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The Global Slack Hypothesis

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Abstract

We illustrate the analytical content of the global slack hypothesis in the context of a variant of the widely used New Open-Economy Macro model of Clarida, Galí, and Gertler (2002) under the assumptions of both producer currency pricing and local currency pricing. The model predicts that the Phillips curve for domestic CPI inflation will be flatter under most plausible parameterizations, the more important international trade is to the domestic economy. The model also predicts that foreign output gaps will matter for inflation dynamics, along with the domestic output gap. We also show that the terms of trade gap can capture foreign influences on domestic CPI inflation in an open economy as well. When the Phillips curve includes the terms of trade gap rather than the foreign output gap, the response of domestic inflation to the domestic output gap is the same as in the closed-economy case *ceteris paribus*. We also note the conceptual and statistical difficulties of measuring the output gaps and suggest that measurement error bias can be a serious concern in the estimation of the open-economy Phillips curve relationship with reduced-form regressions when global slack is not actually observable.

JEL codes: E3, F4
Keywords: Global slack, open-economy Phillips curve, inflation.

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In recent years, a number of policymakers have addressed the question of whether greater global economic integration, or globalization, has had a significant impact on inflation in the U.S. While there appears to be broad agreement on the importance of globalization as a real phenomenon, there is less agreement on what globalization means for inflation developments and monetary policy in the U.S. This appears to be due in part to the relative recentness, in some sense, of globalization, and in part to serious data limitations.

Basic economic theory suggests that globalization, which we will take as being synonymous with greater openness to trade, capital and labor flows, should have affected inflation. Specifically, if we think of the measured inflation rate as having a trend and a cyclical component, there are sound reasons for thinking that *both* have been affected by the greater openness of the U.S. economy.

First, globalization may have lowered the trend rate of inflation by reducing the inflation bias that arises under discretionary policymaking. This is an argument that is most closely associated with Romer (1993) and Rogoff (2003), but it has been made by others as well.[1] Globalization may also have had a permanent one-time disinflationary effect by increasing the competitive pressures faced by firms and workers, although whether and when that one-time effect is played out seems to be an open question. Second, globalization may have altered the cyclical behavior of inflation by changing the composition of the basket of goods from which the aggregate price indexes are calculated—although it may also have an effect through other channels—as suggested by the standard open-economy versions of the workhorse New Open-Economy Macro model of Clarida, Galí, and Gertler (2002).

The first-order effects of greater openness, whether to trade, capital flows or labor, are on *relative* prices and *real* returns. Whether these changes then have implications for inflation, over the medium to long term, depends very much on how monetary policy responds to these developments. Globalization does not alter the fact that inflation is ultimately determined by the actions of monetary policy makers. We will be considering primarily the impact of globalization on the short-run trade-offs that policymakers face between inflation and real economic activity over the business cycle.

We will employ an extension of the two-country model of Clarida, Galí, and Gertler (2002) to derive a benchmark specification for the open-economy Phillips curve that fleshes out the content of the global slack hypothesis. Clarida, Galí, and Gertler (2002) make the assumption of producer currency pricing, which we also adopt here. However, we will consider an alternative assumption about how firms set prices in export markets—local currency pricing—and explore how this extension alters the features of the open-economy Phillips curve that emerges from our version of the Clarida, Galí, and Gertler (2002) framework.

We use this variant of the New Open-Economy Macro model to illustrate two propositions about the impact of globalization on inflation dynamics. First, foreign slack does matter in this framework for the short-run trade-off between inflation and real variables. Moreover, under most plausible parameterizations the coefficient on domestic slack declines as the economy becomes more open—as the domestic basket of goods includes a larger share of imports. Second, international relative prices (specifically, the terms of trade gap) can be sufficient to summarize the influence of foreign factors on domestic inflation in this class of models.

This last result ties in with an older literature on the Phillips curve that includes variables like import and commodity prices on the right-hand side of Phillips curve regressions. When we use the terms of trade gap to measure foreign influences, the theoretical coefficient on domestic slack is exactly the same as in the closed-economy Phillips curve. These propositions hold regardless of what we assume about how firms set their prices internationally, that is, whether they engage in producer currency pricing or local currency pricing.

Finally, we use our variant of the New Open-Economy Macro model as a data generating process (DGP) to evaluate the global slack hypothesis with simple OLS regressions. We find that conventional backward-looking estimates of the Phillips curve relationship may result in coefficient estimates that reject the hypothesis that global slack matters for domestic inflation even though both are related within the context of the model. While this exercise does not prove that the global slack hypothesis is consistent

[1] See in particular the contributions of Bohn (1991), Hardouvelis (1992), Fischer (1998), Lane (1997), Obstfeld (1998) and Evans (2007). All of these papers rely on some variant of the time consistency problem highlighted by Kydland and Prescott (1977) and elaborated in a model of monetary policymaking by Barro and Gordon (1983). Yet it is not clear how important this problem is in practice. Some central bankers argue that simply being aware of the problem has made them less likely to succumb to it. Indeed Blinder (1998) argues that it is hard to reconcile the argument that central banks have an inherent inflation bias with the inflation performance in most industrialized countries since the 1980s. Second, the Barro and Gordon (1983) analysis is conducted in a simple partial equilibrium setting. Extensions to a general equilibrium setting by Neiss (1999), Albanesi, Chari, and Christiano (2003a, 2003b) have found that an increase in a central bank's incentive to engineer a surprise inflation need not always result in higher inflation due to offsetting changes in the costs of inflation. The analyses of Neiss and Albanesi, Chari, and Christiano are conducted in a closed-economy setting—it remains to be seen how their results translate to an open-economy environment.

with the data, it suggests that some of the mixed results in the existing empirical literature may be due to measurement error—as well as the result of misspecification, omitted-variable bias, etc.—indicating that more work needs to be done to test the hypothesis more convincingly.

1. THE GLOBAL SLACK HYPOTHESIS

For the purpose of thinking about inflation dynamics in an open-economy framework, the basic two-country New Open-Economy Macro model of Clarida, Galí, and Gertler (2002) has proven to be quite influential. We work with a straightforward variant of that workhorse model here.[2] We give a quick qualitative review of its main building blocks now, but a full mathematical description of the model in its first principles can be found in Tables A1, A2, A3, A4, and A5 in the appendix. We focus our discussion—unless otherwise noted—primarily on the aggregate supply side of the model and on the derivation of the open-economy Phillips curve since our goal is to illustrate the theoretical underpinnings of the global slack hypothesis.

The New Open-Economy Macro Model

In the basic setup, there are two countries, designated Home (H) and Foreign (F). The notation for all endogenous and exogenous variables of the model is summarized in Table A1 in the appendix. Home and Foreign countries are populated by a mass of households n and $1-n$, respectively. There is a continuum of varieties of goods of mass n produced by Home, and a continuum of varieties of mass $1-n$ produced by Foreign, each variety produced by a monopolistically competitive firm with a linear-in-labor technology that is subject to an aggregate (but country-specific) productivity shock. Each firm supplies the Home and Foreign markets, international trade is assumed to be costless, and nominal exchange rates are allowed to freely float. All varieties produced are perishable—there are no consumer durables, intermediate goods, or capital in this model.

The monopolistically competitive firms set prices to maximize the present discounted value of their profits subject to a Calvo (1983) pricing constraint and the commitment to supply all that is demanded at a given price. We assume the degree of price stickiness implied by the Calvo contracts to be the same in all markets and for all firms. Firms set their prices in the currency of the country where production takes place (producer currency pricing, or PCP), as in Clarida, Galí, and Gertler (2002). However, we also investigate the possibility of firms setting prices in the currency of the market into which they are selling (local currency pricing, or LCP) and how that affects the Phillips curve relationship (see, e.g., Woodford (2010)). Only when firms set Calvo prices under LCP, deviations from the law of one price occur. Reselling is precluded so that the optimal policy of price discrimination is not reversed by resellers exploiting the cross-border arbitrage opportunities. We also abstract from considerations of outsourcing, firm relocation, and FDI in this framework. The problem of the firms is described in Table A2 in the appendix.

Household preferences in each country are defined over aggregate consumption and labor. Aggregate consumption in each country is a composite of a domestically produced bundle of varieties and foreign-produced bundle of varieties, which are assumed to be imperfect substitutes of each other. The bundle of Home varieties that each Home and Foreign household consumes is assumed to be a composite of the mass n of the Home-produced varieties, where these domestic varieties appear as imperfect substitutes of each other as well. Similarly, the bundle of Foreign varieties is a composite of the mass $1-n$ of imperfectly substitutable varieties produced in the Foreign country. We denote ξ the share of the Home bundle of varieties in the Home consumption basket and $(1-\xi^*)$ the share of the Foreign bundle of varieties in the Foreign basket.[3]

Households make consumption plans and labor supply decisions to maximize their lifetime expected discounted utility, yielding demand functions for each variety of domestic and foreign goods, along with standard intratemporal and intertemporal optimality conditions. Asset markets are assumed to be complete, so households are able to share risks efficiently within and across borders. Labor is homogenous and labor markets are perfectly competitive but separate between the two countries.[4] Hence, wages are equalized

[2] The exposition that follows draws heavily on the work of Martínez-García (2008).

[3] Clarida, Galí, and Gertler (2002) and Woodford (2010)—among others—make the assumption that both countries are of the same size (mass 1 each) and that their consumption baskets are identical, i.e., $\xi = \xi^*$. In contrast, the benchmark model discussed here allows for country size differences (where $0 < n < 1$ splits a unit mass of households and varieties between Home and Foreign) and for differences in the basket of consumption goods across countries (i.e., $\xi \neq \xi^*$). Both countries are otherwise symmetric in every respect.

[4] In contrast, Clarida, Galí, and Gertler (2002) assume that households are monopolistically competitive suppliers of labor. Woodford (2010) explores this and other factor market arrangements, including the possibility of an integrated global labor market.

within each country. The problem of the households is fully described in Table A3 in the appendix. There is a limited role for fiscal policy solely providing labor subsidies to firms in order to counteract the markup distortion that arises under monopolistic competition. The labor subsidies are, in turn, funded with a lump-sum tax on households. The model is closed with the specification of a monetary policy rule in the spirit of Taylor (1993). In line with most of the literature, we assume that discretionary movements of the monetary policy instrument are captured as (country-specific) random shocks to the Taylor rule. Table A4 in the appendix describes the monetary and fiscal policy rules as well as the market clearing conditions and the productivity and monetary shock processes.

Table 1 below collects the key structural parameters that will appear in the exposition of the open-economy Phillips curve that follows. A full description of all the structural parameters of the model can be found in Table A5 in the appendix.

Table 1

Structural parameters

Intertemporal discount factor	$0 < \beta < 1$
Inverse of intertemporal elasticity of substitution	$\gamma > 0$
Inverse of Frisch elasticity of labor supply	$\varphi > 0$
Elast. of substitution between Home & Foreign bundles	$\sigma > 0$
Share of Home goods in Home basket	$0 < \xi < 1$
Share of Home goods in Foreign basket	$0 < \xi^* < 1$
Home population size, mass of Home varieties	$0 < n < 1$
Calvo price stickiness parameter	$0 < \alpha < 1$

Aggregate Supply and the Open-Economy Phillips Curve

To explore the first-order effects of shocks on the dynamics of the economy, we log-linearize the equilibrium conditions of the model around the deterministic zero-inflation steady state. We use the notation $\widehat{v}_t \equiv \ln V_t - \ln V$ to denote the log deviation of a variable V_t from its steady-state value V. Likewise, we use the notation $\widehat{\overline{v}} \equiv \ln \overline{V}_t - \ln V$ to denote the deviation of the potential (or frictionless) value of an endogenous variable V_t, which we denote $\overline{V}_t$, from its steady-state level V. While exogenous variables are unchanged across model specifications, the upper bar indicates that the endogenous variables are determined by a frictionless variant of the model where prices are fully flexible. The resulting allocation is the same as under perfect competition since fiscal policy is chosen optimally. The labor subsidy suffices to eliminate the markup distortion introduced by monopolistic competition at the firm level, and it also ensures that the deterministic steady state of the model is the same under either flexible prices or nominal rigidities.

The log-linearized aggregate supply equation for the Home firms selling in the Home market can be written in a familiar form as

$$\widehat{\pi}^H_t = \beta \mathbb{E}_t(\widehat{\pi}^H_{t+1}) + \Phi(\widehat{mc}_t - \widehat{p}^H_t), \tag{1}$$

where the composite parameter $\Phi \equiv \frac{(1-\alpha)(1-\beta\alpha)}{\alpha}$ is a function of the intertemporal discount factor, $0 < \beta < 1$, and the Calvo price stickiness parameter, $0 < \alpha < 1$. The price subindex for the Home bundle of goods is denoted by $\widehat{p}^H_t$, $\widehat{\pi}^H_t \equiv \widehat{p}^H_t - \widehat{p}^H_{t-1}$ is the corresponding inflation rate, and $\widehat{mc}_t$ denotes Home marginal costs. Equation (1) simplifies to the standard closed-economy Phillips curve when the consumption basket consists solely of locally produced goods.

The log-linearized aggregate supply equation for the Foreign firms selling in the Home market can be written analogously as

$$\widehat{\pi}^F_t = \beta \mathbb{E}_t(\widehat{\pi}^F_{t+1}) + \Phi(\widehat{mc}^*_t - \widehat{p}^F_t + \widehat{s}_t), \tag{2}$$

where $\widehat{p}^F_t$ denotes the price subindex for the Foreign bundle of goods in the Home market, $\widehat{\pi}^F_t \equiv \widehat{p}^F_t - \widehat{p}^F_{t-1}$ the corresponding inflation rate, $\widehat{mc}^*_t$ the Foreign marginal costs, and $\widehat{s}_t$ the nominal exchange rate. Substitution of equations (1) and (2) into the log-linearized expression for the CPI in the Home country, i.e.,

$$\widehat{\pi}_t = \xi \widehat{\pi}^H_t + (1-\xi)\widehat{\pi}^F_t, \tag{3}$$

then gives us that

$$\widehat{\pi}_t = \beta \mathbb{E}_t(\widehat{\pi}_{t+1}) + \Phi[\xi(\widehat{mc}_t - \widehat{p}^H_t) + (1-\xi)(\widehat{mc}^*_t - \widehat{p}^F_t + \widehat{s}_t)], \tag{4}$$

where $\widehat{\pi}_t \equiv \widehat{p}_t - \widehat{p}_{t-1}$ is the rate of inflation of the Home CPI and $0 < \xi < 1$ is the share of Home goods in the Home consumption basket. This is a fairly general expression for the open-economy Phillips curve.

It is purely forward-looking and relates Home CPI inflation to expected future Home CPI inflation and a weighted average of domestic and foreign real marginal costs. By invoking additional assumptions on the pricing behavior of firms and other primitives of the model, it is possible to rewrite the open-economy Phillips curve in terms of domestic and foreign output gaps.

The Phillips Curve Under Producer Currency Pricing

We build our benchmark model under the assumption of producer currency pricing (PCP), as in Clarida, Galí, and Gertler (2002). Under that assumption, the law of one price holds and exchange rate pass-through is complete, implying that $\widehat{p}_t^{H*} = \widehat{p}_t^{H} + \widehat{s}_t$ and $\widehat{p}_t^{F*} = \widehat{p}_t^{F} + \widehat{s}_t$ where $\widehat{p}_t^{H*}$ is the price subindex for the Home bundle of goods in the Foreign country and $\widehat{p}_t^{F*}$ the price subindex for the Foreign bundle of goods in the Foreign country. The expression for the open-economy Phillips curve in (4) can then be rewritten as

$$\widehat{\pi}_t = \beta \mathbb{E}_t\left(\widehat{\pi}_{t+1}\right) + \Phi[\xi(\widehat{mc}_t - \widehat{p}_t^{H}) + (1-\xi)\left(\widehat{mc}_t^{*} - \widehat{p}_t^{F*}\right)]. \tag{5}$$

The log-linearized real marginal cost functions for Home and Foreign firms can be expressed as

$$\widehat{mc}_t - \widehat{p}_t^{H} = \gamma\widehat{c}_t + \varphi\widehat{y}_t + (1-\xi)\,\widehat{tot}_t - (1+\varphi)\,\widehat{a}_t, \tag{6}$$

$$\widehat{mc}_t^{*} - \widehat{p}_t^{F*} = \gamma\widehat{c}_t^{*} + \varphi\widehat{y}_t^{*} - \xi^{*}\widehat{tot}_t - (1+\varphi)\,\widehat{a}_t^{*}, \tag{7}$$

where we have made use of the labor market clearing conditions and defined the terms of trade as $\widehat{tot}_t = \widehat{p}_t^{F} - \widehat{s}_t - \widehat{p}_t^{H*}$. When the law of one price holds in this framework, terms of trade can alternatively be expressed as $\widehat{tot}_t = \widehat{p}_t^{F} - \widehat{p}_t^{H}$. We denote Home and Foreign consumption as $\widehat{c}_t$ and $\widehat{c}_t^{*}$, respectively, Home and Foreign output as $\widehat{y}_t$ and $\widehat{y}_t^{*}$, and Home and Foreign productivity shocks as $\widehat{a}_t$ and $\widehat{a}_t^{*}$. The inverse of the intertemporal elasticity of substitution is $\gamma > 0$, the inverse of the Frisch elasticity of labor supply is $\varphi > 0$, the share allocated to the bundle of Home goods in the Home consumption basket is $0 < \xi < 1$, and the share allocated to the bundle of Home goods in the Foreign consumption basket is $0 < \xi^{*} < 1$.

The potential (or frictionless) output of the Home and Foreign countries is defined as the output level that prevails whenever the monopolistic firms set prices at their flexible level in every period, i.e., whenever $\widehat{\widehat{mc}}_t - \widehat{\widehat{p}}_t^{H} = 0$ and $\widehat{\widehat{mc}}_t^{*} - \widehat{\widehat{p}}_t^{F*} = 0$.[5] Thus the log-linear pricing equations in the frictionless case can be written as

$$0 = \widehat{\widehat{mc}}_t - \widehat{\widehat{p}}_t^{H} = \gamma\widehat{\widehat{c}}_t + \varphi\widehat{\widehat{y}}_t + (1-\xi)\widehat{\widehat{tot}}_t - (1+\varphi)\widehat{a}_t, \tag{8}$$

$$0 = \widehat{\widehat{mc}}_t^{*} - \widehat{\widehat{p}}_t^{F*} = \gamma\widehat{\widehat{c}}_t^{*} + \varphi\widehat{\widehat{y}}_t^{*} - \xi^{*}\widehat{\widehat{tot}}_t - (1+\varphi)\widehat{a}_t^{*}, \tag{9}$$

where all endogenous variables are the corresponding frictionless counterparts of those defined before.

We can then use expressions (8) and (9) to rewrite the log-linearized real marginal cost functions in equations (6) and (7) in gap form (in deviations from potential) as

$$\widehat{mc}_t - \widehat{p}_t^{H} = \gamma(\widehat{c}_t - \widehat{\widehat{c}}_t) + \varphi\widehat{x}_t + (1-\xi)\,\widehat{z}_t, \tag{10}$$

$$\widehat{mc}_t^{*} - \widehat{p}_t^{F*} = \gamma(\widehat{c}_t^{*} - \widehat{\widehat{c}}_t^{*}) + \varphi\widehat{x}_t^{*} - \xi^{*}\widehat{z}_t. \tag{11}$$

That is, the real marginal cost for domestic firms can be written in terms of a domestic consumption gap (deviation of consumption from its potential), $(\widehat{c}_t - \widehat{\widehat{c}}_t)$, a domestic output gap (deviation of output from its potential), $\widehat{x}_t \equiv (\widehat{y}_t - \widehat{\widehat{y}}_t)$, and a terms of trade gap (deviation of the terms of trade from its potential), $\widehat{z}_t \equiv (\widehat{tot}_t - \widehat{\widehat{tot}}_t)$. Likewise, the real marginal cost for foreign producers can be written in terms of a foreign consumption gap, $(\widehat{c}_t^{*} - \widehat{\widehat{c}}_t^{*})$, a foreign output gap, $\widehat{x}_t^{*} \equiv (\widehat{y}_t^{*} - \widehat{\widehat{y}}_t^{*})$, and the terms of trade gap, $\widehat{z}_t \equiv (\widehat{tot}_t - \widehat{\widehat{tot}}_t)$.

Substitution back into equation (5) would then give us an expression relating Home CPI inflation to expected future CPI inflation, domestic and foreign output gaps, domestic and foreign consumption gaps, and the terms of trade gap. However, it is possible to simplify further and derive the open-economy Phillips curve in a simpler form that relates domestic inflation to measures of the domestic and foreign output gaps

[5] The price-setting rule under monopolistic competition and flexible prices is that prices must be equal to a markup over marginal costs. The markup is a function of the elasticity of substitution across varieties, $\theta > 1$, and time-invariant. We add a labor subsidy to exactly offset this markup distortion. Hence, prices become equal to (pre-subsidy) marginal costs as it would be the case in a perfectly competitive environment under flexible prices. In any event, since the markup is constant, the price-setting rule with or without a labor subsidy can be log-linearized around a deterministic steady state in terms of prices and marginal costs alone (as stated here).

alone by rewriting the consumption gaps and terms of trade gap in each country in terms of the output gaps. After much algebra (outlined in Martínez-García 2008) we obtain the following expressions for real marginal costs in terms of output gaps alone:

$$\widehat{mc}_t - \widehat{p}_t^H = \left[\varphi + \gamma \left(\frac{\sigma(\xi^* + (\xi - \xi^*)\eta^*) + \frac{1}{\gamma}(\xi - \xi^*)(1-\eta^*) + (1-\xi)}{\sigma - \left(\sigma - \frac{1}{\gamma}\right)(\xi - \xi^*)(\eta - \eta^*)} \right)\right] \widehat{x}_t + \dots$$
$$\left[\gamma \left(\frac{(\sigma-1)(1-\xi) + \left(\sigma - \frac{1}{\gamma}\right)(\xi - \xi^*)(1-\eta)}{\sigma - \left(\sigma - \frac{1}{\gamma}\right)(\xi - \xi^*)(\eta - \eta^*)} \right)\right] \widehat{x}_t^*, \tag{12}$$

$$\widehat{mc}_t^* - \widehat{p}_t^{F*} = \left[\gamma \left(\frac{(\sigma-1)\xi^* + \left(\sigma - \frac{1}{\gamma}\right)(\xi - \xi^*)\eta^*}{\sigma - \left(\sigma - \frac{1}{\gamma}\right)(\xi - \xi^*)(\eta - \eta^*)} \right)\right] \widehat{x}_t + \dots$$
$$\left[\varphi + \gamma \left(\frac{\sigma(1 - \xi + (\xi - \xi^*)(1-\eta)) + \frac{1}{\gamma}(\xi - \xi^*)\eta + \xi^*}{\sigma - \left(\sigma - \frac{1}{\gamma}\right)(\xi - \xi^*)(\eta - \eta^*)} \right)\right] \widehat{x}_t^*, \tag{13}$$

where $\sigma > 0$ is the elasticity of substitution between the domestic and foreign bundles of varieties, and $0 < n < 1$ denotes the share of varieties produced at Home—as well as the Home population share. The composite parameters η and η^* are defined as $\eta \equiv \frac{n\xi}{n\xi + (1-n)\xi^*}$ and $\eta^* \equiv \frac{n(1-\xi)}{n(1-\xi) + (1-n)(1-\xi^*)}$, respectively. Therefore, the real marginal costs in each country are tied to both domestic and foreign output gaps.

Hence, we observe that in an open-economy framework like ours the foreign output gap matters not just for the determination of the marginal cost of foreign firms (and, therefore, to capture the effects on the Home CPI from import prices) but also for the determination of domestic marginal costs because: (a) domestic firms do export their products abroad, so stronger foreign demand will force them to pay higher domestic wages and face the prospect of higher marginal costs; and (b) variations in the terms of trade reflecting the relative strength of the domestic and foreign demand will also affect their exports and domestic market sales and consequently their domestic labor costs. Naturally, the same can be said for the role of the domestic output gap in the determination of foreign real marginal costs.

There are, however, conditions under which the real marginal cost function of each country can be expressed in terms of the output gap of that country alone. That would be the case if the following two restrictions on the structural parameters are satisfied simultaneously, i.e.,

$$\sigma = \frac{1 - \xi + \frac{1}{\gamma}(\xi - \xi^*)(1 - \eta)}{1 - \xi + (\xi - \xi^*)(1-\eta)}, \tag{14}$$

$$\sigma = \frac{\xi^* + \frac{1}{\gamma}(\xi - \xi^*)\eta^*}{\xi^* + (\xi - \xi^*)\eta^*}. \tag{15}$$

Clarida, Galí, and Gertler (2002) and Woodford (2010)—among others—assume that countries are of the same size (i.e., $n = \frac{1}{2}$ in the set-up of our model), and most notably impose the assumption of identical consumption baskets in both countries, i.e., $\xi = \xi^*$. Under the assumption of identical consumption baskets, both restrictions would be satisfied for any value of the inverse of the elasticity of intertemporal substitution $\gamma > 0$ as long as the elasticity of substitution between the home and foreign bundles of varieties σ is set to 1 (which implies that the consumption aggregator is of the Cobb–Douglas type).

We can express the real marginal costs under the assumption of identical consumption baskets (i.e., $\xi = \xi^*$) as

$$\widehat{mc}_t - \widehat{p}_t^H = \left[\varphi + \gamma\left(\frac{\sigma\xi + (1-\xi)}{\sigma}\right)\right]\widehat{x}_t + \left[(1-\xi)\gamma\left(\frac{\sigma-1}{\sigma}\right)\right]\widehat{x}_t^*, \tag{16}$$

$$\widehat{mc}_t^* - \widehat{p}_t^{F*} = \left[\xi\gamma\left(\frac{\sigma-1}{\sigma}\right)\right]\widehat{x}_t + \left[\varphi + \gamma\left(\frac{\sigma(1-\xi) + \xi}{\sigma}\right)\right]\widehat{x}_t^*. \tag{17}$$

If we also assume a Cobb–Douglas consumption aggregator (i.e., $\sigma = 1$), then the expressions in (16) and (17) simplify to

$$\widehat{mc}_t - \widehat{p}_t^H = (\varphi + \gamma)\widehat{x}_t, \tag{18}$$

$$\widehat{mc}_t^* - \widehat{p}_t^{F*} = (\varphi + \gamma)\widehat{x}_t^*. \tag{19}$$

However, in the more general case where $\xi \neq \xi^*$, the two parametric restrictions in (14) and (15) are satisfied simultaneously only if $\sigma = 1$ and $\gamma = 1$, that is, only if the consumption aggregator is Cobb–Douglas and the preferences on consumption are logarithmic.

We can use the expressions for real marginal costs in (12) and (13) to derive a more general characterization of the domestic Phillips curve for overall CPI inflation in terms of domestic and foreign output gaps alone. The dynamics of domestic CPI inflation can then be expressed as

$$\widehat{\pi}_t = \beta \mathbb{E}_t \left(\widehat{\pi}_{t+1}\right) + \Phi \left[\Psi_{\pi,x} \widehat{x}_t + \Psi_{\pi,x^*} \widehat{x}_t^*\right], \tag{20}$$

where,

$$\Psi_{\pi,x} \equiv \xi\varphi + \gamma \left(\frac{\sigma\xi - \left(\sigma - \frac{1}{\gamma}\right)(\xi - \xi^*)(1 - \eta^*)}{\sigma - \left(\sigma - \frac{1}{\gamma}\right)(\xi - \xi^*)(\eta - \eta^*)} \right), \tag{21}$$

$$\Psi_{\pi,x^*} \equiv (1-\xi)\varphi + \gamma \left(\frac{\sigma(1-\xi) + (\sigma - \frac{1}{\gamma})(\xi - \xi^*)(1-\eta)}{\sigma - \left(\sigma - \frac{1}{\gamma}\right)(\xi - \xi^*)(\eta - \eta^*)} \right). \tag{22}$$

Moreover, it is also the case that

$$\Psi_{\pi,x} + \Psi_{\pi,x^*} = \gamma + \varphi, \tag{23}$$

which is what the slope of the Phillips curve would be in the closed-economy case (whenever $\xi = 1$ and $\xi^* = 0$). Hence, when the domestic economy is open to the rest of the world, the concept of slack that is most relevant for thinking about short-run trade-offs between domestic inflation and real economic activity is global rather than local. That is the core message of the global slack hypothesis that we are sketching here.

The Phillips Curve Under Local Currency Pricing

One has to wonder to what extent our results so far are affected by the shared assumption with Clarida, Galí, and Gertler (2002) that firms behave under producer currency pricing (PCP). A natural extension is to consider the alternative assumption of local currency pricing (LCP) (as, e.g., in Woodford 2010), where firms set prices in the currency of the market where they sell their products. Further elaboration on the aggregate supply side of the model shows that the rationale of the global slack hypothesis within the context of this framework is not fundamentally altered by these assumptions about pricing, with one major caveat. The assumption of LCP in combination with price stickiness implies that the law of one price no longer holds, and those deviations of the law of one price have to be accounted for in the specification of the Phillips curve.

Under the alternative LCP price-setting assumption that we are considering now, the general expression for the open-economy Phillips curve in (4) can be rewritten in terms of real marginal costs (defined from the point of view of the producers) as follows:

$$\widehat{\pi}_t = \beta \mathbb{E}_t \left(\widehat{\pi}_{t+1}\right) + \Phi[\xi(\widehat{mc}_t - \widehat{p}_t^H) + (1-\xi)\left(\widehat{mc}_t^* - \widehat{p}_t^{F*} + \widehat{d}_t^*\right)], \tag{24}$$

where $\widehat{d}_t^* \equiv \left(\widehat{s}_t + \widehat{p}_t^{F*} - \widehat{p}_t^F\right)$ measures the deviations from the law of one price for foreign-produced goods. Similarly, we define the deviations from the law of one price for domestically produced goods as $\widehat{d}_t \equiv \left(\widehat{p}_t^H - \widehat{s}_t - \widehat{p}_t^{H*}\right)$.

The log-linearized expressions for the real marginal costs under the LCP assumption are

$$\widehat{mc}_t - \widehat{p}_t^H = \gamma\widehat{c}_t + \varphi\widehat{y}_t + (1-\xi)\,\widehat{tot}_t - (1-\xi)\,\widehat{d}_t - (1+\varphi)\,\widehat{a}_t, \tag{25}$$

$$\widehat{mc}_t^* - \widehat{p}_t^{F*} = \gamma\widehat{c}_t^* + \varphi\widehat{y}_t^* - \xi^*\widehat{tot}_t - \xi^*\widehat{d}_t^* - (1+\varphi)\,\widehat{a}_t^*. \tag{26}$$

The terms of trade are still defined as $\widehat{tot}_t = \widehat{p}_t^F - \widehat{s}_t - \widehat{p}_t^{H*}$ but are no longer equal to $\widehat{p}_t^F - \widehat{p}_t^H$ as in the PCP case because the law of one price does not hold under LCP. As before, the potential (or frictionless) level of output of the Home and Foreign countries is defined as the output level that prevails whenever the monopolistic firms price according to $\widehat{\overline{mc}}_t - \widehat{\overline{p}}_t^H = 0$ and $\widehat{\overline{mc}}_t^* - \widehat{\overline{p}}_t^{F*} = 0$. This gives us the following pair of equations to characterize the frictionless allocation:

$$0 = \gamma\widehat{\overline{c}}_t + \varphi\widehat{\overline{y}}_t + (1-\xi)\,\widehat{\overline{tot}}_t - (1+\varphi)\,\widehat{a}_t, \tag{27}$$

$$0 = \gamma\widehat{\overline{c}}_t^* + \varphi\widehat{\overline{y}}_t^* - \xi^*\widehat{\overline{tot}}_t - (1+\varphi)\,\widehat{a}_t^*, \tag{28}$$

which are identical to (8) and (9) since the law of one price holds whenever prices are fully flexible, i.e., $\widehat{\overline{d}}_t = \widehat{\overline{d}}_t^* = 0$.

We can use the relationships implied by (27) and (28) to rewrite the expressions for real marginal costs in (25) and (26) in terms of gaps as

$$\widehat{mc}_t - \widehat{p}_t^H = \gamma\left(\widehat{c}_t - \widehat{\overline{c}}_t\right) + \varphi\widehat{x}_t + (1-\xi)\,\widehat{z}_t - (1-\xi)\,\widehat{d}_t, \tag{29}$$

$$\widehat{mc}_t^* - \widehat{p}_t^{F*} = \gamma\left(\widehat{c}_t^* - \widehat{\overline{c}}_t^*\right) + \varphi\widehat{x}_t^* - \xi^*\widehat{z}_t - \xi^*\widehat{d}_t^*, \tag{30}$$

where the domestic consumption gap is $(\widehat{c}_t - \widehat{\overline{c}}_t)$, the foreign consumption gap is $(\widehat{c}_t^* - \widehat{\overline{c}}_t^*)$, while the domestic output gap is defined as $\widehat{x}_t \equiv (\widehat{y}_t - \widehat{\overline{y}}_t)$, the foreign output gap as $\widehat{x}_t^* \equiv (\widehat{y}_t^* - \widehat{\overline{y}}_t^*)$, and the terms of trade gap as $\widehat{z}_t \equiv (\widehat{tot}_t - \widehat{\overline{tot}}_t)$. Note that these equations are identical to equations (10) and (11), except for the presence of the terms $\widehat{d}_t$ and $\widehat{d}_t^*$ capturing the deviations from the law of one price.

Working from these equations, we can rewrite the open-economy Phillips curve in terms of (domestic and foreign) output gaps and the real exchange rate (net of terms of trade effects) as

$$\widehat{\pi}_t = \beta\mathbb{E}_t\left(\widehat{\pi}_{t+1}\right) + \Phi[\Psi_{\pi,x}\widehat{x}_t + \Psi_{\pi,x^*}\widehat{x}_t^* - \Psi_{\pi,rp}(\widehat{rs}_t - (\xi-\xi^*)\,\widehat{tot}_t)], \tag{31}$$

where the coefficients on the Home and Foreign output gaps $\Psi_{\pi,x}$ and Ψ_{π,x^*} are the same ones derived in (21) and (22), while the new composite coefficient, $\Psi_{\pi,rp}$, is defined as

$$\Psi_{\pi,rp} \equiv \begin{cases} \gamma\sigma\left(\frac{1-(\xi-\xi^*)(\eta-\eta^*)}{(\xi-\xi^*)(1+(\xi-\xi^*))}\right)\left(\frac{\sigma(1-\xi)+(\sigma-\frac{1}{\gamma})(\xi-\xi^*)(1-\eta)}{\sigma-(\sigma-\frac{1}{\gamma})(\xi-\xi^*)(\eta-\eta^*)}\right) - \gamma\sigma\left(\frac{(1-\xi^*)-\eta(\xi-\xi^*)}{(\xi-\xi^*)(1+(\xi-\xi^*))}\right), & \text{if } \xi \neq \xi^*, \\ \text{or} & \\ -(1-n), & \text{if } \xi = \xi^*. \end{cases} \tag{32}$$

Imposing the assumption of identical consumption baskets (as in Clarida, Galí, and Gertler 2002 and Woodford 2010), i.e., $\xi = \xi^*$, suffices to ensure that the real exchange rate alone accounts for the deviations from the law of one price without having to subtract the effect of terms of trade. The composite coefficients $\Psi_{\pi,x}$ and Ψ_{π,x^*} would then be obtained as special cases of (21) and (22) under the assumption of identical consumption baskets, while $\Psi_{\pi,rp}$ is a function of the Foreign economy's size $0 < (1-n) < 1$ as noted in (32). All of which reflects that the real exchange rate moves with deviations of the law of one price, but also due to differences in the composition of the consumption basket across countries. Movements in the real exchange rate tied to compositional differences are, in turn, well known to be proportional to the terms of trade (see, e.g., Martínez-García 2008).

Once we account for the effect of deviations of the law of one price on the open-economy Phillips curve, we observe that Home and Foreign output gaps enter into the specification in (31) in the same way as they did in (20). In fact, the only difference with the Phillips curve that we derived under the PCP assumption is the presence of a term involving the real exchange rate (net of terms of trade effects), whose role is to account for the impact of deviations from the law of one price.

The Phillips Curve Under a Hybrid Case

CPI inflation under the assumption of producer currency pricing (PCP) was given in equation (20) as

$$\widehat{\pi}_t^{PCP} = \beta\mathbb{E}_t\left(\widehat{\pi}_{t+1}^{PCP}\right) + \Phi[\Psi_{\pi,x}\widehat{x}_t + \Psi_{\pi,x^*}\widehat{x}_t^*], \tag{33}$$

while CPI inflation under the assumption of local currency pricing (LCP) is to be found in equation (31) as

$$\widehat{\pi}_t^{LCP} = \beta\mathbb{E}_t\left(\widehat{\pi}_{t+1}^{LCP}\right) + \Phi[\Psi_{\pi,x}\widehat{x}_t + \Psi_{\pi,x^*}\widehat{x}_t^* - \Psi_{\pi,rp}(\widehat{rs}_t - (\xi-\xi^*)\,\widehat{tot}_t)]. \tag{34}$$

It naturally follows from here that a convex combination with a positive mass of PCP firms and LCP firms can be derived from expressions (33) and (34). Let us assume that a common across countries—constant and exogenous—fraction of firms $0 \leq \epsilon \leq 1$ prices according to the LCP rule, while a fraction $1-\epsilon$ prices according to the PCP rule. Then, Home CPI inflation will be determined as

$$\widehat{\pi}_t = (1-\epsilon)\,\widehat{\pi}_t^{PCP} + \epsilon\widehat{\pi}_t^{LCP}, \tag{35}$$

with the open-economy Phillips curve being

$$\widehat{\pi}_t = \beta \mathbb{E}_t \left(\widehat{\pi}_{t+1}\right) + \Phi[\Psi_{\pi,x}\widehat{x}_t + \Psi_{\pi,x^*}\widehat{x}_t^* - \epsilon \Psi_{\pi,rp}(\widehat{rs}_t - (\xi - \xi^*)\,\widehat{tot}_t)]. \tag{36}$$

While this approximation has its conceptual limitations, it is useful in the sense that it suggests that deviations from the law of one price as captured in international relative prices (the real exchange rate net of terms of trade effects) should be taken into account in the open-economy Phillips curve even if not all firms set prices according to the LCP assumption. If the empirical evidence strongly indicates that firms conform to the PCP rule (the implicit assumption in Clarida, Galí, and Gertler 2002), then deviations of the law of one price become a negligible concern and international relative prices are redundant. In either case, the interpretation of the slope coefficients on the output gaps remains unchanged.

Discussion

The coefficients on the output gap terms defined in (21) and (22) are identical under producer currency pricing (PCP) as illustrated by the domestic Phillips curve in (20), under local currency pricing (LCP) as shown in the Phillips curve in (31), or in a hybrid case that can be approximated as a convex combination of the PCP and LCP cases as in (36). Our analysis of the slope of the open-economy Phillips curve on the output gaps allows us to conclude that the following three propositions are robust to the assumptions made about the currency in which exports are to be priced:

First, the output gap in the Foreign country, as measured by the deviation of foreign output from its potential (or frictionless) level, matters for domestic CPI inflation. In other words, we argue that the global slack hypothesis has analytical content—even under a floating exchange rate regime—in the context of the widely used New Open-Economy Macro framework for thinking about short-run inflation trade-offs in open economies.

Second, in the special case investigated by Clarida, Galí, and Gertler (2002) and Woodford (2010) where the consumption baskets are identical across countries, i.e., $\xi = \xi^*$, there is no ambiguity about the positive sign of the coefficients $\Psi_{\pi,x}$ and Ψ_{π,x^*} in (21) and (22).[6] In general, the signs of the coefficients on the domestic and foreign output gaps will not always be positive across all possible combinations of values in the parameter space. In the appendix we explore in greater detail some parameterizations of the model under which either coefficient can become negative and show that for most (but not all) the coefficients $\Psi_{\pi,x}$ and Ψ_{π,x^*} will be positive. We also note that both coefficients cannot be negative at the same time and that a necessary (but not sufficient) condition for the coefficient on the foreign output gap Ψ_{π,x^*} to turn negative is that the share of Home goods be larger in the Home consumption basket than in the Foreign basket, i.e., $\xi > \xi^*$.

Third, in the special case where the consumption baskets are identical across countries, i.e., $\xi = \xi^*$, the Phillips curve will be flatter relative to the domestic output gap (and steeper relative to the foreign output gap) the more important are Foreign goods in the Home consumption basket and in the Foreign consumption basket (i.e., the higher $(1-\xi)$ and $(1-\xi^*)$ are).[7] In the appendix we explore in greater detail the parameterizations of the model under which the partial derivative $\frac{\partial \Psi_{\pi,x^*}}{\partial \xi}$—computed while keeping ξ^* unchanged—can turn positive, and we show that for most plausible values of the parameter space this partial derivative will be negative. We also note that the partial derivative of the composite coefficient on the domestic output gap can be inferred as $\frac{\partial \Psi_{\pi,x}}{\partial \xi} = -\frac{\partial \Psi_{\pi,x^*}}{\partial \xi}$. Therefore, under most conventional parameterizations, we find that the Phillips curve should become flatter relative to the domestic output gap (and steeper relative to the foreign output gap), the more important are Foreign goods in the Home consumption basket (i.e., the higher $(1-\xi)$ is).

In the appendix we also investigate the parameterizations of the model under which the partial derivative $\frac{\partial \Psi_{\pi,x^*}}{\partial \xi^*}$—computed while keeping ξ unchanged—can turn positive, and we show that the signs of $\frac{\partial \Psi_{\pi,x^*}}{\partial \xi^*}$ and $\frac{\partial \Psi_{\pi,x}}{\partial \xi^*} = -\frac{\partial \Psi_{\pi,x^*}}{\partial \xi^*}$ can be either positive or negative for most reasonable parameterizations of the model depending on the initial degree of openness of both economies as measured by the shares ξ and ξ^*.

It is often thought that the key parameter determining the quantitative importance of foreign factors on the domestic Home Phillips curve in this and other related models is the share of Foreign goods in the

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[6] It must be noted that the slopes on the output gap terms in the Phillips curve are not only determined by the coefficients $\Psi_{\pi,x}$ and Ψ_{π,x^*}, but also by $\Phi \equiv \frac{(1-\alpha)(1-\beta\alpha)}{\alpha} > 0$. However, the latter term does not depend on the shares of imported goods in the consumption basket of each country. In other words, Φ is a scaling factor that affects the absolute value, but not the sign of the coefficients on the output gaps.

[7] The implicit assumption is that the shares ξ and ξ^* move in tandem to preserve the equality between the Home and Foreign consumption baskets.

Home consumption basket, $(1 - \xi)$. It is then argued that given the composition of the consumption basket of the representative U.S. household, and specifically the fact that it seems to be heavily skewed toward goods and services that are either nontraded or nontradable, this puts a significant limit on how important, in a quantitative sense, foreign slack is likely to be for U.S. inflation. While the share of imports of goods and services over U.S. GDP has increased from just over 4 percent to more than 18 percent at the recent peak, international trade in goods and services remains a lot less important for the U.S. economy than for many other economies.

We think such an argument needs to be qualified in light of our findings. Our analysis suggests that another crucial parameter in determining the slope of the open-economy Phillips curve on domestic and foreign output gaps is the share of Home goods in the Foreign consumption basket, ξ^*. The sign of the partial derivative with respect to ξ^* is ambiguous to be sure, but we would argue that the composition of the Home consumption basket may be an insufficient yardstick on which to measure the likely impact of foreign slack on the U.S. Phillips curve and the flattening/steepening of the relationship.

We also argue that our results are consistent with the workhorse New Open-Economy Macro model and robust to alternative assumptions on international pricing behavior (either the PCP or the LCP assumptions). Obviously, we cannot infer from our analysis that this is the better way to establish a relationship between domestic inflation and global slack. On the one hand, the model can be misspecified simply because the assumptions of nominal rigidities and monopolistic competition on the supply side on which the model is predicated might be a very rough approximation of the price-setting dynamics at the firm level. On the other hand, there are a number of other channels through which foreign economic activity may matter for domestic inflation that are absent from the model outlined above, such as trade in intermediate goods and commodities, and immigration and outsourcing practices. However, this simple model can still be useful as a benchmark to guide empirical research on testing the global slack hypothesis and as a useful starting point from where to begin investigating the analytical content of the hypothesis.

2. EMPIRICAL EVIDENCE ON THE GLOBAL SLACK HYPOTHESIS

There has already been a significant amount of empirical work looking at the impact of globalization on inflation and at the impact of foreign economic activity in particular. Orr (1994) was one of the earliest attempts to evaluate the likely restraining effect of greater slack overseas on U.S. inflation. Orr focused on imports from the other members of the Group of Seven (G-7) countries, which at the time he was writing, accounted for over half of U.S. imports. Orr found that despite the restraining effect of excess capacity overseas on producer-level inflation in these trading partners in the early 1990s, it did not translate into significantly lower prices for U.S. imports from these countries, primarily due to offsetting movements in exchange rates. Garner (1994) also investigated the possible impact of the greater openness of the U.S. economy on simple Phillips curve relationships between U.S. inflation and domestic capacity utilization but found no statistically significant effect of the trade share. He also looked at the effect of foreign capacity utilization, proxying it by capacity utilization in Canada since it is the largest trading partner of the U.S., but again found no effect.

Tootell (1998) conducted a more comprehensive assessment of whether resource utilization in the G-7 countries matters for U.S. inflation. Tootell's point of departure was to ask whether globalization could account for the "missing inflation" in the U.S. in the late 1990s, and he used a traditional backward-looking Phillips curve specification to address this question. Tootell found no evidence that foreign slack (as measured by the deviation of unemployment in the other G-7 countries from estimates of the natural rates in those countries) mattered for U.S. inflation, at least through the middle of 1996, when his sample period ended. Wynne and Kersting (2007) attempted to replicate Tootell's findings using a similar sample period and also reported the results of simply extending the sample period to include the past decade. When they extended the sample period, they found that the estimated coefficient on the domestic slack variable declined in magnitude and statistical significance (as many other studies have shown), while that on the foreign slack variable increased. Global slack, at least in the other G-7 countries, seems to matter for U.S. inflation even though the evidence remains incomplete and mixed.

Much of the recent debate about the implications of globalization for inflation stems from the widely cited paper of Borio and Filardo (2007), which examined whether global slack may play a greater role in the determination of domestic inflation than domestic slack. Rather than employ a labor-market-based measure of slack, they use a measure based on the deviation of aggregate output from potential and broaden the definition of "foreign" to include not just the other members of the G-7, but several of the other top trading partners of the U.S. as well. They found a statistically significant role for the foreign output gap in explaining inflation in the U.S., and a declining role for the domestic output gap. Subsequent research by Ihrig et al. (2007) cast doubt on the robustness of Borio and Filardo's results. Ihrig et al. noted two potential problems with the empirical analysis of Borio and Filardo: first, their definition of the dependent variable in their regressions as the difference between headline consumer price inflation and trend core inflation; and second, their measurement of inflation as the four-quarter change in the price index rather than the annualized quarterly change in the price index.[8]

The model presented above suggests that the global slack hypothesis has analytical content, but it is equally clear that the empirical literature has failed to find a robust relationship between inflation in the U.S. and measures of foreign slack. There are a number of reasons for this, including the possibility that the reduced-form empirical models that have been estimated are not well specified or suffer from omitted variable bias (when the model does not fully account for other channels or all the relevant variables). Part of the empirical work to date has relied on traditional backward-looking specifications of the Phillips curve relationship of the form

$$\pi_t = \alpha_0 + \sum\nolimits_{i=1}^{k} \rho_i \pi_{t-i} + \theta \widehat{y}_t + \theta^* \widehat{y}_t^* + \Psi(L)\mathbf{Z}_t + \epsilon_t, \tag{37}$$

where π_t denotes inflation at date t,[9] the distributed lag of earlier inflation rates, $\sum\nolimits_{i=1}^{k} \rho_i \pi_{t-i}$, proxies for expected inflation, $\widehat{y}_t$ and $\widehat{y}_t^*$ denote measures of domestic and foreign slack, respectively, and $\mathbf{Z}_t$ is a vector of other explanatory variables.

In addition, there is an element of arbitrariness to the measurement of the cyclical components of statistical series, and there are also well-known end-of-sample problems that may be particularly important for the short post-1990 sample period for which the coverage of most measures of global slack becomes more complete. Also, measuring resource utilization, slack, or output gaps is challenging at the best of times. For the emerging market economies that are believed to play an increasing role in the dynamics of U.S. inflation, data on aggregate activity are problematic, and traditional measures of resource utilization such as unemployment rates or capacity utilization rates in manufacturing are either not available or have very short histories.

Measurement Error and Endogeneity

There is a deeper conceptual problem hidden in the existing empirical literature based on reduced-form regressions as those in (37). It is not clear what the relationship is between the measures of slack that have been employed in empirical analysis and the measures suggested by the modern literature on monetary theory. The gap concept in the model outlined above was the deviation of output from its potential (or frictionless) level. It is intuitive that the potential level of output in such a model will look a lot different to the sort of smoothed estimate of trend or potential output generated by the statistical filtering or production function approaches to estimating output gaps. Indeed, Neiss and Nelson (2003) and Neiss and Nelson (2005) show that there is a *negative* relationship between the New Open-Economy Macro concept of the output gap (the deviation of output from its potential or frictionless level) and the measure commonly used in empirical research (the deviation of output from a smooth, possibly time-varying, trend), albeit in a closed-economy framework.

By way of illustrating the relevance of the difference between the two concepts of potential output, we simulated the log-linearized model under the producer currency pricing (PCP) assumption as described in Table A6 of the appendix. In this setup, each country is fully described with two exogenous shocks—a productivity shock and a monetary policy shock—and three structural equations: an aggregate demand (AD) equation that ties the output gap to domestic and foreign real interest rates, an aggregate supply (AS) equation in the form of a Phillips curve that ties inflation to domestic and foreign output gaps, and finally a monetary policy rule in the spirit of Taylor (1993).

We set the structural parameters at $\beta = 0.99$, $\gamma = \varphi = 5$, $\sigma = 1.5$, $\xi = 0.94$, and $\alpha = 0.75$. These parametric choices are taken from Chari, Kehoe, and McGrattan (2002) and are very similar to the closed-economy model set-up of Neiss and Nelson (2003) and Neiss and Nelson (2005). Countries are assumed to be of equal size, i.e., $n = \frac{1}{2}$, and symmetric in their allocation of consumption between local goods and

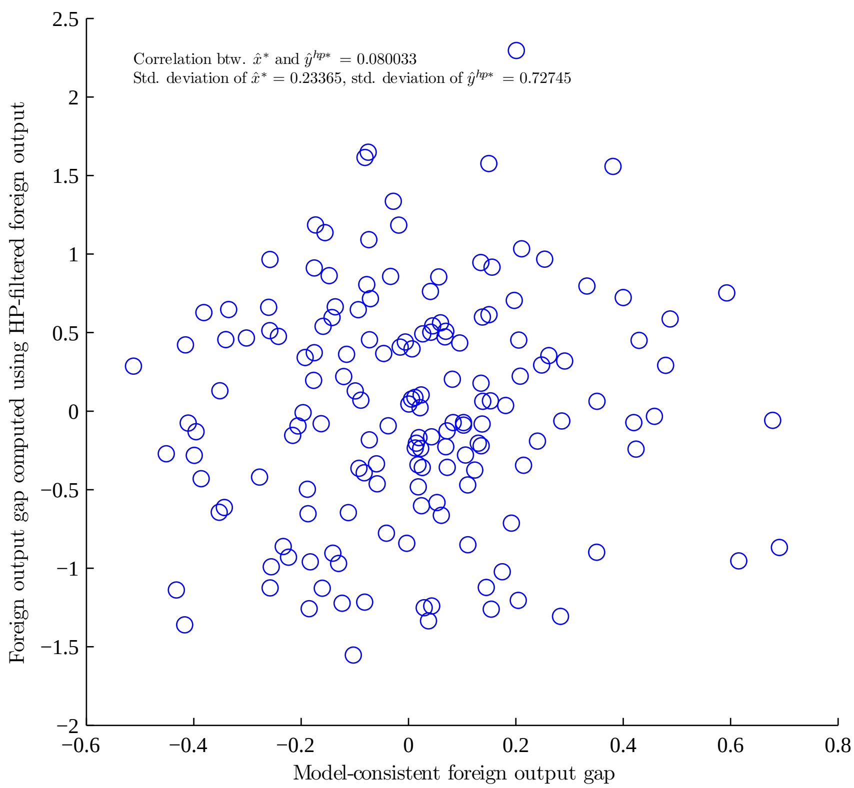
[8] Measuring inflation as a four-quarter change in a quarterly price index creates overlapping observations that induce serial correlation in the error term in a regression. Serially correlated disturbances will lead to unbiased but inefficient parameter estimates.

[9] If we are looking at the cyclical component of inflation, then π_t must be replaced by $\widehat{\pi}_t$ in equation (37). Carlstrom and Fuerst (2008), for instance, emphasize the importance of controlling for changes in trend inflation when looking at the relationship between slack and inflation.

imported goods, i.e., $(1-\xi)=\xi^*$.[10] We assume that the Taylor rule is inertial and takes in both countries the values estimated for the U.S. by Rudebusch (2006), i.e., $\rho = 0.78$, $\psi_\pi = 1.33$, and $\psi_x = 1.29$. For the AR(1) productivity shock process, we follow Kehoe and Perri (2002) in setting $\delta_a = 0.95$ and $\sigma_a = 0.7$ for the persistence and volatility, while we set the correlation between domestic and foreign innovations at $\rho_{\varepsilon^a,\varepsilon^{a*}} = 0.25$ as in Chari, Kehoe, and McGrattan (2002). For the AR(1) monetary shock process, we follow Rudebusch (2006) in setting $\delta_m = 0$ and $\sigma_m = 0.38$ for the persistence and volatility, while we set the correlation between domestic and foreign monetary innovations at $\rho_{\varepsilon^m,\varepsilon^{m*}} = 0.5$ as in Chari, Kehoe, and McGrattan (2002). Otherwise, monetary and productivity innovations are assumed to be uncorrelated.

Then, we simulate the model under this parameterization and compute the potential level of output consistent with the model and the trend output as measured by the application of the Hodrick–Prescott (HP) filter ($\lambda = 1,600$) to the output series generated by the model for a subsample of 160 periods. Figure 1 is an illustrative scatter plot of the two series of the foreign gap for a standard sample of 160 periods. The correlation between the two series in this plot is only 0.08, the standard deviation of the model-consistent foreign output gap is 0.23 and the standard deviation of the HP-filtered output gap is 0.73. Keeping the parameter values unchanged and simulating the model 500 times (each time extracting a subsample of 160 periods), we find that the average correlation between the foreign output gap and the HP-filtered foreign output is only 0.08 (with a standard deviation of 0.11). The average volatility of the model-consistent foreign output gap is merely 0.26 (with a standard deviation of 0.02) compared against a significantly larger standard deviation of 0.62 (with a standard deviation of 0.06) for the HP-filtered foreign output—which arises because the HP-filtered trend is too smooth relative to the model-implied potential output.

Figure 1: Comparison of Model-Consistent and Statistical Measures of the Foreign Output Gap



To further illustrate the problems these conceptual differences add to the evaluation of the global slack hypothesis, we run a series of reduced-form regressions similar to those commonly found in the existing

[10] We assume that households in each country include the same share of locally produced goods and imported goods in their respective consumption baskets (see, e.g., Warnock 2003). We denote ξ the share of the Home goods in the Home consumption basket and $(1-\xi^*)$ the share of the Foreign goods in the Foreign basket. In general, accounting for the fact that the population size of each country can be different, our assumption requires that $n(1-\xi) = (1-n)\xi^*$ and $(1-\xi)=\xi^*$ only if both countries are symmetric (i.e., $n=\frac{1}{2}$). In contrast, Clarida, Galí, and Gertler (2002) and Woodford (2010)—among others—make the assumption that both countries are of the same size and also that their consumption baskets are identical, i.e., $\xi = \xi^*$.

empirical literature (as summarized in equation (37)) on artificial data generated by our model. Specifically, we estimate two simple linear specifications of the following form,

$$\widehat{\pi}_t = a_\pi \widehat{\pi}_{t-1} + a_x \widehat{x}_t + a_{x^*} \widehat{x}_t^* + \epsilon_t, \tag{38}$$

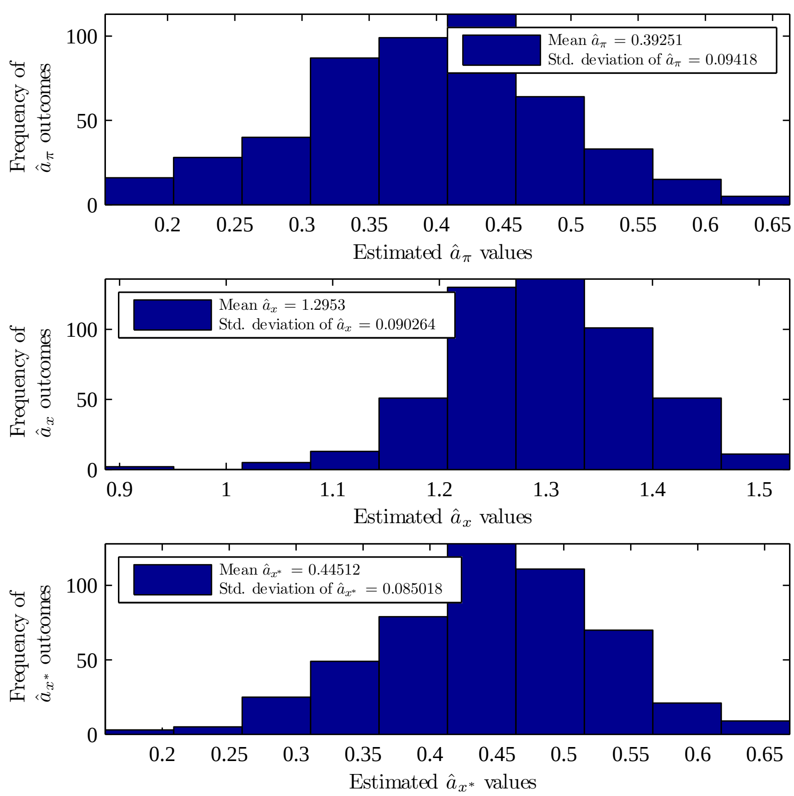
and

$$\widehat{\pi}_t = b_\pi \widehat{\pi}_{t-1} + b_{y^{hp}} \widehat{y}_t^{hp} + b_{y^{hp*}} \widehat{y}_t^{hp*} + v_t, \tag{39}$$

where $\widehat{\pi}_t$ denotes domestic (cyclical) inflation, $\widehat{x}_t$ denotes the domestic output gap implied by the model, $\widehat{x}_t^*$ denotes the model-consistent foreign output gap, $\widehat{y}_t^{hp}$ denotes the domestic HP-filtered output, $\widehat{y}_t^{hp*}$ denotes the foreign HP-filtered output, and ϵ_t and v_t are the error terms in each reduced-form regression. The reduced-form coefficients of interest are a_π, a_x, and a_{x^*}, while b_π, $b_{y^{hp}}$, and $b_{y^{hp*}}$ are the coefficients on the regression where HP-filtered output is used in place of the model-consistent output gap measures.

We simulate the full model 500 times and select 160 periods (approximately the equivalent of 40 years of quarterly data) on each draw of the simulation. We then run the OLS regression on each of the simulated time series for the chosen 160-period subsample. When we measure domestic and foreign slack using the model-consistent output gaps, we obtain the histogram in Figure 2 for the estimated coefficients a_π, a_x, and a_{x^*} of the regression in (38).

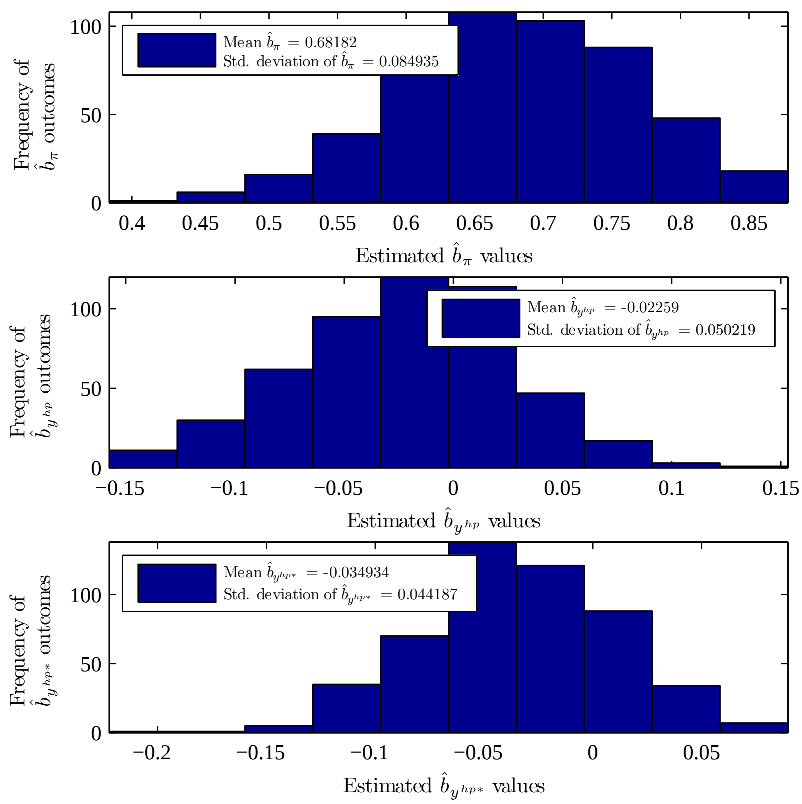
Figure 2: Histogram of the OLS Regression Estimates Over 500 Simulations, with Domestic and Foreign Output Gaps



The key point to note here is that when we measure the domestic and foreign output gaps in a model-consistent manner (that is, as deviations of actual output from its potential or frictionless level), the estimated reduced-form coefficients on domestic and foreign slack are all positive and often significantly so. Figure 2 also shows that the coefficient on domestic slack estimated in this way should be larger than the coefficient on foreign slack, but the latter is still well above the share of imported goods in the domestic consumption basket, $(1 - \xi)$, which in our benchmark parameterization stands at 0.06. While not reported in the paper, it can also be shown that increasing the share of imports from 0.06 up to 0.18 tends to reduce the estimated coefficient on the domestic output gap while at the same time it increases the coefficient on the foreign output gap.[11]

However, if instead we attempt to evaluate the global slack hypothesis in the simulated data using conventional statistical measures of the output gaps (i.e., deviations from smooth HP-trends), we obtain the histogram shown in Figure 3. Note that the coefficients on domestic and foreign slack are now typically close to zero and often of the wrong sign.

Figure 3: Histogram of the OLS Regression Estimates Over 500 Simulations, with HP-Filtered Domestic and Foreign Output



Thus, even if the data were generated by a model wherein the global slack hypothesis made sense, traditional reduced-form econometric methods that relied on statistical measures of the output gaps would likely find mixed evidence in support of the hypothesis. In practice, output gaps are measured with error because potential output is not directly observed and the statistical filtering methods often produce trend estimates that are only weakly correlated with potential output. In other words, what we observe is not the vector of output gaps needed to estimate (38), defined as $\widehat{X}_t = (\widehat{x}_t, \widehat{x}_t^*)^T$, but the vector of HP-filtered output, defined as $\widehat{Y}_t^{hp} = \left(\widehat{y}_t^{hp}, \widehat{y}_t^{hp*}\right)^T$. We postulate that the observable vector $\widehat{Y}_t^{hp}$ is related to the unobservable vector $\widehat{X}_t$ as follows:

$$\widehat{Y}_t^{hp} = \Theta \widehat{X}_t + U_t, \tag{40}$$

where $U_t = (u_t, u_t^*)^T$ defines the vector of measurement error terms, and $\Theta = \begin{pmatrix} \vartheta & 0 \\ 0 & \vartheta^* \end{pmatrix}$ is the matrix of coefficients that capture the strength of the correlation between the unobservable and observable variables. We assume the off-diagonal terms to be zero for simplicity of exposition.

[11] Whenever $\xi = 0.82$, the average of the coefficient on lagged inflation, a_{π}, barely changes from 0.39 under the benchmark parameterization to 0.38 (with a standard deviation of 0.09 across all 500 Monte Carlo simulations). The average of the coefficient on the domestic gap, a_x, drops from 1.30 under the benchmark parameterization to 1.09 (with a standard deviation of 0.07), while the average of the coefficient on the foreign gap increases from 0.45 under the benchmark parameterization to 0.66 (with a standard deviation of 0.07). Moreover, we also observe that the correlation between the model-consistent foreign output gap and the HP-filtered foreign output also increases from 0.08 under the benchmark parameterization to 0.25 (with a standard deviation of 0.10).

Let us assume for now that the linear model in (38) is well-posed and the output gap regressors satisfy that $\mathbb{E}\left[\widehat{X}_t \epsilon_t\right] = 0$. Operating with the equations in (38) and (40), it follows that

$$\begin{aligned}
\widehat{\pi}_t &= a_\pi \widehat{\pi}_{t-1} + \widehat{X}_t^T a + \epsilon_t \\
&= a_\pi \widehat{\pi}_{t-1} + \left(\left(\widehat{Y}_t^{hp}\right)^T - U_t^T\right)\left(\Theta^T\right)^{-1} a + \epsilon_t \\
&= a_\pi \widehat{\pi}_{t-1} + \left(\widehat{Y}_t^{hp}\right)^T \left(\Theta^T\right)^{-1} a + \epsilon_t - U_t^T \left(\Theta^T\right)^{-1} a \\
&= a_\pi \widehat{\pi}_{t-1} + a_x (\vartheta)^{-1} \widehat{y}_t^{hp} + a_{x^*} (\vartheta^*)^{-1} \widehat{y}_t^{hp*} + v_t, \qquad (41)
\end{aligned}$$

where $v_t = \epsilon_t - U_t^T \left(\Theta^T\right)^{-1} a = \epsilon_t - a_x (\vartheta)^{-1} u_t - a_{x^*} (\vartheta^*)^{-1} u_t^*$ defines the error term. From (41), the mapping between the coefficients of interest a_π and $a \equiv (a_x, a_{x^*})^T$ in (38) and the coefficients in (39) for the regression on HP-filtered output b_π and $b \equiv \left(b_{y^{hp}}, b_{y^{hp*}}\right)^T$ can be established as

$$\begin{aligned}
b_\pi &= a_\pi, \qquad (42) \\
b &= \left(\Theta^T\right)^{-1} a = \left(a_x (\vartheta)^{-1}, a_{x^*} (\vartheta^*)^{-1}\right)^T, \qquad (43)
\end{aligned}$$

which implies that the matrix Θ has to be pinned down before we can infer the coefficient vector a from the estimates of the vector b.

For simplicity, let us assume that $b_\pi = a_\pi$ is known and move the corresponding lagged inflation term to the left-hand side of the regression in (41). Even assuming that $\mathbb{E}[U_t \epsilon_t] = 0$ and $\mathbb{E}\left[\widehat{X}_t U_t^T\right] = 0$, the problem is that

$$\begin{aligned}
\mathbb{E}\left[\widehat{Y}_t^{hp} v_t\right] &= \mathbb{E}\left[\left(\Theta \widehat{X}_t + U_t\right)\left(\epsilon_t - U_t^T \left(\Theta^T\right)^{-1} a\right)\right] \\
&= -\mathbb{E}\left[U_t U_t^T\right]\left(\Theta^T\right)^{-1} a \neq 0, \qquad (44)
\end{aligned}$$

which would result in an endogeneity problem if $b = \left(\Theta^T\right)^{-1} a \neq 0$ and $\mathbb{E}\left[U_t U_t^T\right] \neq 0$. It follows that if $\widehat{b}$ is the OLS estimate of the vector b, then it will not be a consistent estimator, i.e.,

$$\widehat{b} \xrightarrow{p} \bar{b} \equiv b - \left(\mathbb{E}\left(\widehat{X}_t \widehat{X}_t^T\right)\right)^{-1} \mathbb{E}\left(U_t U_t^T\right) b \neq b. \qquad (45)$$

Measurement error bias will distort the estimates on these reduced-form regressions. However, that is not the only concern that arises from our discussion so far. First, even with a consistent estimator for b, in order to recover a we would also need to identify Θ. Second, the exogeneity of equation (38) is in question too because the residuals ϵ_t can be expressed as a function of current (and perhaps lagged) shocks which are also moving the regressors $\widehat{X}_t$ themselves. Hence, it is not necessarily obvious that $\mathbb{E}\left[\widehat{X}_t \epsilon_t\right] = 0$ holds either, and simple OLS estimates of (38) may not necessarily produce unbiased estimators even if we are able to observe the model-consistent output gaps collected in the vector $\widehat{X}_t$.

Choice of Regressors and Multicollinearity

In light of the conceptual and measurement challenges associated with estimating open-economy Phillips curves in terms of domestic and foreign output gaps, it is worth asking whether we can derive alternative specifications that rely on more easily measured variables such as the terms of trade. Under the producer currency pricing (PCP) assumption, it is possible to write the terms of trade gap $\widehat{z}_t \equiv (\widehat{tot}_t - \widehat{\overline{tot}}_t)$ as a function of domestic and foreign output gaps as follows:

$$\widehat{z}_t = \left[\frac{1}{\sigma - \left(\sigma - \frac{1}{\gamma}\right)(\xi - \xi^*)(\eta - \eta^*)}\right](\widehat{x}_t - \widehat{x}_t^*). \qquad (46)$$

Using this expression to eliminate the foreign output gap term from the Phillips curve in equation (20) above, we obtain that

$$\widehat{\pi}_t = \beta \mathbb{E}_t(\widehat{\pi}_{t+1}) + \Phi\left[(\varphi + \gamma)\widehat{x}_t + \Psi_{\pi,z} \widehat{z}_t\right], \qquad (47)$$

where,

$$\Psi_{\pi,z} \equiv \begin{cases} -\sigma\left(1-\xi\right)\left(\varphi+\gamma\right)+\left(\sigma-\frac{1}{\gamma}\right)\left(\xi-\xi^{*}\right)\left(\varphi\left(1-\xi\right)\left(\eta-\eta^{*}\right)-\gamma\left(1-\eta\right)\right), & \text{if } \xi \neq \xi^{*}, \\ & \text{or} \\ -\sigma\left(1-\xi\right)\left(\varphi+\gamma\right), & \text{if } \xi = \xi^{*}. \end{cases} \tag{48}$$

That is, in principle the effects of foreign slack on domestic inflation can be fully captured by movements in the terms of trade gap. Note that the slope of the Phillips curve with respect to domestic slack, $\Phi(\varphi+\gamma)$, is *exactly the same* in the open-economy and closed-economy specifications whenever the open-economy version includes the terms of trade gap instead of the foreign output gap.[12]

The expression for $\Psi_{\pi,z}$ can also be written as

$$\Psi_{\pi,z} = -\Psi_{\pi,x^{*}}\left[\sigma-\left(\sigma-\frac{1}{\gamma}\right)\left(\xi-\xi^{*}\right)\left(\eta-\eta^{*}\right)\right], \tag{49}$$

where the composite coefficient $\Psi_{\pi,x^{*}}$ is defined in (22) and the term within square brackets is shown to be positive for the entire parameter space in the appendix. Therefore, the sign of $\Psi_{\pi,z}$ is determined by the sign of $\Psi_{\pi,x^{*}}$. As discussed extensively in the appendix, $\Psi_{\pi,x^{*}}$ is always positive if we assume identical consumption baskets as Clarida, Galí, and Gertler (2002) and Woodford (2010) do, i.e., $\xi=\xi^{*}$. However, in the general case where $\xi \neq \xi^{*}$, we cannot rule out the possibility that $\Psi_{\pi,x^{*}}$ becomes negative in some range of the parameter space. Therefore, while in most instances the terms of trade gap enters with a *negative* coefficient, we cannot exclude the possibility that the sign might also turn positive in some region of the parameter space. The absolute value of this coefficient depends on the shares of Home goods in the consumption baskets, $0<\xi<1$ and $0<\xi^{*}<1$, the elasticity of substitution between Home and Foreign goods, $\sigma>0$, the inverse of the elasticity of intertemporal substitution, $\gamma>0$, and the inverse of the Frisch elasticity of labor supply, $\varphi>0$.

If instead we assume local currency pricing (LCP), the relationship between the terms of trade gap and the output gaps in the Home and Foreign countries must include a term accounting for deviations from the law of one price, i.e.,

$$\widehat{z}_t = \left[\frac{1}{\sigma-\left(\sigma-\frac{1}{\gamma}\right)\left(\xi-\xi^{*}\right)\left(\eta-\eta^{*}\right)}\right]\left(\widehat{x}_t-\widehat{x}_t^{*}\right)+\left[1+\frac{\frac{1}{\gamma}\left(\eta-\eta^{*}\right)}{\sigma-\left(\sigma-\frac{1}{\gamma}\right)\left(\xi-\xi^{*}\right)\left(\eta-\eta^{*}\right)}\right]\widehat{d}_t. \tag{50}$$

This relationship depends exclusively on deviations from the law of one price for Foreign goods in the domestic market, $\widehat{d}_t$, because in our framework it can be shown that $\left(\widehat{p}_t^{F}-\widehat{p}_t^{H}\right) \approx \left(\widehat{p}_t^{F*}-\widehat{p}_t^{H*}\right)$ and in turn that implies $\widehat{d}_t = -\widehat{d}_t^{*}$ (see, e.g., Engel 2009). Moreover, we can derive from the definition of the real exchange rate and the consumption price indexes in both countries the following relationship:

$$\widehat{rs}_t = (\xi-\xi^{*})\widehat{tot}_t - (1+(\xi-\xi^{*}))\widehat{d}_t. \tag{51}$$

In the frictionless equilibrium with flexible prices, expression (51) reduces to $\widehat{\overline{rs}}_t = (\xi-\xi^{*})\widehat{\overline{tot}}_t$. Hence, we can rewrite the open-economy Phillips curve in terms of the domestic output gap, the terms of trade gap, and the real exchange rate (net of terms of trade effects) as

$$\widehat{\pi}_t = \beta\mathbb{E}_t\left(\widehat{\pi}_{t+1}\right)+\Phi[(\varphi+\gamma)\widehat{x}_t+\Psi_{\pi,z}\widehat{z}_t-\Xi_{\pi}(\widehat{rs}_t-(\xi-\xi^{*})\widehat{tot}_t)], \tag{52}$$

[12] The closed-economy specification can be approximated by $\xi=1$ and $\xi^{*}=0$.

where the composite parameter $\Psi_{\pi,z}$ is defined as in (48) and Ξ_{π} is expressed as

$$
\Xi_{\pi} \equiv \begin{cases}
\left(\varphi(1-\xi) + \gamma\left(\frac{\sigma(1-\xi)+(\sigma-\frac{1}{\gamma})(\xi-\xi^{*})(1-\eta)}{\sigma-(\sigma-\frac{1}{\gamma})(\xi-\xi^{*})(\eta-\eta^{*})}\right)\right)\left(\frac{\sigma-((\sigma-\frac{1}{\gamma})(\xi-\xi^{*})-\frac{1}{\gamma})(\eta-\eta^{*})}{1+(\xi-\xi^{*})}\right) + \dots & \\
\gamma\sigma\left(\frac{\sigma(1-\xi)+(\sigma-\frac{1}{\gamma})(\xi-\xi^{*})(1-\eta)}{\sigma-(\sigma-\frac{1}{\gamma})(\xi-\xi^{*})(\eta-\eta^{*})}\right)\left(\frac{1-(\xi-\xi^{*})(\eta-\eta^{*})}{(\xi-\xi^{*})(1+(\xi-\xi^{*}))}\right) - \gamma\sigma\left(\frac{(1-\xi^{*})-\eta(\xi-\xi^{*})}{(\xi-\xi^{*})(1+(\xi-\xi^{*}))}\right), & \text{if } \xi \neq \xi^{*}, \\
\text{or} & \\
(1-\xi)(\gamma+\varphi)\sigma - (1-n), & \text{if } \xi = \xi^{*}.
\end{cases} \tag{53}
$$

The composite parameters on the domestic output gap and the terms of trade gap are the same as under producer currency pricing (PCP), as can be observed by comparing equations (47) and (52). Most significantly, the responsiveness of CPI inflation to the domestic output gap is exactly the same as in the closed-economy case. If we make the additional assumption that the consumption baskets are identical (as do Clarida, Galí, and Gertler 2002 and Woodford 2010), i.e., $\xi = \xi^{*}$, then the real exchange rate suffices to summarize the contribution of the deviations of the law of one price. Even in that special case, however, the sign of Ξ_{π} can be positive or negative in different ranges of the parameter space and depends crucially on the domestic population size, $0 < n < 1$, among other structural parameters.

Thus there is an equivalence between expressing the open-economy Phillips curve in terms of domestic and foreign output gaps and expressing it in terms of the domestic output gap, the terms of trade gap, and the real exchange rate (net of terms of trade effects). To the extent that the traditional Phillips curve literature has included variables such as oil and commodity prices (whose movements are highly correlated with the U.S. terms of trade) or the real exchange rate as right-hand-side variables since the 1970s, global slack has been noted and accounted for implicitly as an important determinant of U.S. inflation for a long time. More recently, Ihrig et al. (2007) specified the inflation equation as a function of lagged inflation; domestic and foreign slack; and import, energy, and food prices.

However, while terms of trade data are more readily available in countries like the U.S., we must note that the open-economy Phillips curve is defined as a function of a terms of trade gap rather than terms of trade alone. Therefore, the proper measurement of potential (or frictionless) terms of trade remains a significant concern and a source of measurement error bias.

Theory suggests that the coefficient on the domestic output gap is invariant to changes in the domestic and foreign consumption baskets whenever we properly account for movements in the U.S. terms of trade gap, which would imply that the stability of the slope coefficient on domestic slack cannot be necessarily interpreted as evidence against the global slack hypothesis. If anything, one would expect greater openness and concurrent changes in the consumption baskets to translate solely into changes on the composite coefficient on the terms of trade gap.

In the context of our model, adding a terms of trade gap into a reduced-form regression where domestic and foreign output gaps are also included as explanatory variables could result in a severe case of multicollinearity. The implication of strict or near multicollinearity is that individual coefficients will be imprecisely estimated. In other words, when the terms of trade gap is highly dependent on other regressors (the domestic and foreign output gaps in our model), then it is statistically difficult to disentangle the impact of the coefficient estimates. However, the greater imprecision in the estimation will be reflected in large standard errors and should imply that inference is undistorted even in the presence of multicollinearity.

Let us again focus our attention on the workhorse model under producer currency pricing (PCP) described in Table A6 in the appendix. Equation (46) under PCP hints already that multicollinearity problems are a distinct possibility since the terms of trade gap is linearly dependent on both domestic and foreign output gaps. Multicollinearity may not be averted by excluding in the reduced-form regressions either the measure of the terms of trade gap or the measure of the foreign output gap. To elaborate on this point, we replace the reduced-form regression in (38) with this alternative specification including the terms of trade gap as defined in (46), i.e.,

$$
\widehat{\pi}_{t} - a_{\pi}\widehat{\pi}_{t-1} = a_{x}\widehat{x}_{t} + a_{z}\widehat{z}_{t} + \epsilon_{t}^{z}, \tag{54}
$$

where we assume that a_{π} is known and that only the vector $a^{z} \equiv (a_{x}, a_{z})^{T}$ needs to be estimated. For the sake of simplicity, we assume that the errors in the reduced-form regression are homoskedastic, i.e., $\sigma_{\epsilon^{z}}^{2}$. If the regression errors were in fact heteroskedastic, then it is possible that the covariance matrix for the estimator $\widehat{a}^{z}$ would be biased as well (affecting the inference).

We define $\widehat{W}_t = (\widehat{x}_t, \widehat{z}_t)^T$ to be the vector of regressors, denote N to be the sample size, and normalize to one the volatility of the domestic and foreign output gaps, i.e., $\frac{1}{N}\sum_{i=1}^{N}(\widehat{x}_t)^2 = \frac{1}{N}\sum_{i=1}^{N}(\widehat{x}_t^*)^2 = 1$.[13] Then, it follows that

$$\frac{1}{N}\sum_{i=1}^{N}\widehat{W}_t\widehat{W}_t^T = \begin{pmatrix} 1 & \widetilde{\rho}_{x,z}\widetilde{\sigma}_z \\ \widetilde{\rho}_{x,z}\widetilde{\sigma}_z & \widetilde{\sigma}_z^2 \end{pmatrix}, \tag{55}$$

where we characterize the volatility of the terms of trade gap, $\widetilde{\sigma}_z^2$, and the correlation of the terms of trade gap with the domestic output gap, $\widetilde{\rho}_{x,z}$, as

$$\widetilde{\sigma}_z^2 = \frac{1}{N}\sum_{i=1}^{N}\widehat{z}_t^2 = 2\left(\frac{1-\frac{1}{N}\sum_{i=1}^{N}\widehat{x}_t\widehat{x}_t^*}{\left(\sigma-\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)(\eta-\eta^*)\right)^2}\right), \tag{56}$$

$$\widetilde{\rho}_{x,z} = \frac{\frac{1}{N}\sum_{i=1}^{N}\widehat{x}_t\widehat{z}_t}{\sigma_z} = \left(\sqrt[2]{\frac{1-\frac{1}{N}\sum_{i=1}^{N}\widehat{x}_t\widehat{x}_t^*}{2}}\right). \tag{57}$$

If we define the correlation coefficient between the domestic and foreign output gaps as $\widetilde{\rho}_{x,x^*} = \frac{1}{N}\sum_{i=1}^{N}\widehat{x}_t\widehat{x}_t^*$, then we can easily rewrite the matrix $\frac{1}{N}\sum_{i=1}^{N}\widehat{W}_t\widehat{W}_t^T$ as follows:

$$\frac{1}{N}\sum_{i=1}^{N}\widehat{W}_t\widehat{W}_t^T = \begin{pmatrix} 1 & \frac{1-\widetilde{\rho}_{x,x^*}}{\sigma-\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)(\eta-\eta^*)} \\ \frac{1-\widetilde{\rho}_{x,x^*}}{\sigma-\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)(\eta-\eta^*)} & 2\left(\frac{1-\widetilde{\rho}_{x,x^*}}{\left(\sigma-\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)(\eta-\eta^*)\right)^2}\right) \end{pmatrix}. \tag{58}$$

In the hypothetical case under homoskedasticity, the covariance matrix of the OLS estimates $\widehat{a}^z$ takes the relatively simple form

$$\begin{aligned} \mathbb{V}\left(\widehat{a}^z \mid \widehat{W}\right) &= \frac{\sigma_{\epsilon^z}^2}{N}\left(\frac{1}{N}\sum_{i=1}^{N}\widehat{W}_t\widehat{W}_t^T\right)^{-1} \\ &= \frac{2\sigma_{\epsilon^z}^2}{N(1+\widetilde{\rho}_{x,x^*})}\begin{pmatrix} 1 & -\frac{\sigma-(\sigma-\frac{1}{\gamma})(\xi-\xi^*)(\eta-\eta^*)}{2} \\ -\frac{\sigma-(\sigma-\frac{1}{\gamma})(\xi-\xi^*)(\eta-\eta^*)}{2} & \frac{(\sigma-(\sigma-\frac{1}{\gamma})(\xi-\xi^*)(\eta-\eta^*))^2}{2(1-\widetilde{\rho}_{x,x^*})} \end{pmatrix}, \end{aligned} \tag{59}$$

which is known up to the unknown scaling factor $\sigma_{\epsilon^z}^2$. There are a number of alternative estimators for $\sigma_{\epsilon^z}^2$ that can be considered, but what matters to illustrate multicollinearity is that we cannot rule out the possibility that the matrix $\frac{1}{N}\sum_{i=1}^{N}\widehat{W}_t\widehat{W}_t^T$ will become near singular. In this particular scenario, multicollinearity is closely tied to the coefficient of correlation between domestic and foreign output gaps, $\widetilde{\rho}_{x,x^*}$. Whenever $\sigma-\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)(\eta-\eta^*) = 2$, we can easily observe that the variance of the OLS estimates $\mathbb{V}\left(\widehat{a}^z \mid \widehat{W}\right)$ approaches infinity as $\widetilde{\rho}_{x,x^*}$ approaches -1. While this is not a general statement about the model, it indicates that multicollinearity problems and imprecision in the estimates can still hamper the interpretation of these reduced-form regressions even if one is careful about the choice of regressors (and even if one is able to maneuver around the conceptual and measurement challenges that the gap concept poses).

[13]Under the inherent symmetry of the model, we know that the population variance of the domestic and foreign output gaps must be equal. Therefore, the normalization to one simplifies our discussion but does not impose a significant loss of generality.

A similar thought experiment can be conducted with the reduced-form regression in (38), where the covariance matrix of the OLS estimates $\widehat{a}$ under homoskedasticity is given by

$$\begin{aligned}\mathbb{V}\left(\widehat{a} \mid \widehat{X}\right) &= \frac{\sigma_\epsilon^2}{N}\left(\frac{1}{N}\sum\nolimits_{i=1}^{N}\widehat{X}_t\widehat{X}_t^T\right)^{-1} \\ &= \frac{\sigma_\epsilon^2}{N}\begin{pmatrix} 1 & \widetilde{\rho}_{x,x^*} \\ \widetilde{\rho}_{x,x^*} & 1\end{pmatrix}^{-1} \\ &= \frac{\sigma_\epsilon^2}{N\left(1-\widetilde{\rho}_{x,x^*}^2\right)}\begin{pmatrix} 1 & -\widetilde{\rho}_{x,x^*} \\ -\widetilde{\rho}_{x,x^*} & 1\end{pmatrix}, \end{aligned} \tag{60}$$

which is known up to the unknown scaling factor σ_ϵ^2. Near singularity arises whenever ρ_{xx^*} approaches 1. In most of our simulations, the coefficient of correlation between the domestic and foreign output gaps appears to be very low and close to zero,[14] which suggests that multicollinearity is not a major problem in the reduced-form regressions we run on data generated from our model. However, the high correlation between certain domestic measures and foreign measures of slack (e.g., capacity utilization rates in the U.S. and the rest of the G-7 seem to move in tandem most of the time) raises the prospect of multicollinearity in empirical work. Still, there are episodes where the divergence between domestic and foreign measures might alleviate these concerns. In fact, it was the striking discrepancy between capacity utilization rates in the U.S. and the rest of the G-7 in the early 1990s that motivated the analysis of Orr (1994).

Ultimately, our analysis tells us that the validity of the global slack hypothesis cannot be determined solely on the basis of simple least squares regressions on reduced-form relationships of the sort reported elsewhere in the empirical literature. A fuller evaluation of the global slack hypothesis would likely require a more structural approach to the multiple factors and diverse channels influencing inflation dynamics in the open economy that can be taken to the data. We leave that for future research.

3. CONCLUSION

Our objective in this paper has been to show that the global slack hypothesis has analytical content in the context of at least one widely used framework for thinking about inflation trade-offs in open economies. Under most possible parameterizations, we have shown that in theory inflation is less responsive to domestic slack the more exposed a country is to international trade. We have also shown that foreign slack does matter for domestic inflation when a country is engaged in international trade, and the importance of foreign slack increases as the domestic share of consumption devoted to foreign-produced goods increases in most cases. We find, however, that the importance of foreign slack may either increase or decline in response to changes in the foreign share of consumption devoted to domestically-produced goods depending on how open the domestic economy is.

We also noted the conceptual and statistical difficulties of measuring the output gaps and suggested that terms of trade (and other international relative prices) may account for some of the foreign influences on domestic inflation and, therefore, allow us to bypass some of those measurement and data availability problems associated with the output gap measures—without being exempt from the same sort of conceptual problems. A fuller evaluation of the global slack hypothesis would complete and extend the specification of the model outlined above, and then would take the full system to the data.

There are several avenues for further research. On the theory side, there are many potential additional channels through which foreign factors might have an impact on domestic inflation developments that would be worth modelling. Two that spring to mind are migration and international trade in raw materials and intermediate inputs. Leith and Malley (2007) and Rumler (2007) have investigated the basic model sketched out above allowing for trade in intermediate inputs. Recent work by Lach (2007), Cortes (2008), Razin and Binyamini (2007), Bentolila, Dolado, and Jimeno (2008) and Engler (2009) has shown how the presence of large immigrant populations can impact domestic prices. And the surge in global commodity prices in 2007 and 2008 was a reminder of how price dynamics at all stages of the production chain have been impacted by the shifting distribution of global economic activity.

The model we sketched out is not well suited to address questions of deep structural change that are arguably at the heart of the debate about the implications of globalization for inflation and monetary

[14] Keeping our benchmark parameterization unchanged and simulating the model 500 times (each time extracting a subsample of 160 periods), we find that the average correlation coefficient between the model-consistent domestic and foreign output gaps is 0 (with a standard deviation of 0.10).

policy, and therein lies another potentially fruitful avenue for future research. In our work, we argued that it is important to abstract from fluctuations in trend when evaluating the global slack hypothesis, but our theory has little to say about these changes in trend, or whether they might have implications for short-run dynamics. The literature that addresses the potential impact of globalization on trend inflation that began with Romer (1993) has largely focused on explaining the role of openness in accounting for cross-country differences in inflation; an extension to account for differences over time would be a logical next step.

APPENDIX

In the general case, the composite coefficients $\Psi_{\pi,x}$ and Ψ_{π,x^*} affecting the slope of the Phillips curve relationship described in equations (20), (31) and (36) can be written as in (21) and (22), where the term within parentheses is a rather intimidating expression involving many of the structural parameters of the model—including the share of the Home goods in the Home consumption basket, $0 < \xi < 1$, and the share of the Home goods in the Foreign basket, $0 < \xi^* < 1$. Under the assumption of identical consumption baskets in both countries (i.e., $\xi = \xi^*$) investigated by Clarida, Galí, and Gertler (2002) and Woodford (2010), the coefficients in (21) and (22) simplify to

$$\begin{aligned} \Psi_{\pi,x} &= \xi (\gamma + \varphi) > 0, \\ \Psi_{\pi,x^*} &= (1 - \xi) (\gamma + \varphi) > 0. \end{aligned}$$

The same expressions can be derived whenever $\sigma = \frac{1}{\gamma}$ without having to impose the assumption of identical consumption baskets. In these two special cases, the foreign output gap will matter for domestic CPI inflation, and there is no ambiguity about the sign of the effect. The importance of the foreign output gap is unequivocally greater, the greater the share of foreign goods in the Home consumption basket, $(1 - \xi)$.

We illustrate with this appendix how the sign of the composite coefficients and their sensitivity to the shares ξ and ξ^* cannot be asserted uniquely across all possible combinations of the parameter space except in special cases.

The Sign of the Coefficients on the Phillips Curve

The sign of the coefficients on the domestic and foreign output gaps in the open-economy Phillips curve is given by the sign of $\Psi_{\pi,x}$ and Ψ_{π,x^*} in (21) and (22), which is not going to be positive across all possible combinations of values in the parameter space. The denominator of the expression within parentheses is common in both (21) and (22) and it can be shown to be positive if and only if

$$\sigma > -\frac{1}{\gamma} \left(\frac{n (1 - n) (\xi - \xi^*)^2}{(1 - n) \xi^* (1 - \xi^*) + n\xi (1 - \xi)} \right).$$

It follows that the term within parentheses in the right-hand side of this inequality constraint is positive. Any combination of the inverse of the elasticity of intertemporal substitution, $\gamma > 0$, and the elasticity of substitution between the Home and Foreign bundles of varieties, $\sigma > 0$, satisfies that inequality. Therefore, the numerator in both cases is what ultimately determines the sign of the coefficients in the Phillips curve.

For the composite coefficient $\Psi_{\pi,x}$, we observe that the numerator of the expression within parentheses becomes negative if and only if the following inequality constraint is satisfied, i.e.,

$$\sigma < -\frac{1}{\gamma} (\xi - \xi^*) \left(\frac{(1 - n) (1 - \xi^*)}{(1 - n) \xi^* (1 - \xi^*) + n\xi (1 - \xi)} \right).$$

If the share of Home goods is larger in the Foreign basket than in the Home basket, i.e., $\xi^* > \xi$, then the right-hand-side term of the constraint is positive and there is some combination of the inverse of the elasticity of intertemporal substitution, $\gamma > 0$, and the elasticity of substitution between the Home and Foreign bundles, $\sigma > 0$, for which the numerator becomes negative. In that case, we cannot rule out the possibility that for some values of the inverse of the Frisch elasticity of labor supply, $\varphi > 0$, the composite coefficient $\Psi_{\pi,x}$ may become negative as well.

Similarly for the composite coefficient Ψ_{π,x^*}, we observe that the numerator of the expression within parentheses becomes negative if and only if the following constraint is satisfied, i.e.,

$$\sigma < \frac{1}{\gamma} (\xi - \xi^*) \left(\frac{(1 - n) \xi^*}{(1 - n) \xi^* (1 - \xi^*) + n\xi (1 - \xi)} \right).$$

If the share of Home goods is larger in the Home basket than in the Foreign basket, i.e., $\xi > \xi^*$, then the right-hand-side term of the constraint is positive and there is some combination of the inverse of the elasticity of intertemporal substitution, $\gamma > 0$, and the elasticity of substitution between the Home and Foreign bundles of varieties, $\sigma > 0$, for which the numerator becomes negative. In that case, we cannot rule out the possibility that for some values of the inverse of the Frisch elasticity of labor supply, $\varphi > 0$, the composite coefficient Ψ_{π,x^*} may become negative too. However, while our findings suggest that the composite coefficients $\Psi_{\pi,x}$ and Ψ_{π,x^*} can become negative in some cases, it cannot happen that both coefficients will be negative simultaneously.

The Sensitivity of the Coefficients on the Phillips Curve

The sensitivity of the Phillips curve coefficients to changes in the consumption basket shares is also different across regions of the parameter space. We can interpret the share of Home goods in the Home basket, $0 < \xi < 1$, as a reciprocal measure of greater openness or integration with the Foreign economy. The larger the share ξ, the more biased Home consumption is toward the Home-produced goods and, hence, the less open—and subject to—foreign influences is the domestic Phillips curve.

One way to assess the sensitivity of the slope of the Phillips curve to changes in ξ is to compute the partial derivative of the coefficient Ψ_{π,x^*} assuming that all other structural parameters are unchanged.[15] Under the assumption of identical consumption baskets in both countries, i.e., $\xi = \xi^*$, the partial derivatives are

$$
\begin{aligned}
\left.\frac{\partial \Psi_{\pi,x}}{\partial \xi}\right|_{\xi=\xi^*} &= (\gamma+\varphi) > 0, \\
\left.\frac{\partial \Psi_{\pi,x^*}}{\partial \xi}\right|_{\xi=\xi^*} &= -(\gamma+\varphi) < 0.
\end{aligned}
$$

The signs of these partial derivatives are unambiguous; if the world economy becomes more oriented toward Home goods, then the Home output gap should matter more and the Foreign output gap less for the domestic Phillips curve *ceteris paribus*. However, the implicit assumption in these calculations is that the share of Home goods in the Home consumption basket, ξ, and the share of Home goods in the Foreign basket, ξ^*, are moving in the same direction and by the same amount to preserve the identity between the Home and Foreign consumption baskets. In other words, these partial derivatives reflect the marginal effect of a simultaneous marginal change in the shares of both countries.

When we investigate the more general setting—without identical consumption baskets—and ask what happens to the Phillips curve coefficients when ξ changes marginally but not any other of the structural parameters (including ξ^*), then the answer is no longer as straightforward. In computing the corresponding partial derivative for Ψ_{π,x^*}, we obtain that

$$
\begin{aligned}
\frac{\partial \Psi_{\pi,x^*}}{\partial \xi} &= -\varphi + \gamma \left(\frac{(\Gamma_n')(\Gamma_d) - (\Gamma_n)(\Gamma_d')}{(\Gamma_d)^2} \right), \\
\Gamma_n &\equiv \sigma(1-\xi) + \left(\sigma - \frac{1}{\gamma}\right)(\xi-\xi^*)(1-\eta) = \begin{cases} < 0 \text{ if } \sigma < \left(\frac{\frac{1}{\gamma}(\xi-\xi^*)(1-n)\xi^*}{(1-n)\xi^*(1-\xi^*)+n\xi(1-\xi)} \right) \text{ and } \xi > \xi^*, \\ > 0 \text{ otherwise,} \end{cases} \\
\Gamma_d &\equiv \sigma - \left(\sigma - \frac{1}{\gamma}\right)(\xi-\xi^*)(\eta-\eta^*) > 0, \\
\Gamma_n' &\equiv -\sigma + \left(\sigma - \frac{1}{\gamma}\right)\left(\frac{(1-n)(\xi^*)^2}{(1-n)\xi^* + n\xi} \right) < 0, \\
\Gamma_d' &\equiv -\left(\sigma - \frac{1}{\gamma}\right)(\xi-\xi^*)\left(\frac{n(1-n)\left((2(1-\xi^*) - n(1+2(\xi-\xi^*)))\xi^* + n\xi\right)}{\left((n\xi+(1-n)\xi^*)^2 - n\xi - (1-n)\xi^*\right)^2} \right) \\
&= \begin{cases} < 0 \text{ if } \left(\sigma - \frac{1}{\gamma}\right)(\xi-\xi^*) > 0, \\ > 0 \text{ otherwise.} \end{cases}
\end{aligned}
$$

In fact, it can be shown that $(\Gamma_n')(\Gamma_d) < 0$ for any combination in the parameter space while $(\Gamma_n)(\Gamma_d')$ can

[15] Given that $\Psi_{\pi,x} + \Psi_{\pi,x^*} = \gamma + \varphi$ as noted in equation (23) in Section 1, it naturally follows that $\frac{\partial \Psi_{\pi,x}}{\partial \xi} = -\frac{\partial \Psi_{\pi,x^*}}{\partial \xi}$ and $\frac{\partial \Psi_{\pi,x}}{\partial \xi^*} = -\frac{\partial \Psi_{\pi,x^*}}{\partial \xi^*}$. As a result, computing the partial derivatives $\frac{\partial \Psi_{\pi,x^*}}{\partial \xi}$ and $\frac{\partial \Psi_{\pi,x^*}}{\partial \xi^*}$ suffices to characterize the response of both Phillips curve composite coefficients to marginal changes in the shares ξ and ξ^*.

be either positive or negative, therefore potentially affecting the sign of the partial derivative. We find that

$$
\begin{aligned}
\text{if } \xi &< \xi^{*}, \text{ then } \left(\Gamma_{n}\right)\left(\Gamma_{d}'\right) = \begin{cases} <0 \text{ if } \sigma < \frac{1}{\gamma}, \\ >0 \text{ if } \sigma > \frac{1}{\gamma}, \end{cases} \\
\text{if } \xi &= \xi^{*}, \text{ then } \left(\Gamma_{n}\right)\left(\Gamma_{d}'\right) = 0, \\
\text{if } \xi &> \xi^{*}, \text{ then } \left(\Gamma_{n}\right)\left(\Gamma_{d}'\right) = \begin{cases} <0 \text{ if } \sigma < \left(\frac{\frac{1}{\gamma}(\xi-\xi^{*})(1-n)\xi^{*}}{(1-n)\xi^{*}(1-\xi^{*})+n\xi(1-\xi)}\right) < \frac{1}{\gamma}, \\ >0 \text{ if } \left(\frac{\frac{1}{\gamma}(\xi-\xi^{*})(1-n)\xi^{*}}{(1-n)\xi^{*}(1-\xi^{*})+n\xi(1-\xi)}\right) < \sigma < \frac{1}{\gamma}, \\ <0 \text{ if } \left(\frac{\frac{1}{\gamma}(\xi-\xi^{*})(1-n)\xi^{*}}{(1-n)\xi^{*}(1-\xi^{*})+n\xi(1-\xi)}\right) < \frac{1}{\gamma} < \sigma. \end{cases}
\end{aligned}
$$

The standard intuition is that an increase in the domestic share ξ, which implies a decline in the share of imported goods in the Home consumption basket $(1-\xi)$, should result in a lower coefficient on the foreign output gap, i.e., $\frac{\partial \Psi_{\pi,x^{*}}}{\partial \xi} < 0$. What our analysis suggests is otherwise since sensitivity of the coefficient on the foreign output gap is certainly more complicated and highly nonlinear than this simple intuition would indicate. As a matter of fact, there might be instances in which the partial derivative is positive $\frac{\partial \Psi_{\pi,x^{*}}}{\partial \xi} > 0$ if

$$
\left(\Gamma_{n}'\right)\left(\Gamma_{d}\right) > \frac{\varphi}{\gamma}\left(\Gamma_{d}\right)^{2} + \left(\Gamma_{n}\right)\left(\Gamma_{d}'\right),
$$

which—for any given combination of $0 < \xi < 1$ and $0 < \xi^{*} < 1$—is a possibility that cannot be ruled out in some range of the parameter space formed by the inverse of the elasticity of intertemporal substitution, $\gamma > 0$, the elasticity of substitution between the Home and Foreign bundles of varieties, $\sigma > 0$, and the inverse of the Frisch elasticity of labor supply, $\varphi > 0$.

To investigate the ambiguity on the sign of the partial derivative, we evaluate it first under our benchmark parameterization but allowing for the elasticity of substitution $\sigma > 0$ and the inverse of the Frisch elasticity of labor supply $\varphi > 0$ to span a range of values in their parameter space. Countries are assumed to be of equal size, i.e., $n = \frac{1}{2}$, we evaluate the Home good shares, ξ and ξ^{*}, at 0.94 and 0.06 respectively as in Chari, Kehoe, and McGrattan (2002), and the inverse of the elasticity of intertemporal substitution, γ, at 5. The region in which the partial derivative turns positive is (vanishingly) small and requires very low values of the elasticity of substitution σ and the inverse of the Frisch elasticity of labor supply φ.[16] In other words, for most parameterizations it seems reasonable to assume that the derivative would still be negative.

We repeat the same exercise by setting a lower domestic share of $\xi = 0.82$ and a higher foreign import share of $\xi^{*} = 0.18$ and plot the positive and negative regions in Figure A1. The size of the region where the partial derivative is positive is sensitive to the parameterization of the shares and larger than it would have been under our benchmark parameterization. In fact, for plausible values of the inverse of the elasticity of intertemporal substitution, $\gamma > 0$, and the inverse of the Frisch elasticity of labor supply, $\varphi > 0$, we find that the partial derivative turns positive only if we are willing to assume a low enough elasticity of substitution between the Home and Foreign bundles of varieties, $\sigma > 0$, well below one.

It has often been argued that the import share in the U.S. is relatively small compared with that of other countries and that it has not increased by that much. However, calculations such as the ones we have conducted so far say little about what happens to the coefficients of the domestic Phillips curve if, in fact, the rest of the world is the one that becomes more open toward the Home economy. Can we still claim that the limited size of the import share in the U.S. is insulating us from foreign forces as well as in the past?

To assess that point, we can take the partial derivative of the slope coefficient of the domestic Phillips curve with respect to the share of imports of Home goods in the Foreign consumption basket, $0 < \xi^{*} < 1$.

[16] This continues to be true at values of γ equal to 1 and 3.

We obtain that

$$
\begin{aligned}
\frac{\partial \Psi_{\pi,x^*}}{\partial \xi^*} &= \gamma \left(\frac{\left(\Gamma_n^*\right)\left(\Gamma_d\right) - \left(\Gamma_n\right)\left(\Gamma_d^*\right)}{\left(\Gamma_d\right)^2} \right), \\
\Gamma_n &\equiv \sigma\left(1-\xi\right) + \left(\sigma - \frac{1}{\gamma}\right)\left(\xi - \xi^*\right)\left(1-\eta\right) = \begin{cases} < 0 \text{ if } \sigma < \left(\frac{\frac{1}{\gamma}(\xi - \xi^*)(1-n)\xi^*}{(1-n)\xi^*(1-\xi^*) + n\xi(1-\xi)} \right) \text{ and } \xi > \xi^*, \\ > 0 \text{ otherwise,} \end{cases} \\
\Gamma_d &\equiv \sigma - \left(\sigma - \frac{1}{\gamma}\right)\left(\xi - \xi^*\right)\left(\eta - \eta^*\right) > 0, \\
\Gamma_n^* &\equiv \left(\sigma - \frac{1}{\gamma}\right) \left(\frac{\left(1-n\right)\left(n\xi\left(\xi - \xi^*\right) - \left(\left(1-n\right)\xi^* + n\xi\right)\xi^*\right)}{\left(n\xi + \left(1-n\right)\xi^*\right)^2} \right) \\
&= \begin{cases} > 0 \text{ if } \sigma > \frac{1}{\gamma} \text{ and } \xi^* < \left(\frac{\sqrt{n}}{\sqrt{n}+1}\right) \text{ and } \xi > \left(\frac{\sqrt{n}+1}{\sqrt{n}}\right)\xi^*, \\ > 0 \text{ if } \sigma < \frac{1}{\gamma} \text{ and } \xi < \left(\frac{\sqrt{n}+1}{\sqrt{n}}\right)\xi^*, \\ < 0 \text{ otherwise,} \end{cases} \\
\Gamma_d^* &\equiv \left(\sigma - \frac{1}{\gamma}\right)\left(\xi - \xi^*\right) \left(\frac{n\left(1-n\right)\left(\left(1 + n\left(1-2\xi\right)\right)\xi + \left(1-n\right)\left(1-2\xi\right)\xi^*\right)}{\left(\left(n\xi + \left(1-n\right)\xi^*\right)^2 - n\xi - \left(1-n\right)\xi^*\right)^2} \right) \\
&= \begin{cases} > 0 \text{ if } \left(\sigma - \frac{1}{\gamma}\right)\left(\xi - \xi^*\right) > 0, \\ < 0 \text{ otherwise,} \end{cases}
\end{aligned}
$$

whose sign is—once again—rather ambiguous.

To illustrate the fact that the sign of this partial derivative can be either positive or negative, we numerically calculate the derivative $\frac{\partial \Psi_{\pi,x^*}}{\partial \xi^*}$ under our benchmark parameterization but allowing for the elasticity of substitution between the Home and Foreign bundles of varieties, $\sigma > 0$, and the inverse of the elasticity of intertemporal substitution, $\gamma > 0$, to span a range of values in their parameter space. In Figure A2 countries are assumed to be of equal size, i.e., $n = \frac{1}{2}$, and we evaluate the Home good shares, ξ and ξ^*, at 0.94 and 0.06, respectively, as in Chari, Kehoe, and McGrattan (2002). We find that—under a conventional parameterization of the model—we are likely to observe a positive partial derivative in response to a marginal increase in the share of domestic goods in the Foreign consumption basket, i.e., $\frac{\partial \Psi_{\pi,x^*}}{\partial \xi^*} > 0$. That is, there is a wide range of values of $\sigma > 0$ and $\gamma > 0$ for which the partial derivative is positive.

In Figure A3 we instead evaluate the Home good shares, ξ and ξ^*, at 0.82 and 0.18, respectively. Now the range of values of $\sigma > 0$ and $\gamma > 0$ for which the derivative is positive is a lot smaller than it is under the parameterization of the shares in Figure A2. The interpretation of this result suggests that one should not rule out the possibility that the slope coefficient on the foreign output gap may increase whenever the rest of the world becomes more open and purchases more Home goods (ξ^* increases), even if the degree of domestic openness measured by ξ remains unchanged. However, whether this partial derivative takes a positive sign or not depends critically on how open the Home country is (how large $(1-\xi)$ is) to begin with.

Figure A1: Magenta Shaded Area Shows Values of σ and φ for Which $\partial\Psi_{\pi,x^*}/\partial\xi > 0$ (Under High Import Shares)

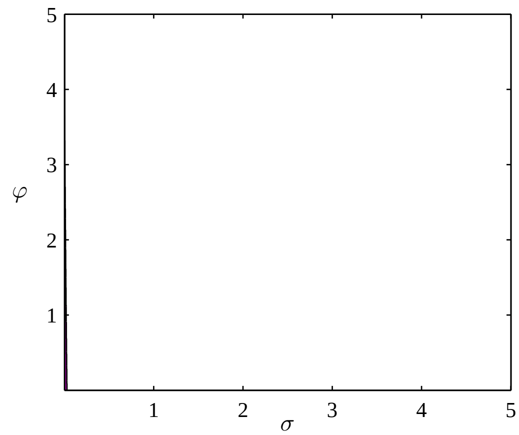


Figure A2: Magenta Shaded Area Shows Values of σ and γ for Which $\partial\Psi_{\pi,x^*}/\partial\xi^* > 0$ (Under Benchmark Import Shares)

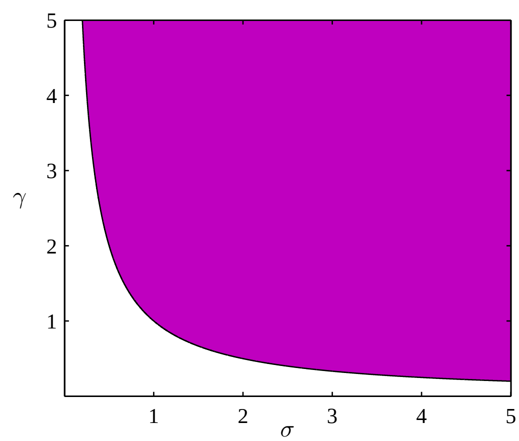


Figure A3: Magenta Shaded Area Shows Values of σ and γ for Which $\partial\Psi_{\pi,x^*}/\partial\xi^* > 0$ (Under High Import Shares)

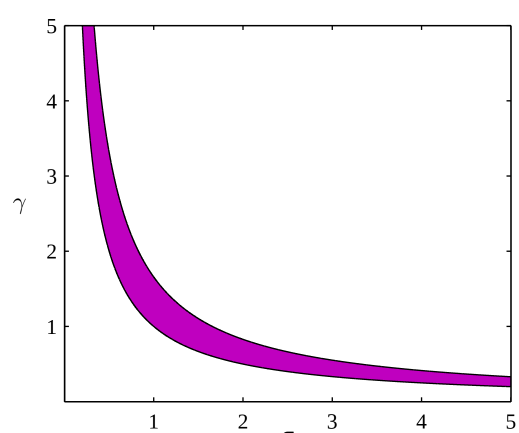


Table A1 (a) - Notation	
	Home
	Real variables
Output of Home variety h	$Y_t(h)$
Potential output of Home variety h	$\overline{Y}_t(h)$
Labor demand of Home variety h	$L_t(h)$
Aggregate labor supply	nL_t
Consumption of Home variety h	$C_t(h)$
Consumption of Foreign variety f	$C_t(f)$
	Nominal variables
Price of Home variety h	$P_t(h)$
Price of Foreign variety f	$P_t(f)$
Re-optimizing price of Home variety h	$\widetilde{P}_t(h)$
Re-optimizing price of Foreign variety f	$\widetilde{P}_t(f)$
Home (contingent) bonds	$B^H\left(\omega_{t+1} \mid \omega^t\right)$
Foreign (contingent) bonds	$B^F\left(\omega_{t+1} \mid \omega^t\right)$
Price of (contingent) bonds	$Q\left(\omega_{t+1} \mid \omega^t\right)$
Nominal exchange rate	S_t
Profits from Home variety h	$\Pi_t(h)$
Nominal wages	W_t
Lump sum tax	T_t
Labor wage tax (or subsidy)	ϕ_t
	Shocks
Productivity shocks	A_t
Monetary policy shocks	M_t
	Useful definitions
Real exchange rate	$RS_t \equiv \frac{S_t P_t^*}{P_t}$
Terms of trade	$ToT_t \equiv \frac{P_t^F}{S_t P_t^{H*}}$
Marginal costs (pre-tax)	$MC_t(h) = MC_t \equiv \frac{W_t}{A_t}$
Marginal costs (after-tax)	$MC_t^{\phi} \equiv (1+\phi_t) MC_t$
Aggregate profits	$n\Pi_t \equiv \int_0^n \Pi_t(h)\, dh$ $= \int_0^n \left[\begin{array}{c} P_t(h)\, nC_t(h) + S_t P_t^*(h)(1-n) C_t^*(h) - \\ -(1+\phi_t) W_t L_t(h) \end{array} \right] dh$
Aggregate output	$nY_t \equiv \int_0^n Y_t(h)\, dh$
Aggregate potential output	$n\overline{Y}_t \equiv \int_0^n \overline{Y}_t(h)\, dh$
SDF	$m_{t,\tau} \equiv \beta^{\tau} \left(\frac{C_{t+\tau}}{C_t}\right)^{-\gamma} \frac{P_t}{P_{t+\tau}}$
Nominal interest rates	$1 + i_t \equiv \frac{1}{\int_{\omega_{t+1}\in\Omega} Q\left(\omega_{t+1} \mid \omega^t\right)}$
Conditional p.d.f.	$\mu\left(\omega_{t+1} \mid \omega^t\right) \; \forall \omega_{t+1} \in \Omega$

Table A1 (b) - Notation

	Foreign
	Real variables
Output of Foreign variety f	$Y_t^*(f)$
Potential output of Foreign variety f	$\overline{Y}_t^*(f)$
Labor demand of Foreign variety f	$L_t^*(f)$
Aggregate labor supply	$(1-n)\,L_t^*$
Consumption of Home variety h	$C_t^*(h)$
Consumption of Foreign variety f	$C_t^*(f)$
	Nominal variables
Price of Home variety h	$P_t^*(h)$
Price of Foreign variety f	$P_t^*(f)$
Re-optimizing price of Home variety h	$\widetilde{P}_t^*(h)$
Re-optimizing price of Foreign variety f	$\widetilde{P}_t^*(f)$
Home (contingent) bonds	$B^{H*}\left(\omega_{t+1} \mid \omega^t\right)$
Foreign (contingent) bonds	$B^{F*}\left(\omega_{t+1} \mid \omega^t\right)$
Price of (contingent) bonds	$Q^*\left(\omega_{t+1} \mid \omega^t\right)$
Nominal exchange rate	$\frac{1}{S_t}$
Profits from Foreign variety f	$\Pi_t^*(f)$
Nominal wages	W_t^*
Lump sum tax	T_t^*
Labor wage tax (or subsidy)	ϕ_t^*
	Shocks
Productivity shocks	A_t^*
Monetary policy shocks	M_t^*
	Useful definitions
Real exchange rate	$\frac{1}{RS_t}$
Terms of trade	$\frac{1}{ToT_t}$
Marginal costs (pre-tax)	$MC_t^*(f) = MC_t^* \equiv \frac{W_t^*}{A_t^*}$
Marginal costs (after-tax)	$MC_t^{\phi*} \equiv (1+\phi_t^*)\,MC_t^*$
Aggregate profits	$(1-n)\,\Pi_t^* \equiv \int_n^1 \Pi_t^*(f)\,df$ $= \int_n^1 \left[\begin{array}{c} \frac{1}{S_t} P_t(f)\, nC_t(f) + P_t^*(f)\,(1-n)\,C_t^*(f) - \\ -(1+\phi_t^*)\,W_t^* L_t^*(f) \end{array} \right] df$
Aggregate output	$(1-n)\,Y_t^* \equiv \int_n^1 Y_t^*(f)\,df$
Aggregate potential output	$(1-n)\,\overline{Y}_t^* \equiv \int_n^1 \overline{Y}_t^*(f)\,df$
SDF	$m_{t,\tau}^* \equiv \beta \left(\frac{C_{t+\tau}^*}{C_t^*}\right)^{-\gamma} \frac{P_t^*}{P_{t+\tau}^*}$
Nominal interest rates	$1+i_t^* \equiv \frac{1}{\int_{\omega_{t+1}\in\Omega} Q^*\left(\omega_{t+1} \mid \omega^t\right)}$
Conditional p.d.f.	$\mu\left(\omega_{t+1} \mid \omega^t\right)\ \forall \omega_{t+1} \in \Omega$

Table A2 (a) - Firms

	Home
	Optimization (potential, flexible prices)*
Technology	$Y_t(h) = A_t L_t(h)$
Profits of firm h	$\left(nC_t^d(h) + (1-n)C_t^{d*}(h)\right)\left(P_t(h) - MC_t^{\phi}\right)$
Aggreg. demand constraint	$nC_t^d(h) + (1-n)C_t^{d*}(h)$ $= n\frac{\xi}{n}\left(\frac{P_t(h)}{P_t^H}\right)^{-\theta}\left(\frac{P_t^H}{P_t}\right)^{-\sigma} C_t + ...$ $(1-n)\frac{\xi^*}{n}\left(\frac{P_t(h)}{P_t^H}\right)^{-\theta}\left(\frac{P_t^{H*}}{P_t^*}\right)^{-\sigma} C_t^*$
	Equilibrium conditions (potential, flexible prices)*
Optimal pricing of firm h	$P_t(h) = \frac{\theta}{\theta-1} MC_t^{\phi}$ $P_t^*(h) = \frac{1}{S_t} P_t(h)$
Potential output of firm h	$\overline{Y}_t(h) = nC_t^d(h) + (1-n)C_t^{d*}(h)$
	Optimization (PCP case)
Technology	$Y_t(h) = A_t L_t(h)$
Discounted profits of h	$\mathbb{E}_t \sum_{\tau=0}^{+\infty} \alpha^{\tau} m_{t,\tau}\left[\widetilde{Y}_{t,t+\tau}^d(h)\left(\widetilde{P}_t(h) - MC_{t+\tau}^{\phi}\right)\right]$
Aggreg. demand constraint	$\widetilde{Y}_{t,t+\tau}^d(h) \equiv n\widetilde{C}_{t,t+\tau}^d(h) + (1-n)\widetilde{C}_{t,t+\tau}^{d*}(h)$ $= n\frac{\xi}{n}\left(\frac{\widetilde{P}_t(h)}{P_{t+\tau}^H}\right)^{-\theta}\left(\frac{P_{t+\tau}^H}{P_{t+\tau}}\right)^{-\sigma} C_{t+\tau} + ...$ $(1-n)\frac{\xi^*}{n}\left(\frac{\widetilde{P}_t(h)}{P_{t+\tau}^H}\right)^{-\theta}\left(\frac{P_{t+\tau}^{H*}}{P_{t+\tau}^*}\right)^{-\sigma} C_{t+\tau}^*$
	Equilibrium conditions (PCP case)
Optimal pricing of firm h	$\widetilde{P}_t(h) = \frac{\theta}{\theta-1}\frac{\sum_{\tau=0}^{+\infty}\alpha^{\tau}\mathbb{E}_t\left[m_{t,\tau}\widetilde{Y}_{t,t+\tau}^d(h) MC_{t+\tau}^{\phi}\right]}{\sum_{\tau=0}^{+\infty}\alpha^{\tau}\mathbb{E}_t\left[m_{t,\tau}\widetilde{Y}_{t,t+\tau}^d(h)\right]}$ $\widetilde{P}_t^*(h) = \frac{1}{S_t}\widetilde{P}_t(h)$
	Optimization (LCP case)
Technology	$Y_t(h) = A_t L_t(h)$
Discounted profits of h	$\mathbb{E}_t \sum_{\tau=0}^{+\infty} \alpha^{\tau} m_{t,\tau}\left[\begin{array}{c} n\widetilde{C}_{t,t+\tau}^d(h)\left(\widetilde{P}_t(h) - MC_{t+\tau}^{\phi}\right) + ... \\ (1-n)\widetilde{C}_{t,t+\tau}^{d*}(h)\left(S_{t+\tau}\widetilde{P}_t^*(h) - MC_{t+\tau}^{\phi}\right) \end{array}\right]$
Home demand constraint	$\widetilde{C}_{t,t+\tau}^d(h) = \frac{\xi}{n}\left(\frac{\widetilde{P}_t(h)}{P_{t+\tau}^H}\right)^{-\theta}\left(\frac{P_{t+\tau}^H}{P_{t+\tau}}\right)^{-\sigma} C_{t+\tau}$
Foreign demand constraint	$\widetilde{C}_{t,t+\tau}^{d*}(h) = \frac{\xi^*}{n}\left(\frac{\widetilde{P}_t^*(h)}{P_{t+\tau}^{H*}}\right)^{-\theta}\left(\frac{P_{t+\tau}^{H*}}{P_{t+\tau}^*}\right)^{-\sigma} C_{t+\tau}^*$
	Equilibrium conditions (LCP case)
Optimal pricing of firm h	$\widetilde{P}_t(h) = \frac{\theta}{\theta-1}\frac{\sum_{\tau=0}^{+\infty}\alpha^{\tau}\mathbb{E}_t\left[m_{t,\tau}\widetilde{C}_{t,t+\tau}^d(h) MC_{t+\tau}^{\phi}\right]}{\sum_{\tau=0}^{+\infty}\alpha^{\tau}\mathbb{E}_t\left[m_{t,\tau}\widetilde{C}_{t,t+\tau}^d(h)\right]}$ $\widetilde{P}_t^*(h) = \frac{\theta}{\theta-1}\frac{\sum_{\tau=0}^{+\infty}\alpha^{\tau}\mathbb{E}_t\left[m_{t,\tau}\widetilde{C}_{t,t+\tau}^{d*}(h) MC_{t+\tau}^{\phi}\right]}{\sum_{\tau=0}^{+\infty}\alpha^{\tau}\mathbb{E}_t\left[m_{t,\tau}\widetilde{C}_{t,t+\tau}^{d*}(h) S_{t+\tau}\right]}$

* In a slight abuse of notation, we use the same symbols for the variables under the potential scenario with flexible prices as for the full model with nominal rigidities. We only distinguish potential output with an upper bar since these variables are key to defining the output gaps in the model.

Table A2 (b) - Firms

	Foreign
	Optimization (potential, flexible prices)*
Technology	$Y_t^*(f) = A_t^* L_t^*(f)$
Profits of firm f	$\left(nC_t^d(f) + (1-n)\,C_t^{d*}(f)\right)\left(P_t^*(f) - MC_t^{\phi *}\right)$
Aggreg. demand constraint	$nC_t^d(f) + (1-n)\,C_t^{d*}(f)$ $= n\frac{1-\xi}{1-n}\left(\frac{P_t^*(f)}{P_t^{F*}}\right)^{-\theta}\left(\frac{P_t^F}{P_t}\right)^{-\sigma} C_t + ...$ $(1-n)\,\frac{1-\xi^*}{1-n}\left(\frac{P_t^*(f)}{P_t^{F*}}\right)^{-\theta}\left(\frac{P_t^{F*}}{P_t^*}\right)^{-\sigma} C_t^*$
	Equilibrium conditions (potential, flexible prices)*
Optimal pricing of firm f	$P_t^*(f) = \frac{\theta}{\theta-1} MC_t^{\phi *}$ $P_t(f) = S_t P_t^*(f)$
Potential output of firm f	$\overline{Y}_t^*(f) = nC_t^d(f) + (1-n)\,C_t^{d*}(f)$
	Optimization (PCP case)
Technology	$Y_t^*(f) = A_t^* L_t^*(f)$
Discounted profits f	$\mathbb{E}_t \sum_{\tau=0}^{+\infty} \alpha^\tau m_{t,\tau}^* \left[\widetilde{Y}_{t,t+\tau}^{d*}(f)\,(\widetilde{P}_t^*(f) - MC_{t+\tau}^{\phi *})\right]$
Aggreg. demand constraint	$\widetilde{Y}_{t,t+\tau}^{d*}(f) \equiv n\widetilde{C}_{t,t+\tau}^d(f) + (1-n)\,\widetilde{C}_{t,t+\tau}^{d*}(f)$ $= n\frac{1-\xi}{1-n}\left(\frac{\widetilde{P}_t^*(f)}{P_{t+\tau}^{F*}}\right)^{-\theta}\left(\frac{P_{t+\tau}^F}{P_{t+\tau}}\right)^{-\sigma} C_{t+\tau} + ...$ $(1-n)\,\frac{1-\xi^*}{1-n}\left(\frac{\widetilde{P}_t^*(f)}{P_{t+\tau}^{F*}}\right)^{-\theta}\left(\frac{P_{t+\tau}^{F*}}{P_{t+\tau}^*}\right)^{-\sigma} C_{t+\tau}^*$
	Equilibrium conditions (PCP case)
Optimal pricing of firm f	$\widetilde{P}_t^*(f) = \frac{\theta}{\theta-1}\frac{\sum_{\tau=0}^{+\infty}\alpha^\tau \mathbb{E}_t\left[m_{t,\tau}^* \widetilde{Y}_{t,t+\tau}^{d*}(f) MC_{t+\tau}^{\phi *}\right]}{\sum_{\tau=0}^{+\infty}\alpha^\tau \mathbb{E}_t\left[m_{t,\tau}^* \widetilde{Y}_{t,t+\tau}^{d*}(f)\right]}$ $\widetilde{P}_t(f) = S_t \widetilde{P}_t^*(f)$
	Optimization (LCP case)
Technology	$Y_t^*(f) = A_t^* L_t^*(f)$
Discounted profits f	$\mathbb{E}_t \sum_{\tau=0}^{+\infty} \alpha^\tau m_{t,\tau}^* \begin{bmatrix} n\widetilde{C}_{t,t+\tau}^d(f)\left(\frac{1}{S_{t+\tau}}\widetilde{P}_t(f) - MC_{t+\tau}^{\phi *}\right) + ... \\ (1-n)\,\widetilde{C}_{t,t+\tau}^{d*}(f)\left(\widetilde{P}_t^*(f) - MC_{t+\tau}^{\phi *}\right) \end{bmatrix}$
Home demand constraint	$\widetilde{C}_{t,t+\tau}^d(f) = \frac{1-\xi}{1-n}\left(\frac{\widetilde{P}_t(f)}{P_{t+\tau}^F}\right)^{-\theta}\left(\frac{P_{t+\tau}^F}{P_{t+\tau}}\right)^{-\sigma} C_{t+\tau}$
Foreign demand constraint	$\widetilde{C}_{t,t+\tau}^{d*}(f) = \frac{1-\xi^*}{1-n}\left(\frac{\widetilde{P}_t^*(f)}{P_{t+\tau}^{F*}}\right)^{-\theta}\left(\frac{P_{t+\tau}^{F*}}{P_{t+\tau}^*}\right)^{-\sigma} C_{t+\tau}^*$
	Equilibrium conditions (LCP case)
Optimal pricing of firm f	$\widetilde{P}_t^*(f) = \frac{\theta}{\theta-1}\frac{\sum_{\tau=0}^{+\infty}\alpha^\tau \mathbb{E}_t\left[m_{t,\tau}^* \widetilde{C}_{t,t+\tau}^{d*}(f) MC_{t+\tau}^{\phi *}\right]}{\sum_{\tau=0}^{+\infty}\alpha^\tau \mathbb{E}_t\left[m_{t,\tau}^* \widetilde{C}_{t,t+\tau}^{d*}(f)\right]}$ $\widetilde{P}_t(f) = \frac{\theta}{\theta-1}\frac{\sum_{\tau=0}^{+\infty}\alpha^\tau \mathbb{E}_t\left[m_{t,\tau}^* \widetilde{C}_{t,t+\tau}^{d}(f) MC_{t+\tau}^{\phi *}\right]}{\sum_{\tau=0}^{+\infty}\alpha^\tau \mathbb{E}_t\left[m_{t,\tau}^* \widetilde{C}_{t,t+\tau}^{d}(f)\frac{1}{S_{t+\tau}}\right]}$

* In a slight abuse of notation, we use the same symbols for the variables under the potential scenario with flexible prices as for the full model with nominal rigidities. We only distinguish potential output with an upper bar since these variables are key to defining the output gaps in the model.

Table A3 (a) - Households	
	Home
	Optimization
Lifetime utility	$\mathbb{E}_t \sum_{\tau=0}^{+\infty} \beta^{\tau} \left[\frac{1}{1-\gamma} (C_{t+\tau})^{1-\gamma} - \frac{1}{1+\varphi} (L_{t+\tau})^{1+\varphi} \right]$
Aggregate consumption	$C_t \equiv \left[\xi^{\frac{1}{\sigma}} \left(C_t^H \right)^{\frac{\sigma-1}{\sigma}} + (1-\xi)^{\frac{1}{\sigma}} \left(C_t^F \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$
Bundle of Home varieties	$C_t^H \equiv \left[\left(\frac{1}{n} \right)^{\frac{1}{\theta}} \int_0^n C_t(h)^{\frac{\theta-1}{\theta}} dh \right]^{\frac{\theta}{\theta-1}}$
Bundle of Foreign varieties	$C_t^F \equiv \left[\left(\frac{1}{1-n} \right)^{\frac{1}{\theta}} \int_n^1 C_t(f)^{\frac{\theta-1}{\theta}} df \right]^{\frac{\theta}{\theta-1}}$
Budget constraint	$P_t C_t + \int_{\omega_{t+1} \in \Omega} Q\left(\omega_{t+1} \mid \omega^t\right) B^H \left(\omega_{t+1} \mid \omega^t\right) +$ $+ S_t \int_{\omega_{t+1} \in \Omega} Q^* \left(\omega_{t+1} \mid \omega^t\right) B^F \left(\omega_{t+1} \mid \omega^t\right)$ $\leq \frac{1}{S_t} B^H \left(\omega_t \mid \omega^{t-1}\right) + B^F \left(\omega_t \mid \omega^{t-1}\right) + W_t L_t + \Pi_t - T_t$
	Equilibrium conditions
CPI	$P_t = \left[\xi \left(P_t^H \right)^{1-\sigma} + (1-\xi) \left(P_t^F \right)^{1-\sigma} \right]^{\frac{1}{1-\sigma}}$
Home bundle price subindex	$P_t^H = \left[\frac{1}{n} \int_0^n P_t(h)^{1-\theta} dh \right]^{\frac{1}{1-\theta}}$ $= \left[\alpha \left(P_{t-1}^H \right)^{1-\theta} + (1-\alpha) \left(\widetilde{P}_t(h) \right)^{1-\theta} \right]^{\frac{1}{1-\theta}}$
Foreign bundle price subindex	$P_t^F = \left[\frac{1}{1-n} \int_n^1 P_t(f)^{1-\theta} df \right]^{\frac{1}{1-\theta}}$ $= \left[\alpha \left(P_{t-1}^F \right)^{1-\theta} + (1-\alpha) \left(\widetilde{P}_t(f) \right)^{1-\theta} \right]^{\frac{1}{1-\theta}}$
Demand of Home variety h	$C_t(h) = \frac{1}{n} \left(\frac{P_t(h)}{P_t^H} \right)^{-\theta} C_t^H = \frac{\xi}{n} \left(\frac{P_t(h)}{P_t^H} \right)^{-\theta} \left(\frac{P_t^H}{P_t} \right)^{-\sigma} C_t$
Demand of Foreign variety f	$C_t(f) = \frac{1}{1-n} \left(\frac{P_t(f)}{P_t^F} \right)^{-\theta} C_t^F = \frac{1-\xi}{1-n} \left(\frac{P_t(f)}{P_t^F} \right)^{-\theta} \left(\frac{P_t^F}{P_t} \right)^{-\sigma} C_t$
Labor supply equation	$\frac{W_t}{P_t} = (C_t)^{\gamma} (L_t)^{\varphi}$
Intert. efficiency condition	$Q\left(\omega_{t+1} \mid \omega^t\right) = \beta \left(\frac{C(\omega_{t+1})}{C(\omega_t)} \right)^{-\gamma} \frac{P(\omega_t)}{P(\omega_{t+1})} \mu \left(\omega_{t+1} \mid \omega^t\right)$
Perfect risk-sharing condition	$RS_t = \left(\frac{C_t^*}{C_t} \right)^{-\gamma}$

Table A3 (b) - Households	
	Foreign
	Optimization
Lifetime utility	$\mathbb{E}_t \sum_{\tau=0}^{+\infty} \beta^{\tau} \left[\frac{1}{1-\gamma} \left(C_{t+\tau}^{*} \right)^{1-\gamma} - \frac{1}{1+\varphi} \left(L_{t+\tau}^{*} \right)^{1+\varphi} \right]$
Aggregate consumption	$C_t^{*} \equiv \left[(\xi^{*})^{\frac{1}{\sigma}} \left(C_t^{H*} \right)^{\frac{\sigma-1}{\sigma}} + (1-\xi^{*})^{\frac{1}{\sigma}} \left(C_t^{F*} \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$
Bundle of Home varieties	$C_t^{H*} \equiv \left[\left(\frac{1}{n} \right)^{\frac{1}{\theta}} \int_0^n C_t^{*}(h)^{\frac{\theta-1}{\theta}} dh \right]^{\frac{\theta}{\theta-1}}$
Bundle of Foreign varieties	$C_t^{F*} \equiv \left[\left(\frac{1}{1-n} \right)^{\frac{1}{\theta}} \int_n^1 C_t^{*}(f)^{\frac{\theta-1}{\theta}} df \right]^{\frac{\theta}{\theta-1}}$
Budget constraint	$P_t^{*} C_t^{*} + \frac{1}{S_t} \int_{\omega_{t+1} \in \Omega} Q\left(\omega_{t+1} \mid \omega^t \right) B^{H*}\left(\omega_{t+1} \mid \omega^t \right) +$ $+ \int_{\omega_{t+1} \in \Omega} Q^{*}\left(\omega_{t+1} \mid \omega^t \right) B^{F*}\left(\omega_{t+1} \mid \omega^t \right)$ $\leq \frac{1}{S_t} B^{H*}\left(\omega_t \mid \omega^{t-1} \right) + B^{F*}\left(\omega_t \mid \omega^{t-1} \right) + W_t^{*} L_t^{*} + \Pi_t^{*} - T_t^{*}$
	Equilibrium conditions
CPI	$P_t^{*} = \left[\xi^{*} \left(P_t^{H*} \right)^{1-\sigma} + (1-\xi^{*}) \left(P_t^{F*} \right)^{1-\sigma} \right]^{\frac{1}{1-\sigma}}$
Home bundle price subindex	$P_t^{H*} = \left[\frac{1}{n} \int_0^n P_t^{*}(h)^{1-\theta} dh \right]^{\frac{1}{1-\theta}}$ $= \left[\alpha \left(P_{t-1}^{H*} \right)^{1-\theta} + (1-\alpha) \left(\widetilde{P}_t^{*}(h) \right)^{1-\theta} \right]^{\frac{1}{1-\theta}}$
Foreign bundle price subindex	$P_t^{F*} = \left[\frac{1}{1-n} \int_n^1 P_t^{*}(f)^{1-\theta} df \right]^{\frac{1}{1-\theta}}$ $= \left[\alpha \left(P_{t-1}^{F*} \right)^{1-\theta} + (1-\alpha) \left(\widetilde{P}_t^{*}(f) \right)^{1-\theta} \right]^{\frac{1}{1-\theta}}$
Demand of Home variety h	$C_t^{*}(h) = \frac{1}{n} \left(\frac{P_t^{*}(h)}{P_t^{H*}} \right)^{-\theta} C_t^{H*} = \frac{\xi^{*}}{n} \left(\frac{P_t^{*}(h)}{P_t^{H*}} \right)^{-\theta} \left(\frac{P_t^{H*}}{P_t^{*}} \right)^{-\sigma} C_t^{*}$
Demand of Foreign variety f	$C_t^{*}(f) = \frac{1}{1-n} \left(\frac{P_t^{*}(f)}{P_t^{F*}} \right)^{-\theta} C_t^{F*} = \frac{1-\xi^{*}}{1-n} \left(\frac{P_t^{*}(f)}{P_t^{F*}} \right)^{-\theta} \left(\frac{P_t^{F*}}{P_t^{*}} \right)^{-\sigma} C_t^{*}$
Labor supply equation	$\frac{W_t^{*}}{P_t^{*}} = \left(C_t^{*} \right)^{\gamma} \left(L_t^{*} \right)^{\varphi}$
Intert. efficiency condition	$Q^{*}\left(\omega_{t+1} \mid \omega^t \right) = \beta \left(\frac{C^{*}(\omega_{t+1})}{C^{*}(\omega_t)} \right)^{-\gamma} \frac{P^{*}(\omega_t)}{P^{*}(\omega_{t+1})} \mu\left(\omega_{t+1} \mid \omega^t \right)$
Perfect risk-sharing condition	$RS_t = \left(\frac{C_t^{*}}{C_t} \right)^{-\gamma}$

Table A4 (a) - Policy rules, market clearing conditions, and shock processes	
	Home
	Policy rules
Fiscal policy	$\phi_t = \frac{-1}{\theta}$
Government budget constraint	$n\left[T_t + \phi_t W_t L_t\right] = 0$
Monetary policy (Taylor rule)	$1 + i_t = \beta^{\rho-1} M_t \left(1 + i_{t-1}\right)^{\rho} \left[\left(\frac{P_t}{P_{t-1}}\right)^{\psi_\pi} \left(\frac{Y_t}{\overline{Y}_t}\right)^{\psi_x}\right]^{1-\rho}$
	Market clearing conditions
Home variety h	$Y_t\left(h\right) = nC_t\left(h\right) + \left(1-n\right) C_t^*\left(h\right)$
Home labor market	$nL_t = \int_0^n L_t\left(h\right) dh$
Home (contingent) bonds	$nB^H\left(\omega_{t+1} \mid \omega^t\right) + \left(1-n\right) B^{H*}\left(\omega_{t+1} \mid \omega^t\right) = 0,\ \forall \omega_{t+1} \in \Omega$
	Shock processes
Productivity shock	$A_t = \left(A\right)^{1-\delta_a} \left(A_{t-1}\right)^{\delta_a} e^{\varepsilon_t^a}$
Monetary policy shock	$M_t = \left(M\right)^{1-\delta_m} \left(M_{t-1}\right)^{\delta_m} e^{\varepsilon_t^m}$

Table A4 (b) - Policy rules, market clearing conditions, and shock processes	
	Foreign
	Policy rules
Fiscal policy	$\phi_t^* = \frac{-1}{\theta}$
Government budget constraint	$\left(1-n\right)\left[T_t^* + \phi_t^* W_t^* L_t^*\right] = 0$
Monetary policy (Taylor rule)	$1 + i_t^* = \beta^{\rho-1} M_t^* \left(1 + i_{t-1}^*\right)^{\rho} \left[\left(\frac{P_t^*}{P_{t-1}^*}\right)^{\psi_\pi} \left(\frac{Y_t^*}{\overline{Y}_t^*}\right)^{\psi_x}\right]^{1-\rho}$
	Market clearing conditions
Foreign variety f	$Y_t^*\left(f\right) = nC_t\left(f\right) + \left(1-n\right) C_t^*\left(f\right)$
Foreign labor market	$\left(1-n\right) L_t^* = \int_n^1 L_t^*\left(f\right) df$
Foreign (contingent) bonds	$nB^F\left(\omega_{t+1} \mid \omega^t\right) + \left(1-n\right) B^{F*}\left(\omega_{t+1} \mid \omega^t\right) = 0,\ \forall \omega_{t+1} \in \Omega$
	Shock processes
Productivity shock	$A_t^* = \left(A^*\right)^{1-\delta_a} \left(A_{t-1}^*\right)^{\delta_a} e^{\varepsilon_t^{a*}}$
Monetary policy shock	$M_t^* = \left(M^*\right)^{1-\delta_m} \left(M_{t-1}^*\right)^{\delta_m} e^{\varepsilon_t^{m*}}$

Table A5 - Model parameters

Structural parameters	
Intertemporal discount factor	$0 < \beta < 1$
Inverse of the intertemporal elasticity of substitution	$\gamma > 0$
Inverse of the Frisch elasticity of labor supply	$\varphi > 0$
Elasticity of substitution across varieties within a country	$\theta > 1$
Elasticity of substitution between Home and Foreign bundles	$\sigma > 0$
Share of Home goods in the Home basket	$0 < \xi < 1$
Share of Home goods in the Foreign basket	$0 < \xi^* < 1$
Home population size, Mass of Home varieties	$0 < n < 1$
Foreign population size, Mass of Foreign varieties	$0 < 1 - n < 1$
Calvo price stickiness parameter	$0 < \alpha < 1$
Monetary policy parameters	
Monetary policy inertia	$0 < \rho < 1$
Sensitivity to deviations from inflation target	$\psi_\pi > 1$
Sensitivity to deviations from potential output target	$\psi_x > 0$
Shock parameters	
Persistence of the productivity shock	$-1 < \delta_a < 1$
Volatility of the productivity shock	$\sigma_a > 0$
Correl. between Home and Foreign product. innovations	$-1 < \rho_{\varepsilon^a, \varepsilon^{a*}} < 1$
Persistence of the monetary policy shock	$-1 < \delta_m < 1$
Volatility of the monetary policy shock	$\sigma_m > 0$
Correl. between Home and Foreign monetary innovations	$-1 < \rho_{\varepsilon^m, \varepsilon^{m*}} < 1$

Table A6 - Workhorse log-linearized New Open-Economy Macro model (under PCP)

	Home Economy
Output gap	$\gamma\left(\mathbb{E}_t\left[\widehat{x}_{t+1}\right]-\widehat{x}_t\right) \approx \Lambda_{x,i}[(\widehat{i}_t-\widehat{\bar{i}}_t)-\mathbb{E}_t[\widehat{\pi}_{t+1}]]-\Lambda_{x,i^*}[(\widehat{i}^*_t-\widehat{\bar{i}}^*_t)-\mathbb{E}_t[\widehat{\pi}^*_{t+1}]]$
Phillips curve	$\widehat{\pi}_t \approx \beta\mathbb{E}_t\left(\widehat{\pi}_{t+1}\right)+\left(\frac{(1-\alpha)(1-\beta\alpha)}{\alpha}\right)\left[\Psi_{\pi,x}\widehat{x}_t+\Psi_{\pi,x^*}\widehat{x}^*_t\right]$
Monetary policy	$\widehat{i}_t \approx \rho_i\widehat{i}_{t-1}+(1-\rho_i)\left[\psi_\pi\widehat{\pi}_t+\psi_x\widehat{x}_t\right]+\widehat{\varepsilon}^m_t$
Natural rate	$\widehat{\bar{i}}_t \approx \left(\frac{1+\varphi}{\gamma+\varphi}\right)\left[\Theta_{i,a}\mathbb{E}_t\left[\Delta\widehat{a}_{t+1}\right]+\Theta_{i,a^*}\mathbb{E}_t\left[\Delta\widehat{a}^*_{t+1}\right]\right]$
Potential output	$\widehat{\bar{y}}_t \approx \left(\frac{1+\varphi}{\gamma+\varphi}\right)\left[\widetilde{\lambda}_a\widehat{a}_t+\widetilde{\lambda}_{a^*}\widehat{a}^*_t\right]$
Productivity	$\widehat{a}_t \approx \delta_a\widehat{a}_{t-1}+\widehat{\varepsilon}^a_t$
	Foreign Economy
Output gap	$\gamma\left(\mathbb{E}_t\left[\widehat{x}^*_{t+1}\right]-\widehat{x}^*_t\right) \approx -\Lambda_{x^*,i}[(\widehat{i}_t-\widehat{\bar{i}}_t)-\mathbb{E}_t[\widehat{\pi}_{t+1}]]+\Lambda_{x^*,i^*}[(\widehat{i}^*_t-\widehat{\bar{i}}^*_t)-\mathbb{E}_t[\widehat{\pi}^*_{t+1}]]$
Phillips curve	$\widehat{\pi}^*_t \approx \beta\mathbb{E}_t\left(\widehat{\pi}^*_{t+1}\right)+\left(\frac{(1-\alpha)(1-\beta\alpha)}{\alpha}\right)\left[\Psi_{\pi^*,x}\widehat{x}_t+\Psi_{\pi^*,x^*}\widehat{x}^*_t\right]$
Monetary policy	$\widehat{i}^*_t \approx \rho_i\widehat{i}^*_{t-1}+(1-\rho_i)\left[\psi_\pi\widehat{\pi}^*_t+\psi_x\widehat{x}^*_t\right]+\widehat{\varepsilon}^{m*}_t$
Natural rate	$\widehat{\bar{i}}^*_t \approx \left(\frac{1+\varphi}{\gamma+\varphi}\right)\left[\Theta_{i^*,a}\mathbb{E}_t\left[\Delta\widehat{a}_{t+1}\right]+\Theta_{i^*,a^*}\mathbb{E}_t\left[\Delta\widehat{a}^*_{t+1}\right]\right]$
Potential output	$\widehat{\bar{y}}^*_t \approx \left(\frac{1+\varphi}{\gamma+\varphi}\right)\left[\widetilde{\lambda}^*_a\widehat{a}_t+\widetilde{\lambda}^*_{a^*}\widehat{a}^*_t\right]$
Productivity	$\widehat{a}^*_t \approx \delta_a\widehat{a}^*_{t-1}+\widehat{\varepsilon}^{a*}_t$

Composite Coefficients

$$\Lambda_{x,i} \equiv \left(\frac{(\sigma(1-\xi^*)-(\sigma-\frac{1}{\gamma})(\xi-\xi^*)\eta)(\sigma-(\sigma-\frac{1}{\gamma})(\xi-\xi^*)(\eta-\eta^*))}{(\xi-\xi^*)(\sigma^2-(\sigma-\frac{1}{\gamma})(\sigma+\frac{1}{\gamma}(\xi-\xi^*)(\eta-\eta^*))}\right),$$

$$\Lambda_{x,i^*} \equiv \left(\frac{(\sigma(1-\xi)+(\sigma-\frac{1}{\gamma})(\xi-\xi^*)(1-\eta))(\sigma-(\sigma-\frac{1}{\gamma})(\xi-\xi^*)(\eta-\eta^*))}{(\xi-\xi^*)(\sigma^2-(\sigma-\frac{1}{\gamma})(\sigma+\frac{1}{\gamma}(\xi-\xi^*)(\eta-\eta^*)))}\right),$$

$$\Lambda_{x^*,i} \equiv \left(\frac{(\sigma\xi^*+(\sigma-\frac{1}{\gamma})(\xi-\xi^*)\eta^*)(\sigma-(\sigma-\frac{1}{\gamma})(\xi-\xi^*)(\eta-\eta^*))}{(\xi-\xi^*)(\sigma^2-(\sigma-\frac{1}{\gamma})(\sigma+\frac{1}{\gamma}(\xi-\xi^*)(\eta-\eta^*)))}\right),$$

$$\Lambda_{x^*,i^*} \equiv \left(\frac{(\sigma\xi-(\sigma-\frac{1}{\gamma})(\xi-\xi^*)(1-\eta^*))(\sigma-(\sigma-\frac{1}{\gamma})(\xi-\xi^*)(\eta-\eta^*))}{(\xi-\xi^*)(\sigma^2-(\sigma-\frac{1}{\gamma})(\sigma+\frac{1}{\gamma}(\xi-\xi^*)(\eta-\eta^*)))}\right),$$

$$\Psi_{\pi,x} \equiv \xi\varphi+\gamma\left(\frac{\sigma\xi-\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)(1-\eta^*)}{\sigma-\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)(\eta-\eta^*)}\right),\ \Psi_{\pi,x^*} \equiv \varphi(1-\xi)+\gamma\left(\frac{\sigma(1-\xi)+\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)(1-\eta)}{\sigma-\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)(\eta-\eta^*)}\right),$$

$$\Psi_{\pi^*,x} \equiv \xi^*\varphi+\gamma\left(\frac{\sigma\xi^*+\left(\sigma-\frac{1}{\gamma}\right)\eta^*(\xi-\xi^*)}{\sigma-\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)(\eta-\eta^*)}\right),\ \Psi_{\pi^*,x^*} \equiv (1-\xi^*)\varphi+\gamma\left(\frac{\sigma(1-\xi^*)-\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)\eta}{\sigma-\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)(\eta-\eta^*)}\right),$$

$$\Theta_{i,a} \equiv \gamma\left[\left(\frac{\sigma\xi-\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)(1-\eta^*)}{\sigma-\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)(\eta-\eta^*)}\right)\widetilde{\lambda}_a+\left(\frac{\sigma(1-\xi)+\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)(1-\eta)}{\sigma-\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)(\eta-\eta^*)}\right)\widetilde{\lambda}^*_a\right],$$

$$\Theta_{i,a^*} \equiv \gamma\left[\left(\frac{\sigma\xi-\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)(1-\eta^*)}{\sigma-\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)(\eta-\eta^*)}\right)\widetilde{\lambda}_{a^*}+\left(\frac{\sigma(1-\xi)+\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)(1-\eta)}{\sigma-\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)(\eta-\eta^*)}\right)\widetilde{\lambda}^*_{a^*}\right],$$

$$\Theta_{i^*,a} \equiv \gamma\left[\left(\frac{\sigma\xi^*+\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)\eta^*}{\sigma-\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)(\eta-\eta^*)}\right)\widetilde{\lambda}_a+\left(\frac{\sigma(1-\xi^*)-\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)\eta}{\sigma-\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)(\eta-\eta^*)}\right)\widetilde{\lambda}^*_a\right],$$

$$\Theta_{i^*,a^*} \equiv \gamma\left[\left(\frac{\sigma\xi^*+\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)\eta^*}{\sigma-\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)(\eta-\eta^*)}\right)\widetilde{\lambda}_{a^*}+\left(\frac{\sigma(1-\xi^*)-\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)\eta}{\sigma-\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)(\eta-\eta^*)}\right)\widetilde{\lambda}^*_{a^*}\right],$$

$$\widetilde{\lambda}_a \equiv 1+\left(\sigma-\frac{1}{\gamma}\right)\left[\frac{\gamma\left((1-\xi)+(\xi-\xi^*)(1-\eta)\right)}{\varphi\left(\sigma-\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)(\eta-\eta^*)\right)+1}\right],\ \widetilde{\lambda}_{a^*} \equiv -\left(\sigma-\frac{1}{\gamma}\right)\left[\frac{\gamma\left((1-\xi)+(\xi-\xi^*)(1-\eta)\right)}{\varphi\left(\sigma-\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)(\eta-\eta^*)\right)+1}\right],$$

$$\widetilde{\lambda}^*_a \equiv -\left(\sigma-\frac{1}{\gamma}\right)\left[\frac{\gamma\left(\xi^*+(\xi-\xi^*)\eta^*\right)}{\varphi\left(\sigma-\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)(\eta-\eta^*)\right)+1}\right],\ \widetilde{\lambda}^*_{a^*} \equiv 1+\left(\sigma-\frac{1}{\gamma}\right)\left[\frac{\gamma\left(\xi^*+(\xi-\xi^*)\eta^*\right)}{\varphi\left(\sigma-\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^*)(\eta-\eta^*)\right)+1}\right],$$

$$\eta \equiv \frac{n\xi}{n\xi+(1-n)\xi^*},\ \eta^* \equiv \frac{n(1-\xi)}{n(1-\xi)+(1-n)(1-\xi^*)}.$$

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