by the foreign exporters. This approach to tariffs closely resembles a U.S. style sales tax. Similar equations hold in the foreign country:

$$\pi_{M,t}^{*,Post} = \pi_{M,t}^{*,Pre} + \Delta\tau_{M,t}^{*} - \Delta\tau_{X,t}. \tag{22}$$

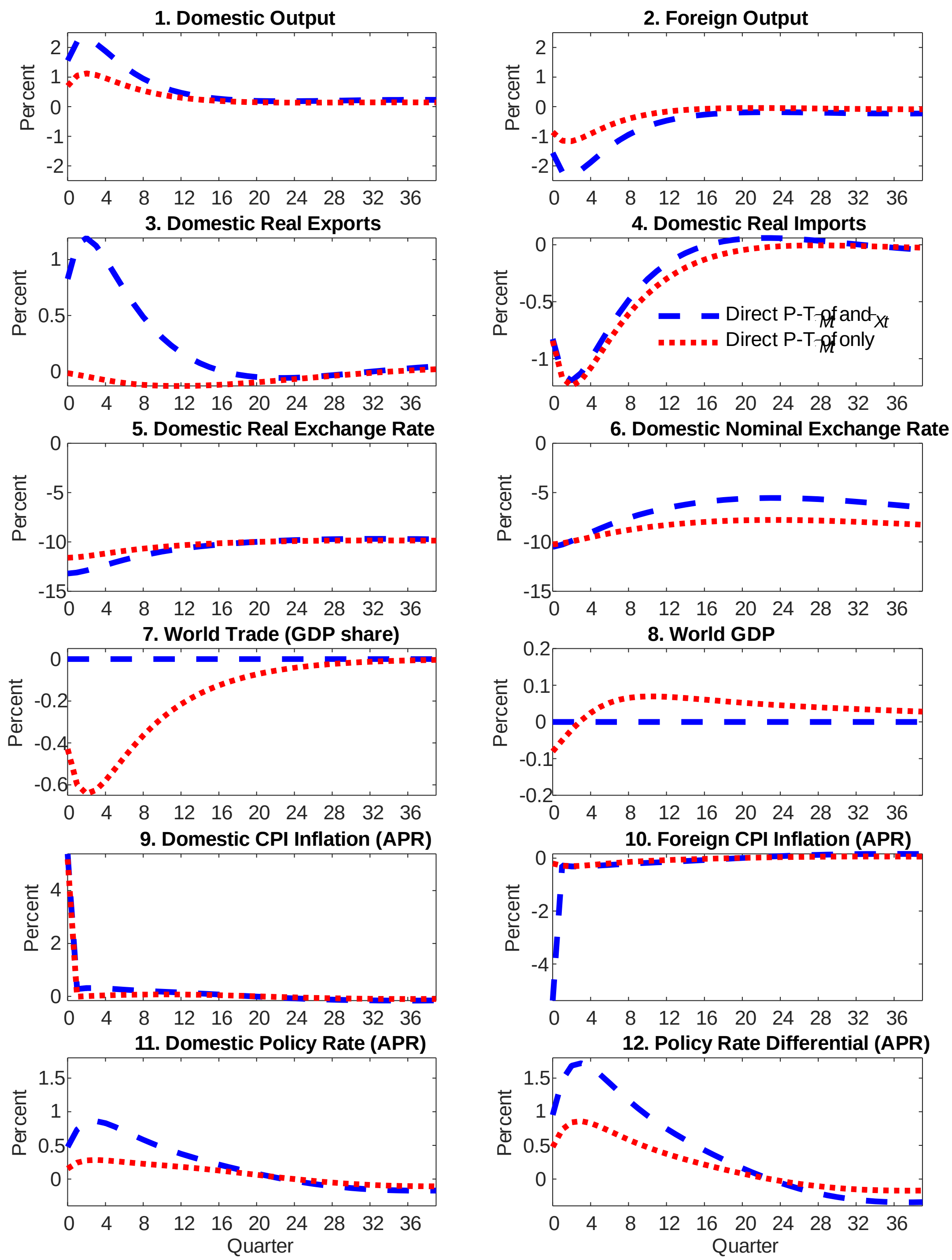
In the second alternative, we assume that foreign export firms fully pass on the home import tariffs $\tau_{M,t}$ to import prices, whereas the home export firms do not, implying that the export subsidy pass-through remains unchanged (i.e. smaller) and determined by eq. (5) and the foreign equivalent eq. (6).

The blue dashed line in Figure 5 reports the effects of a combined rise in $\tau_{M,t}$ and $\tau_{X,t}$ under the first alternative pass-through assumption.[24] As can be seen from Panels 9 and 10 in the figure, home (foreign) CPI inflation jumps (plummet) with almost 5 percent in the first period, reflecting the immediate pass-through. A little more than 1 percent of points of the annualized CPI inflation in the first period partly reflect an increase in domestic inflation, because imported inflation only contributes by 4 p.p. for a 10 percent import tariff hike ($\Delta\tau_M$) when the assumed import-consumption trade share is about 10 percent ($\Delta\tau_M \times$ 4 $\times M/C$ = 4 p.p.). The slight rise in overall CPI inflation in the following periods reflects that economic activity (Panel 1) in the home economy rises persistently above potential (recalling that domestic potential output is unchanged since Lerner symmetry holds in the flex-price economy). Hence, higher inflation on domestically produced goods outweighs the deflationary pressures from lower import prices (not shown) due the appreciated nominal exchange rate (Panel 6) which gradually transmits into lower import prices according to eqs. (20) and (4). The home real exchange rate (Panel 5) appreciates even more than 10 percent in the near term, reflecting that foreign (domestic) prices jump down (up). But over time, the gap between the actual and potential real exchange rate closes as the effects of slow price adjustment dissipate.[25] Even though the Lerner symmetry breaks down, there are no effects

[24] All other features of the experiment are exactly as in Figure 1, except for both domestic and foreign central banks which are assumed to react to expected CPI inflation $\mathrm{E}_t\pi_{C,t+1}$ so that they do not react massively in response to the short-lived impetus of $\tau_{M,t}$ and $\tau_{X,t}$.

[25] Because the central banks in these simulations are assumed to react to one-period ahead inflation (see footnote 24) they see through the short-run inflation dynamics. The foreign central bank, on the other hand, implements an equally-sized policy rate cut (see Panels 11 and 12) due to the downward pressure on foreign CPI inflation (Panel 10) and output gap (Panel 2). In the foreign economy, the deflationary pressure on domestic inflation outweighs the positive contribution of $\pi^{*,Post}_{M,t}$ from higher imported inflation $\pi^{*,Pre}_{M,t}$ in eq. (22), stemming from its depreciated nominal exchange rate.

Figure 5: Effects of Permanent Import Tariffs and Export Subsidies Under Asymmetric Pricing Behavior.



on World GDP (Panel 8) and trade neither in the near or long-term. World trade does not change as the rise in home export is exactly offset by lower home import (Panel 3, 4, and 7).

In the second case, instead, World trade falls over 1/2 percent in the near term because home real exports do not rise immediately whereas foreign exports fall sharply due to the quick influence of $\tau_{M,t}$. World GDP falls somewhat initially before expanding. Monetary policy plays an important role for subsequent expansion in World GDP as the foreign CB cuts policy rates more than the home CB hikes rates (the interest rate differential shown in Panel 12 is more than twice as elevated as the hike in the home policy rate in Panel 11).

5. The Macroeconomic Costs of a Trade War

In this section, we examine the effects of a "Trade War", which we assume to play out in two different incarnations. First, we assume that the foreign economy retaliates to a home BAT by imposing *only* an import tariff equal to the sum of the import and export subsidy (i.e., $\tau^*_{M,t} = \tau_{X,t} + \tau_{M,t} = 20$ percent). This retaliation scheme ensures that the tariff-subsidy differentials $\tau_{M.t} - \tau^*_{X,t}$ and $\tau^*_{M.t} - \tau_{X,t}$ in eqs. (3) and (5) rise 10 percent each. Second, the foreign economy retaliates in a fully symmetric way by imposing *both* a foreign import tariff equal to the home export subsidy (i.e. $\tau^*_{M,t} = \tau_{X,t}$) and an export subsidy equal to the home import tariff (i.e. $\tau^*_{X,t} = \tau_{M,t}$). In this latter case, both countries impose the same BAT, and is henceforth referred to as "symmetric retaliation".

5.1. Retaliation through Import Tariffs

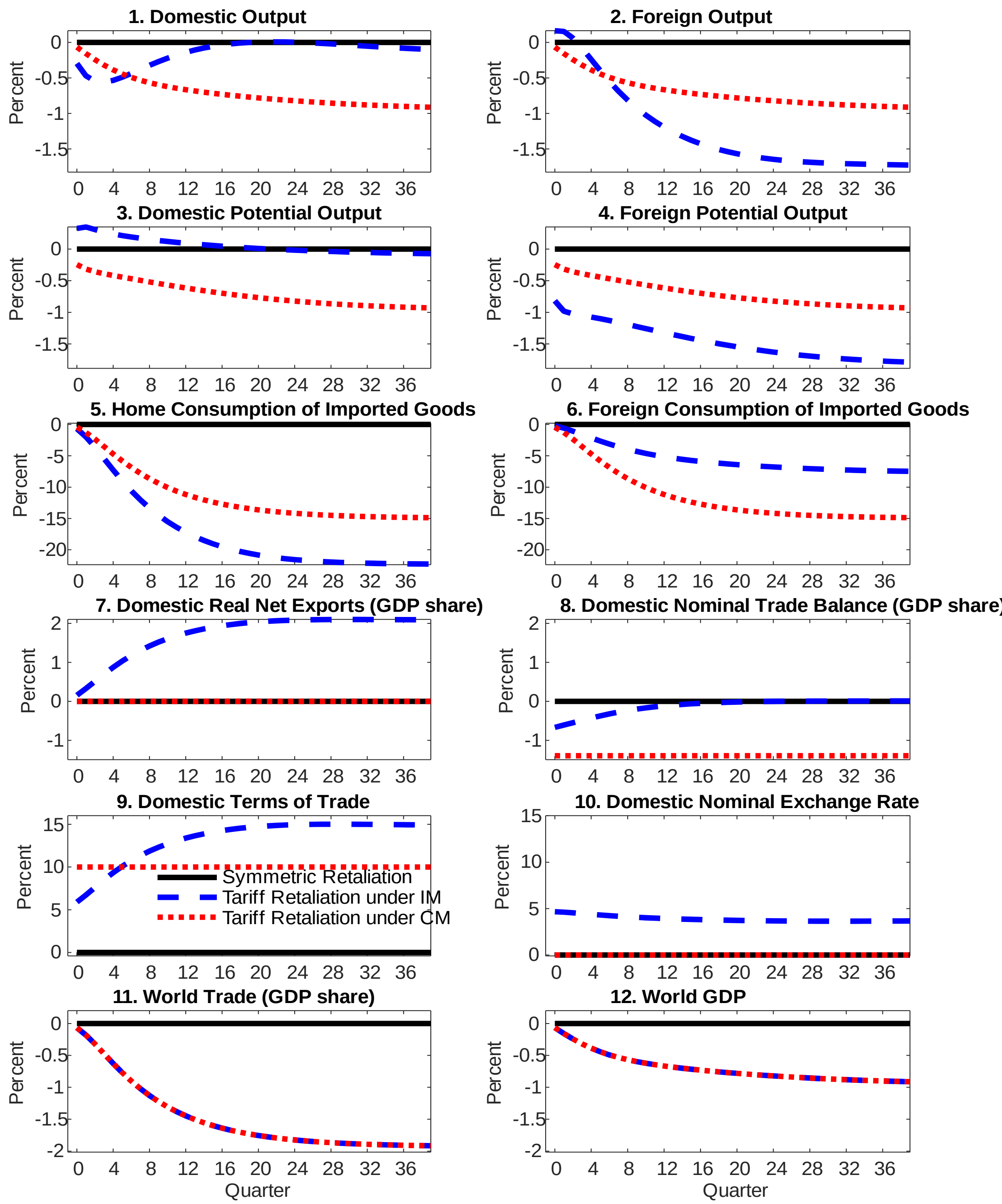
Figure 6 reports the effects of the foreign economy retaliation through import tariffs under incomplete markets (IM; blue dashed line) and complete markets (CM; red dotted line).

The CM assumption implies that the effects on the home and foreign quantities and prices are completely symmetric and the nominal exchange rate remains unaffected. However, the home terms of trade worsens by 10 percent as the foreign tariff $\tau^*_{M,t}$ is hiked by 10 percent more than the domestic tariff $\tau_{M,t}$. This implies that the home trade balance as share of nominal GDP deteriorates permanently — by roughly -1.4 percent (i.e., the terms of trade deprecation times the steady state import share of output, which equals 0.14). Since the trade deficit is assumed to be financed by lump sum transfers by unconstrained households, it does not have any real effects in the model.

In contrast, the impact under IM features non-symmetric effects on allocations. Since the home and foreign economies are both effectively imposing the same increase in net-tariffs $\tau_{M.t} - \tau^*_{X,t}$ and $\tau^*_{M,t} - \tau_{X,t}$ (see eqs. (3) and (5)), the non-symmetric effect on home and foreign output shown in Figure 6 may be surprising at first glance. However, results can be explained by the fact that the import tariffs ($\tau_{M,t}$ and $\tau^*_{M,t}$) have a direct effect on the terms of trade (see eq. (8)) and thereby on the nominal trade balance as share of GDP (eq. (9)). In our example, $\tau^*_{M,t}$ is increased by 20 percent whereas $\tau_{M,t}$ is only increased by 10 percent. This has a direct depreciative effect on the home terms of trade with 10 percent; but since the relatively larger hike in the foreign import tariff causes the home nominal exchange rate to depreciate about 5 percent (Panel 10), the depreciation of the home terms of trade totals 15 percent (Panel 9).

Another way of thinking about the asymmetric responses under incomplete markets is to use the Lerner symmetry results in Figure 1. Since Lerner symmetry holds for $\tau_{M.t}$ and $\tau_{X.t}$, the retaliation experiment is isomorphic to a 20 percent hike in the foreign import tariff $\tau^*_{M,t}$. Hence, except for the home nominal exchange rate, the IM responses of Figure 6 effectively

Figure 6: Effects of a Trade War: Import Tariffs in Both Economies.



show the partial impact of a permanent 20 percent hike in the foreign import tariff.

Importantly, retaining a CM or IM assumption does not make a difference for the global effects of the trade war (Panels 11 and 12). Alternative asset markets assumptions simply affect the distribution between the home and foreign economies. At the global level the macroeconomic costs are substantial, with output deteriorating permanently with nearly 1 percent whereas trade declines with 2 percent of baseline GDP. Furthermore, it should be noted that the invariance of global trade and GDP to the asset market assumption is not contingent on both economies being of equal size. When the domestic economy is assumed to account only for 23 percent of the world economy, that is we think about the home economy as the U.S. and the foreign economy as the rest of the world, global trade and GDP still fall equally much under incomplete and complete asset markets albeit half as less as in Figure 6 (i.e. with 1 and 1/2 percent, respectively). These results are qualitatively similar to the tariff scenario presented in IMF (2016).

5.2. The Benign Case: A Fully Symmetric Response

Finally, we analyze the case when the foreign economy responds by providing export subsidies to their exporters to match the hike in home tariffs and raising the import tariff to barely offset the home export subsidy (i.e., $\tau_{M,t} = -\tau^*_{X,t}$ and $\tau^*_{M,t} = -\tau_{X,t}$). A fully symmetric response nullifies the adverse impact of a trade war regardless of how exchange rates are determined (Figure 6; black line). In addition, if trade is balanced, the budgetary implications are only of second order.

Thus, there is a "bad" and a "good" way for foreign economies to respond to trade reform in the home economy. The bad way involves slapping an import tariff large enough to offset the home export subsidy and match the hike in the home import tariff. The good way involves the foreign government using both import tariffs and export subsidies to mimic adjustment in home tariffs and subsidies.

6. Conclusions

We have quantified the macroeconomic effects of tariffs and of border adjustment taxes (BATs) in an empirically validated New Keynesian open-economy model under various firm-pricing behavior assumptions, exchange rate determination mechanisms, and asset market assumptions.

Under incomplete markets and flexible exchange rates, we find support for the view that a BAT is allocative neutral in the long run (i.e., the Lerner symmetry holds) and, thus, is not akin to a protectionist measure. Still, the Lerner symmetry breaks down in the short-term when various frictions such as implementation lags or gradual nominal exchange rate adjustment prevent the real exchange rate from adjusting fully immediately. Neither sticky prices (and sticky wages) nor local-currency pricing per se — and, hence, dollar-invoicing per se — are sufficient conditions to break the Lerner symmetry. Even so, when tariffs are passed to prices more quickly than exchange rate movements, the exchange rate overshoots and the home country output expands while global trade and output are unaffected, providing some support for the Keynesian view even under flexible exchange rate regimes.

Under complete markets, the symmetry result breaks down in both the short- and long-run, and that the real exchange rate appreciates by a smaller extent (relative to the incomplete market case) and is not able to fully offset the price distortions induced by the trade policy. Global trade and output are still unaffected but production is shifted to the home country while consumption is shifted to the foreign country. The effects are quantitatively important and provide strong support to the Keynesian view.

Finally, we assessed the macroeconomic costs of trade wars. A fully symmetric retaliation that implies an analogous boarder adjustment tax in the foreign country is completely neutral. However, if the foreign countries retaliate exclusively through higher import tariffs, then global trade and output will be adversely affected.

In future work, it would be interesting to consider the impact of the zero lower bound on the results and to estimate the effects of import and export tariffs using empirical methods. In addition, throughout the paper we have retained the assumptions that trade is balanced and no tariffs are in place in the steady state trade. As a consequence, there are no fiscal implications from the boarder adjustment tax. Also, in the case of incomplete markets we assume no balance sheet effects from exchange rate movements. It would be interesting to explore the implications of relaxing these assumptions. Furthermore, as our analysis has demonstrated that the macroeconomic effects of trade tariffs and subsidies are highly contingent on the functioning of international asset markets, the empirical merits of the incomplete and complete markets assumption deserve further attention.

Finally, an important issue we leave for future research is the normative welfare implications of the import tariffs and export subsidies on both the domestic and foreign economies.

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Online Appendix for Lindé and Pescatori "The Macroeconomic Effects of Trade Tariffs: Revisiting the Lerner Symmetry Result"

Appendix A. The Open Economy New Keynesian Model

The large-scale model closely follows Erceg, Guerrieri and Gust (2006) and Erceg and Lindé (2013). The model consists of two equally sized countries (or regions) – home and foreign – and allows for endogenous investment, hand-to-mouth (HM) or "Keynesian" households, sticky wages as well as sticky prices, trade adjustment costs, and incomplete financial markets across the two countries. Given the isomorphic structure of the two countries, our exposition below largely focuses on the structure of the home economy.

As the recent recession has provided strong evidence in favor of the importance of financial frictions, our model also features a financial accelerator channel which closely parallels earlier work by Bernanke, Gertler, and Gilchrist (1999) and Christiano, Motto, and Rostagno (2008). Given that the mechanics underlying this particular financial accelerator mechanism are well-understood, we simplify our exposition by focusing on a special case of our model which abstracts from the financial accelerator. However, we conclude our model description with a brief description of how the model is modified to include the financial accelerator (Section A.6).

A.1. Firms and Price Setting

A.1.1. Production of Domestic Intermediate Goods

There is a continuum of differentiated intermediate goods (indexed by $i \in [0,1]$) in the home economy, each of which is produced by a single monopolistically competitive firm. In the domestic market, firm i faces a demand function that varies inversely with its output price $P_{Dt}(i)$ and directly with aggregate demand at home Y_{Dt}:

$$Y_{Dt}(i) = \left[\frac{P_{Dt}(i)}{P_{Dt}}\right]^{\frac{-(1+\theta_p)}{\theta_p}} Y_{Dt}, \tag{A.1}$$

where $\theta_p > 0$, and P_{Dt} is an aggregate price index defined below. Similarly, firm i faces the following export demand function:

$$X_t(i) = \left[\frac{P^*_{Mt}(i)}{P^*_{Mt}}\right]^{\frac{-(1+\theta_p)}{\theta_p}} M^*_t, \tag{A.2}$$

where $X_t(i)$ denotes the quantity demanded of domestic good i in the foreign block, $P^*_{Mt}(i)$ denotes the price that firm i sets in the foreign market, P^*_{Mt} is the import price index abroad, and M^*_t is an aggregate of the home's imports (we use an asterisk to denote the foreign's variables).

Each producer utilizes capital services $K_t(i)$ and a labor index $L_t(i)$ (defined below) to produce its respective output good. The production function is assumed to have a constant-elasticity of substitution (CES) form:

$$Y_t(i) = \left(\omega_K^{\frac{\rho}{1+\rho}} K_t(i)^{\frac{1}{1+\rho}} + \omega_L^{\frac{\rho}{1+\rho}} (Z_t L_t(i))^{\frac{1}{1+\rho}}\right)^{1+\rho}. \tag{A.3}$$

The production function exhibits constant-returns-to-scale in both inputs, and Z_t is a country-specific shock to the level of technology. Firms face perfectly competitive factor markets for hiring capital and labor. Thus, each firm chooses $K_t(i)$ and $L_t(i)$, taking as given both the rental price of capital R_{Kt} and the aggregate wage index W_t (defined below). Firms can costlessly adjust either factor of production, which implies that each firm has an identical marginal cost per unit of output, MC_t. The (log-linearized) technology shock is assumed to follow an AR(1) process:

$$z_t = \rho_z z_{t-1} + \varepsilon_{z,t}. \tag{A.4}$$

The prices of the intermediate goods are determined by Calvo-style staggered contracts (see Calvo, j1983). In each period, a firm selling its goods in the home market faces a constant probability, $1-\xi_p$, of being able to re-optimize its price ($P_{Dt}(i)$). This probability of receiving a signal to reoptimize is independent across firms and time. If a firm is not allowed to optimize its prices, we follow Christiano, Eichenbaum and Evans (2005) and Smets and Wouters (2003), and assume that the firm must reset its home price as a weighted combination of the lagged and steady state rate of inflation $P_{Dt}(i) = \pi_{t-1}^{\iota_p} \pi^{1-\iota_p} P_{Dt-1}(i)$ for the non-optimizing firms. This formulation allows for structural persistence in price-setting if ι_p exceeds zero.

When a firm i is allowed to reoptimize its price in period t, the firm maximizes:

$$\max_{P_{Dt}(i)} \mathbb{E}_t \sum_{j=0}^{\infty} \psi_{t,t+j} \xi_p^j \left[\prod_{h=1}^{j} \pi_{t+h-1} (P_{Dt}(i) - MC_{t+j}) Y_{Dt+j}(i)\right]. \tag{A.5}$$

The operator $\mathbb{E}_t$ represents the conditional expectation based on the information available to agents at period t. The firm discounts profits received at date $t+j$ by the state-contingent discount factor $\psi_{t,t+j}$; for notational simplicity, we have suppressed all of the state indices.[A.1] The first-order condition for setting the contract price of good i is:

$$\mathbb{E}_t \sum_{j=0}^{\infty} \psi_{t,t+j} \xi_p^j \left(\frac{\prod_{h=1}^{j} \pi_{t+h-1}(i) P_{Dt}(i)}{(1+\theta_p)} - MC_{t+j} \right) Y_{Dt+j}(i) = 0. \tag{A.6}$$

For the goods sold abroad, we assume local currency pricing (LCP) as explained in Section 2.1. Although the price-setting problem for the exporting firms is isomorphic to the problem for the firms selling its goods on the domestic market (and we assume $\xi_m = \xi_p$ and $\iota_m = \iota_p$), the LCP assumption implies that the price of foreign import goods $P_{M,t}^*$ will deviate from the producer currency price$\frac{P_{X,t}}{S_t} \times \frac{(1+\tau_{M,t}^*)}{1+\tau_{X,t}}$ as follows (in log-linear form)

$$\delta_t^* = -p_{M,t}^* - s_t + p_{X,t} + \tau_{M,t}^* - \tau_{X,t}, \tag{A.7}$$

where $p_{X,t} = p_{D,t}$. The deviations from the law of one price are due to price stickiness, the foreign import tariffs ($\tau_{M,t}^*$) and export subsidy the home block provides ($\tau_{X,t}$).

A.1.2. Production of the Domestic Output Index

Because households have identical Dixit-Stiglitz preferences, it is convenient to assume that a representative aggregator combines the differentiated intermediate products into a composite home-produced good Y_{Dt}:

$$Y_{Dt} = \left[\int_0^1 Y_{Dt}(i)^{\frac{1}{1+\theta_p}} di \right]^{1+\theta_p}. \tag{A.8}$$

The aggregator chooses the bundle of goods that minimizes the cost of producing Y_{Dt}, taking the price $P_{Dt}(i)$ of each intermediate good $Y_{Dt}(i)$ as given. The aggregator sells units of each sectoral output index at its unit cost P_{Dt}:

$$P_{Dt} = \left[\int_0^1 P_{Dt}(i)^{\frac{-1}{\theta_p}} di \right]^{-\theta_p}. \tag{A.9}$$

[A.1] We define $\xi_{t,t+j}$ to be the price in period t of a claim that pays one dollar if the specified state occurs in period $t+j$ (see the household problem below); then the corresponding element of $\psi_{t,t+j}$ equals $\xi_{t,t+j}$ divided by the probability that the specified state will occur.

We also assume a representative aggregator in the foreign block who combines the differentiated home products $X_t(i)$ into a single index for foreign imports:

$$M_t^* = \left[\int_0^1 X_t\left(i\right)^{\frac{1}{1+\theta_p}} di \right]^{1+\theta_p}, \tag{A.10}$$

and sells M_t^* at price $P_{M,t}^*$.

$$P_{Mt}^* = \left[\int_0^1 P_{Mt}^*\left(i\right)^{\frac{-1}{\theta_p}} di \right]^{-\theta_p}. \tag{A.11}$$

A.1.3. Production of Consumption and Investment Goods

Final consumption goods are produced by a representative consumption goods distributor. This firm combines purchases of domestically-produced goods with imported goods to produce a final consumption good (C_{At}) according to a constant-returns-to-scale CES production function:

$$C_{At} = \left(\omega_C^{\frac{\rho_C}{1+\rho_C}} C_{Dt}^{\frac{1}{1+\rho_C}} + \left(1-\omega_C\right)^{\frac{\rho_C}{1+\rho_C}} \left(\varphi_{Ct} M_{Ct}\right)^{\frac{1}{1+\rho_C}} \right)^{1+\rho_C}, \tag{A.12}$$

where C_{Dt} denotes the consumption good distributor's demand for the index of domestically-produced goods, M_{Ct} denotes the distributor's demand for the index of foreign-produced goods, and φ_{Ct} reflects costs of adjusting consumption imports. The final consumption good is used by both households and by the government.[A.2] The form of the production function mirrors the preferences of households and the government sector over consumption of domestically-produced goods and imports. Accordingly, the quasi-share parameter ω_C may be interpreted as determining the preferences of both the private and public sector for domestic relative to foreign consumption goods, or equivalently, the degree of home bias in consumption expenditure. Finally, the adjustment cost term φ_{Ct} is assumed to take the quadratic form:

$$\varphi_{Ct} = \left[1 - \frac{\varphi_{M_C}}{2} \left(\frac{\frac{M_{Ct}}{C_{Dt}}}{\frac{M_{Ct-1}}{C_{Dt-1}}^{a}} - 1 \right)^2 \right]. \tag{A.13}$$

This specification implies that it is costly to change the proportion of domestic and foreign goods in the aggregate consumption bundle, even though the level of imports may jump costlessly in response to changes in overall consumption demand. We assume that the

[A.2] Thus, the larger-scale model constrains the import share of government consumption to equal that of private consumption.

adjustment costs for each distributor depend on distributor's current import ratio $\frac{M_{Ct}}{C_{Dt}}$ relative to the economy-wide ratio in the previous period $\frac{M_{Ct-1}}{C_{Dt-1}}^{a}$, so that adjustment costs are external to individual distributors.

Given the presence of adjustment costs, the representative consumption goods distributor chooses (a contingency plan for) C_{Dt} and M_{Ct} to minimize its discounted expected costs of producing the aggregate consumption good:

$$\min_{C_{Dt+k},M_{Ct+k}} \mathbb{E}_t \sum_{k=0}^{\infty} \psi_{t,t+k} \left(P_{Dt+k} C_{Dt+k} + P_{Mt+k} M_{Ct+k} \right) \tag{A.14}$$
$$+ P_{Ct+k} \left[C_{A,t+k} - \left(\omega_C^{\frac{\rho_C}{1+\rho_C}} C_{Dt+k}^{\frac{1}{1+\rho_C}} + (1-\omega_C)^{\frac{\rho_C}{1+\rho_C}} \left(\varphi_{Ct+k} M_{Ct+k} \right)^{\frac{1}{1+\rho_C}} \right)^{1+\rho_C} \right] \Bigg\}.$$

The distributor sells the final consumption good to households and the government at a price P_{Ct}, which may be interpreted as the consumption price index (or equivalently, as the shadow cost of producing an additional unit of the consumption good).

We model the production of final investment goods in an analogous manner, although we allow the weight ω_I in the investment index to differ from that of the weight ω_C in the consumption goods index.[A.3]

A.2. Households and Wage Setting

We assume a continuum of monopolistically competitive households (indexed on the unit interval), each of which supplies a differentiated labor service to the intermediate goods-producing sector (the only producers demanding labor services in our framework) following Erceg, Henderson and Levin (2000). A representative labor aggregator (or "employment agency") combines households' labor hours in the same proportions as firms would choose. Thus, the aggregator's demand for each household's labor is equal to the sum of firms' demands. The aggregate labor index L_t has the Dixit-Stiglitz form:

$$L_t = \left[\int_0^1 \left(\zeta N_t(h) \right)^{\frac{1}{1+\theta_w}} dh \right]^{1+\theta_w}, \tag{A.15}$$

where $\theta_w > 0$ and $N_t(h)$ is hours worked by a typical member of household h. The parameter ζ is the size of a household of type h, and effectively determines the size of the population

[A.3] Government spending is assumed to fall exclusively on consumption, so that all investment is private investment.

in the home country. The aggregator minimizes the cost of producing a given amount of the aggregate labor index, taking each household's wage rate $W_t(h)$ as given, and then sells units of the labor index to the production sector at their unit cost W_t:

$$W_t = \left[\int_0^1 W_t(h)^{\frac{-1}{\theta_w}}\, dh\right]^{-\theta_w}. \tag{A.16}$$

The aggregator's demand for the labor services of a typical member of household h is given by

$$N_t(h) = \left[\frac{W_t(h)}{W_t}\right]^{-\frac{1+\theta_w}{\theta_w}} L_t/\zeta. \tag{A.17}$$

We assume that there are two types of households: households that make intertemporal consumption, labor supply, and capital accumulation decisions in a forward-looking manner by maximizing utility subject to an intertemporal budget constraint (FL households, for "forward-looking"); and the remainder that simply consume their after-tax disposable income (HM households, for "hand-to-mouth" households). The latter type receive no capital rental income or profits, and choose to set their wage to be the average wage of optimizing households. We denote the share of FL households by *1*-ς and the share of HM households by ς.

We consider first the problem faced by FL households. The utility functional for an optimizing representative member of household h is

$$\mathbb{E}_t \sum_{j=0}^{\infty} \beta^j \left\{ \frac{1}{1-\sigma}\left(C^O_{t+j}(h) - \varkappa C^O_{t+j-1} - C\nu_{ct+j}\right)^{1-\sigma} + \frac{\chi_0 Z^{1-\sigma}_{t+j}}{1-\chi}(1-N_{t+j}(h))^{1-\chi} + \mu_0 F\left(\frac{MB_{t+j+1}(h)}{P_{Ct+j}}\right)\right\}, \tag{A.18}$$

where the discount factor β satisfies $0 < \beta < 1$. As in Smets and Wouters (2003, 2007), we allow for the possibility of external habit formation in preferences, so that each household member cares about its consumption relative to lagged aggregate consumption per capita of forward-looking agents C^O_{t-1}. The period utility function depends on an each member's current leisure $1 - N_t(h)$, his end-of-period real money balances, $\frac{MB_{t+1}(h)}{P_{Ct}}$, and a preference shock, ν_{ct}. The subutility function $F(.)$ over real balances is assumed to have a satiation point to account for the possibility of a zero nominal interest rate; see Eggertsson and

Woodford (2003) for further discussion.[A.4] The (log-linearized) consumption demand shock ν_{ct} is assumed to follow an AR(1) process:

$$\nu_{ct} = \rho_\nu \nu_{ct-1} + \varepsilon_{\nu_c,t.} \tag{A.19}$$

Forward-looking household h faces a flow budget constraint in period t which states that its combined expenditure on goods and on the net accumulation of financial assets must equal its disposable income:

$$\begin{gathered} P_{Ct}\left(1+\tau_{Ct}\right) C_t^O\left(h\right) + P_{It} I_t\left(h\right) + MB_{t+1}\left(h\right) - MB_t(h) + \int_s \xi_{t,t+1} B_{Dt+1}(h) \\ -B_{Dt}(h) + P_{Bt} B_{Gt+1} - B_{Gt} + S_t \frac{P_{Bt}^* B_{Ft+1}(h)}{\phi_{bt}} - S_t B_{Ft}(h) \\ = (1-\tau_{Nt}) W_t\left(h\right) N_t\left(h\right) + \Gamma_t\left(h\right) + TR_t(h) + (1-\tau_{Kt}) R_{Kt} K_t(h) + \\ P_{It} \tau_{Kt} \delta K_t(h) - P_{Dt} \phi_{It}(h). \end{gathered} \tag{A.20}$$

Consumption purchases are subject to a sales tax of τ_{Ct}. Investment in physical capital augments the per capita capital stock $K_{t+1}(h)$ according to a linear transition law of the form:

$$K_{t+1}\left(h\right) = (1-\delta) K_t(h) + I_t(h), \tag{A.21}$$

where δ is the depreciation rate of capital.

Financial asset accumulation of a typical member of FL household h consists of increases in nominal money holdings $(MB_{t+1}\left(h\right) - MB_t\left(h\right))$ and the net acquisition of bonds. While the domestic financial market is complete through the existence of state-contingent bonds B_{Dt+1}, cross-border asset trade is restricted to a single non-state contingent bond issued by the government of the foreign economy.[A.5]

The terms B_{Gt+1} and B_{Ft+1} represent each household member's net purchases of the government bonds issued by the home and foreign governments, respectively. Each type of bond pays one currency unit in the subsequent period, and is sold at price (discount) of P_{Bt} and P_{Bt}^*, respectively. S_t is the nominal exchange rate. To ensure the stationarity of foreign asset positions, we follow Turnovsky (1985) by assuming that domestic households must pay a transaction cost when trading in the foreign bond. The intermediation cost depends on the ratio of economy-wide holdings of net foreign assets to nominal GDP, $P_{Dt} Y_{Dt}$, and are

[A.4] For simplicity, we assume that μ_0 is sufficiently small that changes in the monetary base have a negligible impact on equilibrium allocations, at least to the first-order approximation we consider.
[A.5] The domestic contingent claims B_{Dt+1} are in zero net supply from the standpoint of home economy as a whole.

given by:

$$\phi_{bt} = \exp\left(-\phi_b\left(\frac{B_{Ft+1}}{P_{Dt}Y_{Dt}}\right)\right). \tag{A.22}$$

If the home country is an overall net lender position internationally, then a household will earn a lower return on any holdings of foreign bonds; conversely, if the home country is a net debtor position, home households pay a higher return on their foreign liabilities. Given that the domestic government bond in the home economy and foreign bond have the same payoff, the price faced by home residents net of the transaction cost is identical, so that $P_{Bt} = \frac{P_{Bt}^*}{\phi_{bt}}$. The effective nominal interest rate on domestic bonds (and similarly for foreign bonds) hence equals $i_t = 1/P_{Bt} - 1$.

Each member of FL household h earns after-tax labor income, $(1-\tau_{Nt})W_t\,(h)\,N_t\,(h)$, where τ_{Nt} is a stochastic tax on labor income. The household leases capital at the after-tax rental rate $(1-\tau_{Kt})R_{Kt}$, where τ_{Kt} is a stochastic tax on capital income. The household receives a depreciation write-off of $P_{It}\tau_{Kt}\delta$ per unit of capital. Each member also receives an aliquot share $\Gamma_t\,(h)$ of the profits of all firms and a lump-sum government transfer, $TR_t\,(h)$ (which is negative in the case of a tax). Following Christiano, Eichenbaum and Evans (2005), we assume that it is costly to change the level of gross investment from the previous period, so that the acceleration in the capital stock is penalized:

$$\phi_{It}(h) = \frac{1}{2}\phi_I\frac{(I_t(h) - I_{t-1})^2}{I_{t-1}}. \tag{A.23}$$

In every period t, each member of FL household h maximizes the utility functional (A.18) with respect to its consumption, investment, (end-of-period) capital stock, money balances, holdings of contingent claims, and holdings of domestic and foreign bonds, subject to its labor demand function (A.17), budget constraint (A.20), and transition equation for capital (A.21). In doing so, a household takes as given prices, taxes and transfers, and aggregate quantities such as lagged aggregate consumption and the aggregate net foreign asset position.

Forward-looking (FL) households set nominal wages in staggered contracts that are analogous to the price contracts described above. In particular, with probability $1-\xi_w$, each member of a household is allowed to reoptimize its wage contract. If a household is not allowed to optimize its wage rate, we assume each household member resets its wage according to:

$$W_t(h) = \omega_{t-1}^{\iota_w} \omega^{1-\iota_w} W_{t-1}(h), \tag{A.24}$$

where ω_{t-1} is the gross nominal wage inflation rate in period $t-1$, i.e. W_t/W_{t-1}, and $\omega = \pi$ is the steady state rate of change in the nominal wage (equal to gross price inflation since steady state gross productivity growth is assumed to be unity). Dynamic indexation of this form introduces some element of structural persistence into the wage-setting process. Each member of household h chooses the value of $W_t(h)$ to maximize its utility functional (A.18) subject to these constraints.

Finally, we consider the determination of consumption and labor supply of the hand-to-mouth (HM) households. A typical member of a HM household simply equates his nominal consumption spending, $P_{Ct}(1+\tau_{Ct}) C_t^{HM}(h)$, to his current after-tax disposable income, which consists of labor income plus lump-sum transfers from the government:

$$P_{Ct}(1+\tau_{Ct}) C_t^{HM}(h) = (1-\tau_{Nt}) W_t(h) N_t(h) + TR_t(h). \tag{A.25}$$

The HM households are assumed to set their wage equal to the average wage of the forward-looking households. Since HM households face the same labor demand schedule as the forward-looking households, this assumption implies that each HM household works the same number of hours as the average for forward-looking households.

A.3. Monetary Policy

The central bank is assumed to adhere to a Taylor-type policy rule although we allow here for some inertia in the interest rate reaction function that is captured by the term $\gamma_i i_{t-1}$:

$$i_t = (1-\gamma_i)\left[\gamma_\pi \pi_{Ct} + \gamma_x x_t + \gamma_{\Delta x} \Delta x_t\right] + \gamma_i i_{t-1}, \tag{A.26}$$

where π_{Ct} is consumer price inflation, and x_t is the model consistent output gap, i.e. the percent deviation of actual output from the notional level of output that would prevail if prices and wages were fully flexible.

A.4. Fiscal Policy

The government does not need to balance its budget each period, and issues nominal debt B_{Gt+1} at the end of period t to finance its deficits according to:

$$P_{B,t}B_{G,t+1} - B_{G,t} = P_{C,t}G_t + TR_t^O + TR_t^{HM} - \tau_{N,t}W_tL_t - \tau_{C,t}P_{C,t}C_t - \tau_{K,t}(R_{K,t} - \delta P_{I,t})K_t \\ -(MB_{t+1} - MB_t) - \tau_{M,t}P_{M,t}M_t/(1+\tau_{M,t}) + \tau_{X,t}P_{X,t}X_t/(1+\tau_{X,t}), \tag{A.27}$$

where C_t is total private consumption. Equation (A.27) aggregates the capital stock, money and bond holdings, and transfers and taxes over all households so that, for example, $TR_t^O = \int_0^O TR_t^O(h)dh$. The taxes on capital τ_{Kt}, consumption τ_{Ct} and labor income τ_{Nt}, as well as the ratio of real transfers to (trend) GDP to hand to mouth households, $tr_t^{HM} = \frac{TR_t^{HM}}{P_tY}$, are also assumed to be fixed.[A.6] Government purchases have no direct effect on the utility of households, nor do they affect the production function of the private sector.

The process for the (log of) government spending is given by an AR(1) process:

$$(g_t - g) = \rho_G (g_{t-1} - g) + \varepsilon_{g,t}, \tag{A.28}$$

where $\varepsilon_{g,t}$ is independently normally distributed with zero mean and standard deviation σ_G.

We assume that policymakers adjust the ratio of real transfers to (trend) GDP for optimizing households, $tr_t^O = \frac{TR_t^O}{P_tY}$, to stabilize the debt/GDP ratio and the deficit. Specifically, the labor tax rate evolves according to:

$$tr_t^O - tr^O = \nu_1 \left(tr_{t-1}^O - tr^O\right) - (1-\nu_1)\left[\nu_2 (b_{Gt} - b_G) + \nu_3 (\Delta b_{Gt+1} - \Delta b_G)\right], \tag{A.29}$$

where $b_{Gt} = B_{Gt}/(4\bar{P}_tY)$ (i.e. government debt as share of nominal trend output).

A.5. Resource Constraint and Net Foreign Assets

The home economy's aggregate resource constraint can be written as:

$$Y_{Dt} = C_{Dt} + I_{Dt} + \phi_{It} + \frac{\zeta^*}{\zeta}M_t^*, \tag{A.30}$$

where ϕ_{It} is the adjustment cost on investment aggregated across all households. The final consumption good is allocated between households and the government:

$$C_{At} = C_t + G_t, \tag{A.31}$$

[A.6] Given that the central bank uses the nominal interest rate as its policy instrument, the level of seigniorage is determined by nominal money demand.

where C_t is (per capita) private consumption of FL (optimizing) and HM households:

$$C_t = (1 - \varsigma)C_t^O + \varsigma C_t^{HM}. \tag{A.32}$$

Total exports may be allocated to either the consumption or the investment sector abroad:

$$M_t^* = M_{Ct}^* + M_{It}^*. \tag{A.33}$$

The evolution of net foreign assets can be expressed as:

$$\frac{P_{B,t}^* B_{F,t+1}}{\phi_{bt}} = B_{F,t} + P_{Mt}^* \frac{\zeta^*}{\zeta} M_t^* - P_{Mt} M_t. \tag{A.34}$$

This expression can be derived from the budget constraint of the FL households after imposing the government budget constraint, the consumption rule of the HM households, the definition of firm profits, and the condition that domestic state-contingent non-government bonds (B_{Dt+1}) are in zero net supply

Finally, we assume that the structure of the foreign country is isomorphic to that of the home country.

A.6. Production of capital services

The model is amended to include a financial accelerator mechanism into both country blocks of our benchmark model following the basic approach of Bernanke, Gertler and Gilchrist (1999). Thus, the intermediate goods producers rent capital services from entrepreneurs (at the price R_{Kt}) rather than directly from households. Entrepreneurs purchase physical capital from competitive capital goods producers (and resell it back at the end of each period), with the latter employing the same technology to transform investment goods into finished capital goods as described by eqs. (A.21) and (A.23). To finance the acquisition of physical capital, each entrepreneur combines his net worth with a loan from a bank, for which the entrepreneur must pay an external finance premium (over the risk-free interest rate set by the central bank) due to an agency problem. Banks obtain funds to lend to the entrepreneurs by issuing deposits to households at the interest rate set by the central bank, with households bearing no credit risk (reflecting assumptions about free competition in banking and the ability of banks to diversify their portfolios). In equilibrium, shocks that affect entrepreneurial net worth – i.e., the leverage of the corporate sector – induce fluctuations in the corporate finance premium.[A.7]

A.7. Solution Method and Calibration

To analyze the behavior of the model, we log-linearize the model's equations around the non-stochastic steady state. Nominal variables are rendered stationary by suitable transformations. To solve the unconstrained version of the model, we compute the reduced-form solution of the model for a given set of parameters using the numerical algorithm of Anderson and Moore (1985), which provides an efficient implementation of the solution method proposed by Blanchard and Kahn (1980).

The model is calibrated at a quarterly frequency. The country size parameter $\zeta = 1$, so that the home and foreign countries are equally large. The trade share of the home economy is set to 18 percent of its GDP, which intended to match U.S. trade with the rest of the world. This pins down the trade share parameters ω_C and ω_I for the home country under the additional assumption that the import intensity of consumption is equal to 3/4 that of investment. The trade share of the foreign economy is thus 7.5 percent. We assume that $\rho_C = \rho_I = 2.5$, which together with our price markup $\theta_p = 0.2$ is consistent with a long-run price elasticity of demand for imported consumption and investment goods of 1.5. The import adjustment cost parameters are set so that $\varphi_{M_C} = \varphi_{M_I} = 1$, which slightly damps the near-term relative price sensitivity. The financial intermediation parameter ϕ_b is set to a very small value (0.00001), which is sufficient to ensure the model has a unique steady state.

The utility functional parameter σ is set equal to 1 to ensure that the model exhibit balanced growth, while the $\varkappa$ parameter determining the degree of habit persistence in consumption is set to 0.8 (following empirical evidence). The Frisch elasticity of labor supply is set to 0.4 (so $\chi = 2.5$). The utility parameter χ_0 is set so that employment comprises one-third of the household's time endowment, while the parameter μ_0 on the subutility function

[A.7] We follow Christiano, Motto and Rostagno (2008) by assuming that the debt contract between entrepreneurs and banks is written in nominal terms (rather than real terms as in Bernanke, Gertler and Gilchrist, 1999). For further details about the setup, see Bernanke, Gertler and Gilchrist (1999), and Christiano, Motto and Rostagno (2008). An excellent exposition is also provided in Christiano, Trabandt and Walentin (2007).

for real balances is set at an arbitrarily low value (so that variation in real balances do not affect equilibrium allocations). We set the share of HM agents $\varsigma = 0.5$, implying that these agents account for about one quarter of aggregate private consumption spending (the latter is much smaller than the population share of HM agents because the latter own no capital).

The parameter determining investment adjustment costs is estimated to be $\phi_I = 3$. The depreciation rate of capital δ is set at 0.03 (consistent with an annual depreciation rate of 12 percent). The parameter ρ in the CES production function of the intermediate goods producers is set to -2, implying an elasticity of substitution between capital and labor $(1+\rho)/\rho$, of 1/2. The quasi-capital share parameter ω_K – together with the price markup parameter of $\theta_P = 0.20$ – is chosen to imply a steady state investment to output ratio of 20 percent. In the augmented version of the model with a financial accelerator, our calibration of parameters follows Bernanke, Gertler and Gilchrist (1999). In particular, the monitoring cost, μ, expressed as a proportion of entrepreneurs' total gross revenue, is set to 0.12. The default rate of entrepreneurs is 3 percent per year, and the variance of the idiosyncratic productivity shocks to entrepreneurs is 0.28.

The Calvo price contract duration parameters are set to be $\xi_p = \xi_m = 0.92$, while the wage contract duration parameter is estimated to be $\xi_w = 0.90$. We set the degree of price indexation $\iota_p = 0.5$ and wage indexation ι_w to unity, while the wage markup $\theta_W = 1/3$.[A.8] The parameters of the monetary rule are set such that $\gamma_\pi = 1.5$, $\gamma_x = 0.125$, $\gamma_{\Delta x} = \gamma_x/2$, and $\gamma_i = 0.7$. With the discount factor set at $\beta = 0.995$ and the inflation target at 2 percent, the steady state nominal interest rate is 4 percent.

The parameters pertaining to fiscal policy are intended to roughly capture the revenue and spending sides of the U.S. government budgets. The share of government spending on goods and services is set equal to 18 percent of steady state output. The government debt to GDP ratio, b_G, is set to 0.90, roughly equal to the average level of consolidated federal debt at end-2016. The ratio of transfers to GDP is set to 7.5 percent. The steady state sales (i.e., VAT) tax rate τ_C is set to 6 percent, while the capital tax τ_K is set to 0.30. Given the annualized steady state real interest rate (of 2 percent), the government's intertemporal

[A.8] Given strategic complementarities in wage-setting, the wage markup influences the slope of the wage Phillips Curve.

budget constraint then implies that the labor income tax rate τ_N equals 0.375 in steady state. We assume an unaggressive tax adjustment rule in (A.29) by setting $\nu_1 = 0.985$ and $\nu_2 = \nu_3 = .1$.

Appendix B. Additional Results

In this appendix, we present some additional results referred to in the main text.

B.1. Effects on Flexible Price-Wage Allocations

In Figure B.1 we report the results on the allocations in the notional equilibrium with flexible prices and wages of exactly the same experiment as in Figure 1. As some variables in Figure 1 are specific to the sticky price version of the economy, those variables are replaced with other ones in the figures (potential real rate and investment at home and abroad).

B.2. Results Under Producer Currency Pricing

In Figure B.2 we report the effects of exactly the same experiment as in Figure 1 but under PCP instead of LCP assumption.

B.3. Results Under Home Currency Invoicing

In Figure B.3 we report the effects of exactly the same experiment as in Figure 1, but under the alternative assumption that all trades goods are priced in the home currency when they are traded. Technically, we implement this by assumption LCP in the home import sector, but PCP for the home export (foreign import) sector.

B.4. Results under a domestic Exchange Rate Peg

The blue dashed line in Figure B.4 shows the effects of a BAT reform under a foreign exchange rate peg for an extended set of variables discussed in the main text. For completeness, the red dotted line shows the responses to BAT shock for the hypothetical case when the home economy is pegging its nominal exchange rate to the foreign economy. In this case, the foreign economy is assumed to follow the Taylor rule (eq. A.26) and be able to react to domestic conditions whereas the home economy follows the rule

$$i_t = \gamma_s \Delta S_t, \tag{B.35}$$

where γ_s is set arbitrarily large. As can be seen from the figure, the effects are completely symmetric but flipped; in the hypothetical case of a home peg the real exchange rate appreciation occurs gradually via higher home prices and the home economy experiences a sharp boom in economic activity due to the lower real rates (and associated rise in consumption and investment) despite a slight worsening of home real net exports through higher real imports.

Figure B.1: Effects of Import Tariffs and Export Subsidies on Flex−price Equilibrium.

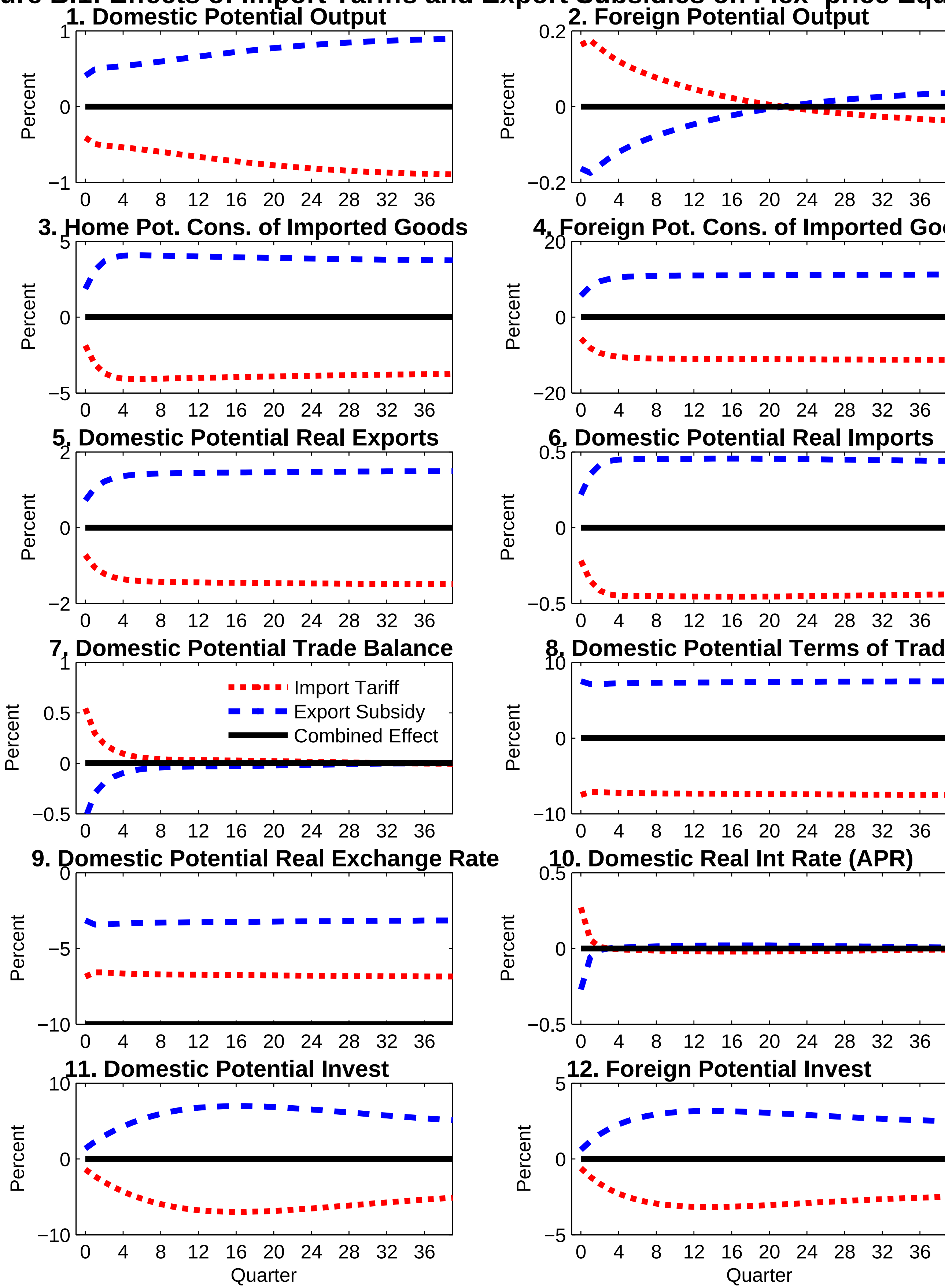


Figure B.2: Effects of Permanent Import Tariffs and Export Subsidies Under PCP.

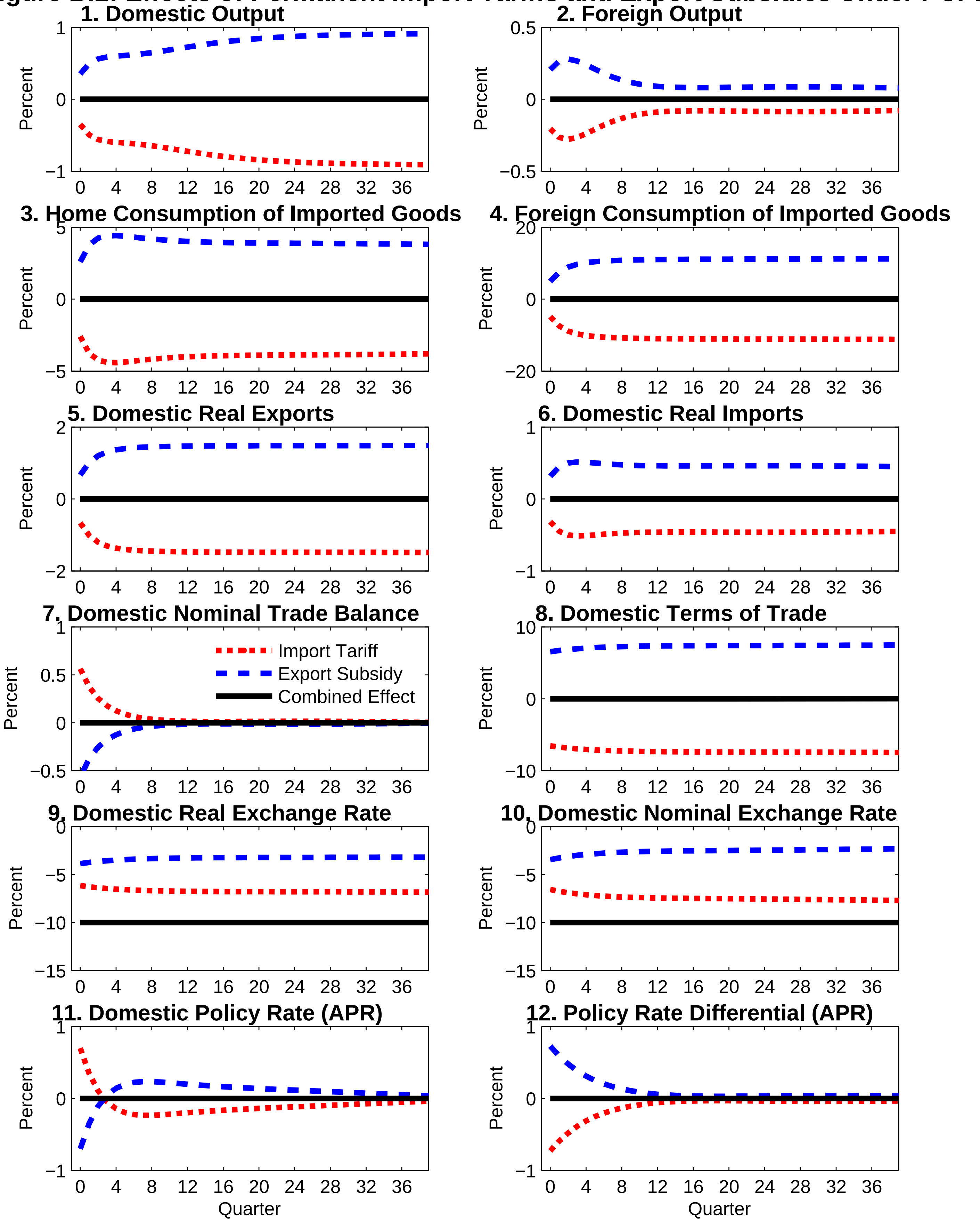


Figure B.3: Import Tariff and Export Subsidy Under Home Currency Invoicing.

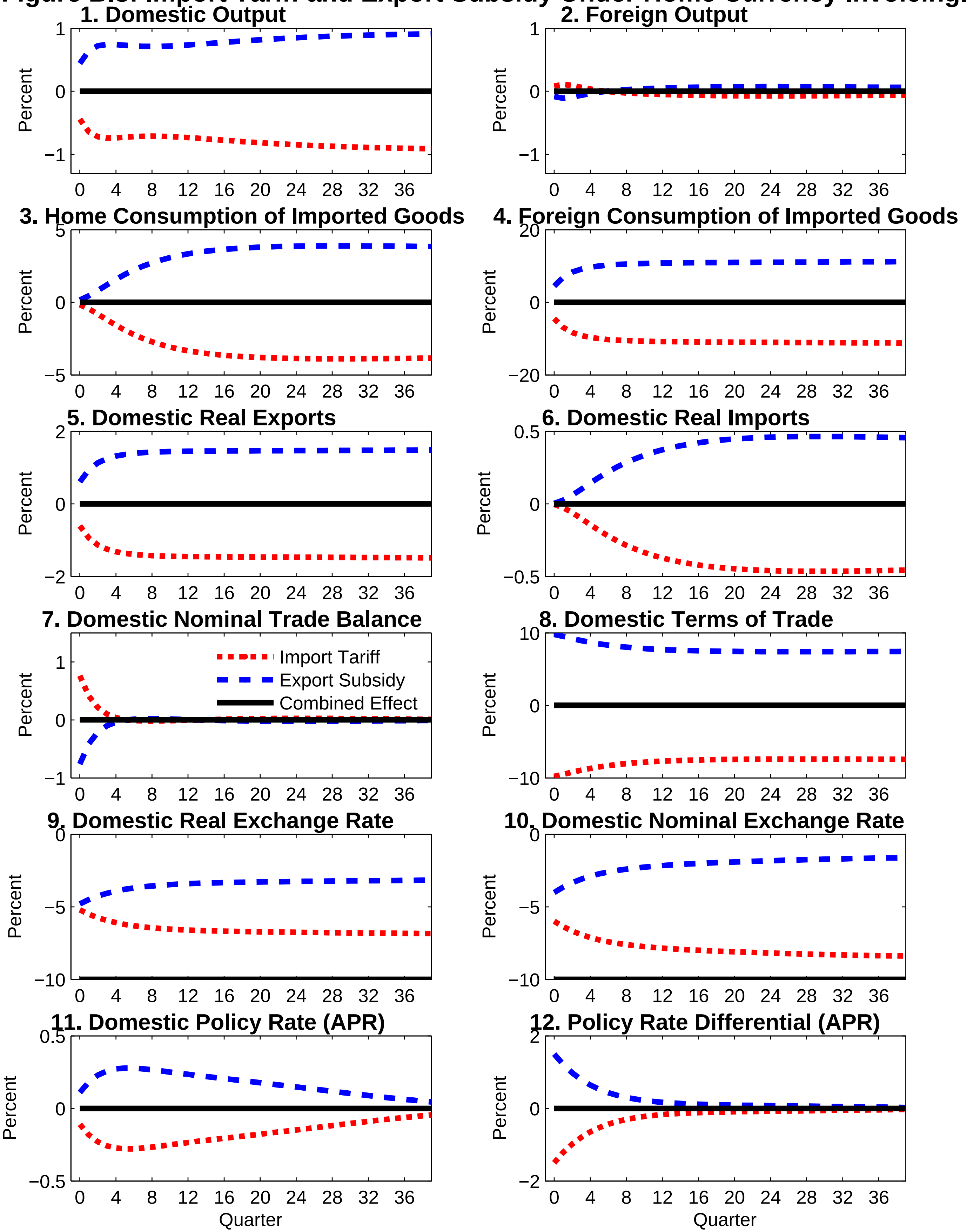
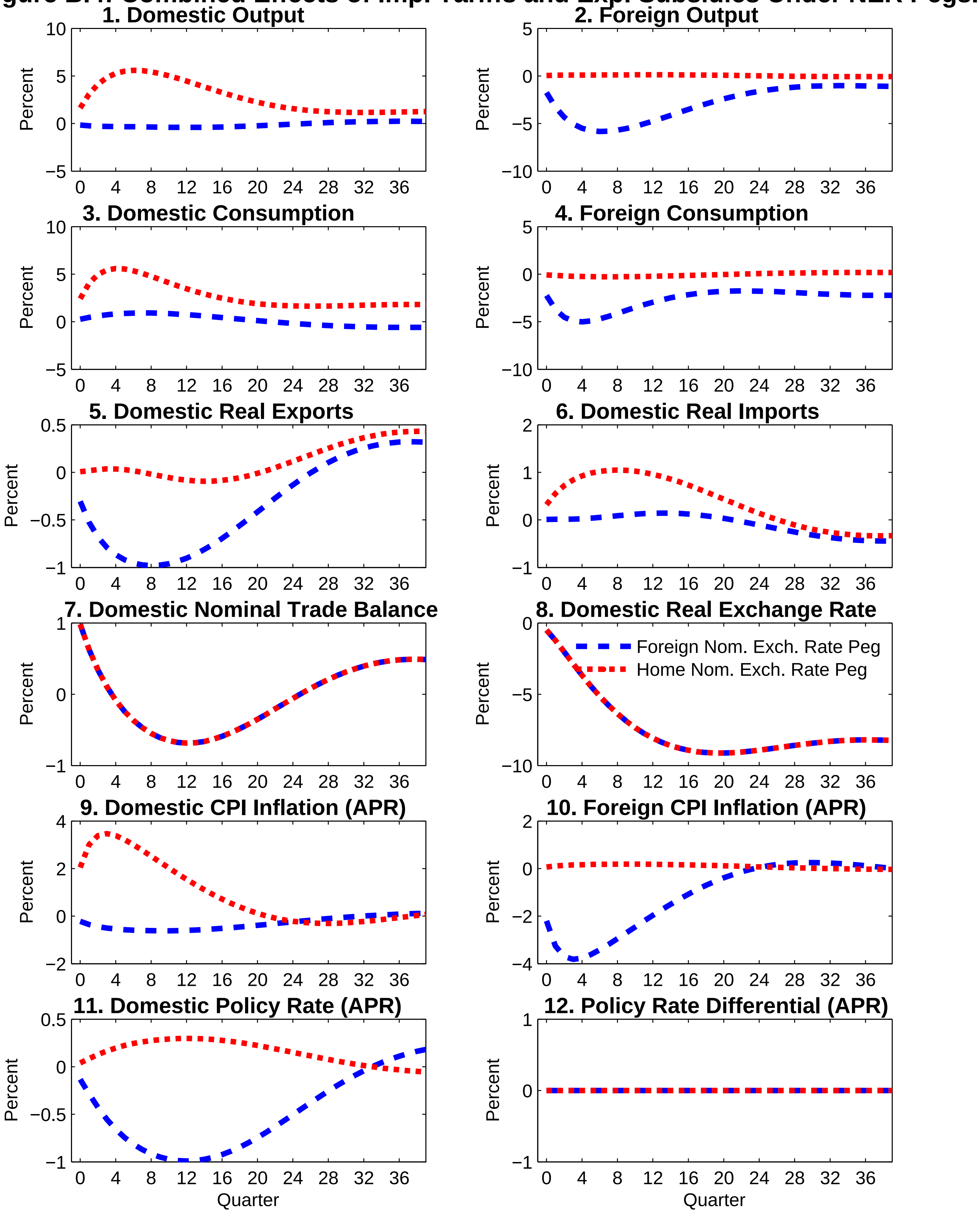


Figure B.4: Combined Effects of Imp. Tariffs and Exp. Subsidies Under NER Pegs.



Appendix C. Analytical Results under Complete Markets

In this appendix, we show that uncertainty about trade policy rather than the introduction of tariffs and subsidies per se is the key mechanism whereby the complete markets assumption causes deviations from Lerner symmetry. We first outline the model setup. Next, we show that Lerner symmetry holds when there is no trade policy uncertainty. Finally, we establish the breakdown from the equivalence when there is uncertainty.

C.1. Model Setup

Following Dellas and Stockman (1986), we assume an endowment world economy where there are two countries, two tradable goods (X and Y) that are endowments for both countries, and 4 state of the world. In State 0 there are no tariffs, in State 1 the home country imposes an import tariff τ. In State 2, the home country imposes and export subsidy σ and in State 3 the home economy imposes both an import tariff and an export subsidy. Each state has a probability $\pi_i \geq 0$, $i = 1, ..., 3$. We will denote the foreign country variables with an asterisk (*).

The endowment of the two goods for the home country is $\bar{X}$ and $\bar{Y}$, and $\bar{X}^\star$ and $\bar{Y}^\star$ in the foreign country. Moreover, it is assumed that $\bar{X}/\bar{Y}$ and $\bar{Y}^\star/\bar{X}^\star$ are sufficiently high so that the home (foreign) country is an exporter of good X (Y) in equilibrium.

Households in both countries have a separable and symmetric utility function $U(x, y) = \ln x + \ln y$. The government collects the revenues from the import tariff and extend export subsidies to export firms. It balances its budget each period through lump sum taxes, T, which are extended to the households.

C.2. Deterministic Trade Policy

In the absence of trade policy uncertainty, we consider the state when the government introduces an import tariff τ and export subsidy σ with certainty. Formally, this means that we set $\pi_3 = 1$ and $\pi_1 = \pi_2 = \pi_4 = 0$. In this case, the household problem in the home economy is

$$\max_{x,y} U(x,y) \tag{C.1}$$
$$-T = p(\bar{X} - x)(1+\sigma) + q(\bar{Y} - y)(1+\tau)$$

where p and q are the price of x and y, respectively. A similar problem holds for the foreign country with $\sigma^\star = \tau^\star = 0$.

The first order conditions are (where λ is the lagrange multiplier associated to the budget constraint)

$$1/x = \lambda p(1+\sigma) \tag{C.2}$$
$$1/y = \lambda q(1+\tau) \tag{C.3}$$

A similar pair of equations hold for the foreign country. No arbitrage conditions also imply that $p = p^\star(1+\sigma)$ and $q = q^\star(1+\tau)$. We set $p^\star = 1$ as numeraire.

If the export subsidy equals the import tariff, $\sigma = \tau$, eqs. (C.2) and (C.3) can be combined to show that relative prices are undistorted by the trade policy within a country $q/p = q^\star/p^\star = X^w/Y^w$, where $X^w = \bar{X} + \bar{X}^\star$ is global production of good X (similarly for Y). The terms of trade p/q and the real allocation are, thus, not affected by the trade policy.[C.1]

The real exchange rate E, however, will move with the policy. Following the workhorse model, the real exchange rate is defined as $E = P^\star/P$ where $P = \omega p + (1-\omega)q$ and $P^\star = \omega p^\star + (1-\omega)q^\star$, for some allocation share of the X and Y goods $\omega \geq 0$. Hence, we have $\mathcal{E} = P^\star/P = 1/(1+\tau)$

Since prices are free to adjust, the introduction of an import tariff and export subsidy appreciates the home-country real exchange rate while keeping relative prices unaffected. While consumption volumes are unaffected, the relative value of the home consumption bundle, $C/C^* \equiv (px+qy)/(p^*x^* + q^*y^*) = 1+\tau$, increases at rate τ. In fact, the additional value of money (i.e., the shadow price of government transfers) is lower in the home country $\lambda < \lambda^\star$.

[C.1] It is easy to verify the solution $x = \bar{X}/2 + \bar{Y}X^w/Y^w$, $x^\star = \bar{X}^\star/2 + \bar{Y}^\star X^w/Y^w$, $q/p = X^w/Y^w$, $y = x/q$, and $y^\star = x^\star/q$.

C.3. Trade Policy Uncertainty

Now we consider the general case with uncertainty about trade policy, i.e. $\pi_i > 0\ \forall i$. The representative consumer of both countries can trade Arrow-Debreu securities (i.e., claims of a unit of good i in state j) to maximize

$$\begin{aligned} &\max_{x,y} \sum_{i=0}^{3} \pi_i U(x_i, y_i), \\ &\qquad s.t. \\ &-T_i = p_i(\bar{X} - x_i)(1+\sigma_i) + q_i(\bar{Y} - y_i)(1+\tau_i) \end{aligned} \tag{C.4}$$

Where p_i and q_i are the prices of the claims.[C.2] The foreign consumer faces a similar problem but in this country tariffs and subsidies are zero in all states, that is $\sigma_i^\star = \tau_i^\star = 0\ \forall i$.

Without loss of generality, we assume that the two countries are symmetric $\bar{X} = \bar{Y}^\star$ and $\bar{Y} = \bar{X}^\star$. In this case, in State 0 consumption must be symmetric $x_0 = y_0 = x_0^\star = y_0^\star = X^w/2$ and prices undistorted $p_0 = q_0$. This allows us to determine the lagrange multiplier associated with an additional unit of money as

$$\lambda = \lambda^\star = 0.5\pi_0/(p_0 X^w) = 0.5\pi_0/X^w, \tag{C.5}$$

having set $p_0 = 1$ as numeraire.[C.3] The fact that the shadow value of an additional unit of money is constant across countries is a departure from the deterministic case previously studied and will be key to understand the departure from the Lerner equivalence.

State of the world with import tariff and export subsidy In this case the price distortion induced by the tariffs is symmetric for net exported and imported good such that $p_3/q_3 = 1$. However, since in equilibrium contracts ensure that the marginal utility from an additional unit of money is proportional between home and foreign consumers in all states,

[C.2] Recall that we have assumed $\sigma_0 = \tau_0 = 0$, $\sigma_1 = 0$ and $\tau_1 = \tau$, $\sigma_2 = \sigma$ and $\tau_2 = 0$, and $\sigma_3 = \sigma$ and $\tau_3 = \tau$.
[C.3] Using p_0 as numeraire only requires $\pi_0 > 0$.

the following relationships has to hold in State 3:

$$\lambda p_3/\pi_3 = \frac{1}{(1+\sigma)x_3} = \frac{1}{x_3^\star}, \tag{C.6}$$

$$\lambda q_3/\pi_3 = \frac{1}{(1+\tau)y_3} = \frac{1}{y_3^\star}. \tag{C.7}$$

As a result, the value of the consumption is equated across the two countries

$$C_3 = (1+\tau)p_3 x_3 + (1+\sigma)q_3 y_3 = p_3 x_3^\star + q_3 y_3^\star = C_3^\star, \tag{C.8}$$

but the Lerner symmetry breaks down because volumes differ (assuming $\tau = \sigma$):

$$\frac{c}{c^*} = \frac{x_3 + y_3}{x_3^\star + y_3^*} = \frac{1}{1+\tau}, \tag{C.9}$$

where c (c^*) is consumption volume in the home (foreign) country.

We have introduced assets that allow shifting wealth to or from a state where a border adjustment tax (by the home countries) is introduced. Households optimally choose to ensure the value of their wealth (i.e., the value of an additional unit of money) from the trade policy shock. In the standard static deterministic framework, it is only the relative price of a good that guides resource allocation and this relative price remains the same. However, in a stochastic framework with asset markets, consumers also respond to changes in the relative price of a good across states by shifting consumption from one state to another via asset markets.