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The Global Slack Hypothesis[1]

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Executive Summary: We illustrate the analytical content of the global slack hypothesis in the context of a variant of the widely-used New Keynesian model of Clarida *et al.* (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, 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 report some empirical evidence in support of the global slack hypothesis, and document some of the data challenges associated with estimating foreign output gaps. We also show that the terms of trade, or a combination of the terms of trade and the real exchange rate, depending on what one assumes about the choice of currency in which exporters price their goods, can capture foreign influences on domestic inflation in an open economy. When the Phillips Curve includes the terms of trade rather than the foreign output gap, the response of inflation to the domestic output gap is exactly the same as in the closed economy case.

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1 Introduction

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 the greater openness of the U.S. economy 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.[2] Second, globalization may have altered the cyclical behavior of inflation by changing the composition of the basket of goods that is priced for aggregate price indexes, as suggested by the standard open-economy versions of the workhorse New Keynesian model of Clarida, Galí and Gertler (2002). 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.

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 over the medium to long term inflation is ultimately determined by the actions of monetary policymakers.

The structure of this paper is as follows. We will employ an extension of the two-

[2]See in particular the contributions of Bohn (1991), Hardouvelis (1992), Fischer (1997), 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 policy making by Barro and Gordon (1983). Yet it is not clear how important this problem is in practice. Some central bankers argue that simply by 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 industrial countries since the 1980s. Second, the Barro-Gordon (1983) analysis is conducted in a simple partial equilibrium setting. Extensions to a general equilibrium setting by Neiss (1999), and Albanesi *et al.* (2003a,b) 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.

country model of Clarida *et al.* (2002) to derive a benchmark specification for the open economy Phillips Curve. We will consider two different assumptions about how firms set prices in export markets: local currency pricing (which is not considered by Clarida *et al.* (2002)) and producer currency pricing. We use this model to illustrate two propositions about the impact of globalization on inflation dynamics. First, foreign slack does matter for the short-run trade-off between inflation and real variables. Moreover, the coefficient on domestic slack declines as the economy becomes more open. Second, international relative prices (specifically, the terms of trade) 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 to measure foreign influences, the theoretical coefficient on domestic slack is exactly the same as in the closed economy case. These propositions hold regardless of what we assume about how firms set their prices internationally, that is, whether they engage in local currency pricing or producer currency pricing.

We then present some empirical evidence in support of the open economy Phillips Curve specification. We argue that when it comes to testing open economy specifications of the Phillips Curve, abstracting from changes in trend inflation is important and makes a big difference to the estimates. We conclude with a brief discussion of the data challenges associated with estimation of open economy Phillips Curves, and the conceptual difficulties associated with the measurement of output gaps.

2 Globalization and the cyclical component of inflation - the global slack hypothesis

For the purposes of thinking about inflation dynamics in a multi-country environment, the basic two-country model of Clarida *et al.* (2002) has proven to be quite useful. We will work with a simple extension of that model, which is described in detail in the Appendix.[3] Here we give a quick qualitative review of the main features of the framework.

In the basic setup, there are two countries, designated home (H) and foreign (F) that have mass of households n and $1-n$ respectively but are otherwise symmetric and identical in all respects. There is a continuum of goods produced by a continuum of monopolistically competitive firms with a linear-in-labor technology that is subject to aggregate productivity shocks. Each firm supplies the home and foreign markets. All consumption goods are

[3] The exposition that follows draws heavily on an extension of Martinez-Garcia (2008).

perishable - there are no consumer durables or capital. The monopolistically competitive firms that are engaged in production set prices to maximize profits subject to a Calvo (1983) pricing constraint, and supply all that is demanded at a given price.

Household preferences in each country are defined over aggregate consumption and labor. Aggregate consumption in each country is in turn a composite of domestically produced and foreign produced goods, and the composite domestic and foreign goods are assumed to be imperfect substitutes. The bundles of domestic and foreign goods that each household consumes are in turn assumed to be composites of an infinite number of domestically produced and foreign produced varieties of goods, with these varieties also assumed to be imperfect substitutes. Furthermore we assume that consumers in each country have a preference for domestically produced goods (home bias). Households make consumption plans and labor supply decisions to maximize utility, yielding demand functions for each variety of domestic and foreign goods, along with standard intratemporal and intertemporal optimality conditions. The labor force is homogenous within a country and immobile across borders, and the national labor markets are perfectly competitive.[4] Hence, wages are equalized within each country but not necessarily across countries.

International trade is assumed to be costless, and there is no active role for government. The only nominal friction in the model is the nominal price stickiness in the goods market which is modelled à la Calvo (1983). Firms may set prices in their local currency (producer currency pricing), or in the currency of the market into which they are selling (local currency pricing). When firms engage in local currency pricing, deviations of the law of one price occur. Furthermore, firms engage in third-degree price discrimination across markets and enjoy monopolistic power in their own product variety. Re-selling is precluded so that the optimal pricing policy is not reversed by re-sellers exploiting the arbitrage opportunities that arise in the goods market. The model is described in more mathematical detail in Tables A1-A4 of the Appendix.

To explore the first-order effects of shocks on the dynamics of the economy, we log-linearize the equilibrium conditions around the deterministic zero-inflation steady state. Let $\widehat{x}_t \equiv \ln X_t - \ln X$ denote the log deviation of a variable X_t from its steady state value X. Assuming that Calvo contracts are symmetric across countries, the log-linearized aggregate supply equation for the domestic firm in the home market can be written in a familiar form as,

$$\widehat{\pi}_t^H = \beta \mathbb{E}_t \left(\widehat{\pi}_{t+1}^H \right) + \lambda \left(\widehat{mc}_t - \widehat{p}_t^H \right), \tag{1}$$

where $\lambda \equiv \frac{(1-\alpha)(1-\beta\alpha)}{\alpha}$. Of course, equation (1) simplifies to the standard New Keynesian

[4] Clarida *et al.* (2002) assume that households are monopolostically competetive suppliers of labor.

Phillips Curve when the consumption basket consists solely of domestically produced goods. The log-linearized aggregate supply equation for the the foreign firm selling in the domestic market can be written analogously as,

$$\widehat{\pi}_t^F = \beta \mathbb{E}_t \left(\widehat{\pi}_{t+1}^F \right) + \lambda \left(\widehat{mc}_t^* - \widehat{p}_t^F + \widehat{s}_t \right). \tag{2}$$

Substitution of each of these expressions into the log-linearized equation for the CPI in the home country, i.e.

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

then gives us,

$$\widehat{\pi}_t = \beta \mathbb{E}_t \left(\widehat{\pi}_{t+1} \right) + \lambda \left[\xi \left(\widehat{mc}_t - \widehat{p}_t^H \right) + (1-\xi) \left(\widehat{mc}_t^* - \widehat{p}_t^F + \widehat{s}_t \right) \right]. \tag{4}$$

This is a fairly general expression for the open economy New Keynesian Phillips Curve. It relates domestic CPI inflation to expected future CPI inflation and a weighted average of domestic and foreign real marginal costs. By invoking additional assumptions on firms' pricing behavior and other primitives of the model we will see that it is possible to rewrite the Phillips Curve in terms of domestic and foreign output gaps.

2.1 Producer currency pricing

We will start with the case of producer currency pricing as in Clarida *et al.* (2002). Under producer currency pricing, the law of one price holds and exchange rate pass-through is complete, i.e. $\widehat{p}_t^{F*} = \widehat{p}_t^F + \widehat{s}_t$. The expression for the dynamics of domestic CPI inflation can then be rewritten as,

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

which tells us that domestic CPI inflation is a function of expected future domestic CPI inflation and a weighted average for domestic and foreign real marginal costs. In turn, the log-linearized real marginal cost functions for domestic and foreign firms can be written as,

$$\begin{aligned} \widehat{mc}_t - \widehat{p}_t^H &= \gamma \widehat{c}_t + \varphi \widehat{y}_t + (1-\xi) \widehat{tot}_t - (1+\varphi) \widehat{a}_t, & (6) \\ \widehat{mc}_t^* - \widehat{p}_t^{F*} &= \gamma \widehat{c}_t^* + \varphi \widehat{y}_t^* - \xi^* \widehat{tot}_t - (1+\varphi) \widehat{a}_t^*, & (7) \end{aligned}$$

where we have made use of the labor market clearing conditions as well as the fact that whenever the law of one price holds terms of trade can be expressed as $\widehat{tot}_t = \widehat{p}_t^F - \widehat{s}_t - \widehat{p}_t^{H*} =$

$\widehat{p}_t^F - \widehat{p}_t^H$, in which case $\widehat{p}_t - \widehat{p}_t^H = (1-\xi)\widehat{tot}_t$.

To rewrite the expressions for real marginal costs in terms of gaps (deviations from the frictionless allocation), we note that the potential or frictionless level of output of the domestic and foreign countries is defined as the output level that prevails whenever the monopolistic firms price as if prices were fully flexible, i.e. $\widehat{\overline{mc}}_t - \widehat{\overline{p}}_t^H = 0$ and $\widehat{\overline{mc}}_t^* - \widehat{\overline{p}}_t^{F*} = 0$.[5] We use the notation $\widehat{\overline{x}}$ to denote the log deviation of a variable X_t from its frictionless steady-state level $\overline{X}$. Thus the pricing equations in the frictionless case can be written in log-linear terms as,

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

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

We can then use these expressions to rewrite the log-linearized real marginal cost functions in gap form as,

$$\widehat{mc}_t - \widehat{p}_t^H = \gamma(\widehat{c}_t - \widehat{\overline{c}}_t) + \varphi(\widehat{y}_t - \widehat{\overline{y}}_t) + (1-\xi)\left(\widehat{tot}_t - \widehat{\overline{tot}}_t\right), \tag{10}$$

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

That is, real marginal costs for domestic firms selling into the domestic economy can be written in terms of a domestic consumption gap (deviation of consumption from its frictionless level), $(\widehat{c}_t - \widehat{\overline{c}}_t)$, a domestic output gap (deviation of output from its frictionless level), $(\widehat{y}_t - \widehat{\overline{y}}_t)$, and a terms of trade gap (deviation of the terms of trade from its frictionless level), $(\widehat{tot}_t - \widehat{\overline{tot}}_t)$. Likewise, for foreign producers selling into the domestic market, real marginal costs can be written in terms of a foreign consumption gap, $(\widehat{c}_t^* - \widehat{\overline{c}}_t^*)$, a foreign output gap, $(\widehat{y}_t^* - \widehat{\overline{y}}_t^*)$, and a terms of trade gap, $(\widehat{tot}_t - \widehat{\overline{tot}}_t)$. Substitution back into equation (5) would then give us an expression relating domestic 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 an expression for the Phillips Curve in a more familiar form that relates inflation to measures of the output gaps alone by rewriting the consumption gap and terms of trade gap in each country in terms of the output gaps. After much algebra (outlined in detail in Martínez-García (2008)) we obtain the following

[5] The Dixit-Stiglitz pricing rule for monopolistic competition under flexible prices implies that prices are equal to a mark-up over marginal costs. The mark-up is a function of the elasticity of substitution across varieties, θ, and time-invariant. Therefore, the pricing rule can be log-linearized around the steady state in terms of prices and marginal costs as stated. The mark-up only affects the steady state allocation, and it is conventional to add a labor subsidy to eliminate this distortion as well.

expressions,

$$\begin{aligned}\widehat{mc}_t - \widehat{p}_t^H = & \left[\varphi + \gamma \left(\frac{\sigma(\xi^* + (\xi - \xi^*)\eta^*) + \frac{1}{\gamma}(\xi - \xi^*)(1-\eta^*) + (1-\xi)}{\sigma - \left(\sigma - \frac{1}{\gamma}\right)(\xi - \xi^*)(\eta - \eta^*)} \right)\right] \left(\widehat{y}_t - \widehat{\overline{y}}_t\right) + \\ & + \left[\gamma \left(\frac{\sigma(1-\xi + (\xi - \xi^*)(1-\eta)) - \frac{1}{\gamma}(\xi - \xi^*)(1-\eta) - (1-\xi)}{\sigma - \left(\sigma - \frac{1}{\gamma}\right)(\xi - \xi^*)(\eta - \eta^*)} \right)\right] \left(\widehat{y}_t^* - \widehat{\overline{y}}_t^*\right),\end{aligned} \tag{12}$$

$$\begin{aligned}\widehat{mc}_t^* - \widehat{p}_t^{F*} = & \left[\gamma \left(\frac{\sigma(\xi^* + (\xi - \xi^*)\eta^*) - \frac{1}{\gamma}(\xi - \xi^*)\eta^* - \xi^*}{\sigma - \left(\sigma - \frac{1}{\gamma}\right)(\xi - \xi^*)(\eta - \eta^*)} \right)\right] \left(\widehat{y}_t - \widehat{\overline{y}}_t\right) + \\ & + \left[\varphi + \gamma \left(\frac{\sigma(1-\xi + (\xi - \xi^*)(1-\eta)) + \frac{1}{\gamma}(\xi - \xi^*)\eta + \xi^*}{\sigma - \left(\sigma - \frac{1}{\gamma}\right)(\xi - \xi^*)(\eta - \eta^*)} \right)\right] \left(\widehat{y}_t^* - \widehat{\overline{y}}_t^*\right),\end{aligned} \tag{13}$$

where $\eta \equiv \frac{n\left(\frac{\xi}{n}\right)}{n\left(\frac{\xi}{n}\right) + (1-n)\left(\frac{\xi^*}{n}\right)}$ and $\eta^* \equiv \frac{n\left(\frac{1-\xi}{1-n}\right)}{n\left(\frac{1-\xi}{1-n}\right) + (1-n)\left(\frac{1-\xi^*}{1-n}\right)}$. If we impose the assumption of no home bias in consumption (as do Clarida *et al.* (2002) and Woodford (2007)), i.e. $\xi = \xi^*$, then we can write real marginal costs as,

$$\widehat{mc}_t - \widehat{p}_t^H = \left[\varphi + \gamma \left(\frac{\sigma\xi + (1-\xi)}{\sigma} \right)\right] \left(\widehat{y}_t - \widehat{\overline{y}}_t\right) + \left[(1-\xi)\gamma \left(\frac{\sigma - 1}{\sigma} \right)\right] \left(\widehat{y}_t^* - \widehat{\overline{y}}_t^*\right), \tag{14}$$

$$\widehat{mc}_t^* - \widehat{p}_t^{F*} = \left[\xi\gamma \left(\frac{\sigma - 1}{\sigma} \right)\right] \left(\widehat{y}_t - \widehat{\overline{y}}_t\right) + \left[\varphi + \gamma \left(\frac{\sigma(1-\xi) + \xi}{\sigma} \right)\right] \left(\widehat{y}_t^* - \widehat{\overline{y}}_t^*\right). \tag{15}$$

If we additionally assume (as also do Clarida *et al.* (2002) and Woodford (2007)) that the elasticity of substitution between the home and foreign bundles of varieties is $\sigma = 1$, which implies that the consumption aggregator is of the Cobb-Douglas type, then the expressions above for the real marginal costs become,

$$\widehat{mc}_t - \widehat{p}_t^H = [\varphi + \gamma] \left(\widehat{y}_t - \widehat{\overline{y}}_t\right), \tag{16}$$

$$\widehat{mc}_t^* - \widehat{p}_t^{F*} = [\varphi + \gamma] \left(\widehat{y}_t^* - \widehat{\overline{y}}_t^*\right). \tag{17}$$

Domestic and foreign real marginal costs can be written solely in terms of the domestic and foreign output gaps.

However, in an open economy the foreign output gap matters not just for the determination of the marginal cost of foreign firms (and, therefore, to capture the effects on imported prices) but also for the determination of domestic marginal costs because: (a) domestic firms do export their products abroad, so higher foreign demand will force them to pay higher domestic wages; and (b) variations in the terms of trade against foreign competition will affect their domestic market share and consequently their domestic costs.

We can use the expressions for real marginal costs in (12) and (13) to derive a 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 be written as,

$$\widehat{\pi}_t = \beta \mathbb{E}_t \left(\widehat{\pi}_{t+1}\right) + \lambda \left[\Psi_{\pi,x} \left(\widehat{y}_t - \widehat{\overline{y}}_t\right) + \Psi_{\pi,x^*} \left(\widehat{y}_t^* - \widehat{\overline{y}}_t^*\right)\right], \tag{18}$$

where,

$$\Psi_{\pi,x} \equiv \xi\varphi + \gamma \left(\frac{\sigma\xi - \left(\sigma - \frac{1}{\gamma}\right)(\xi - \xi^*)(1 - \eta^*)}{\sigma - \left(\sigma - \frac{1}{\gamma}\right)(\xi - \xi^*)(\eta - \eta^*)} \right), \tag{19}$$

$$\Psi_{\pi,x^*} \equiv \varphi(1 - \xi) + \gamma \left(\frac{\sigma(1 - \xi) + \left(\sigma - \frac{1}{\gamma}\right)(\xi - \xi^*)(1 - \eta)}{\sigma - \left(\sigma - \frac{1}{\gamma}\right)(\xi - \xi^*)(\eta - \eta^*)} \right). \tag{20}$$

If we impose the Clarida *et al.* (2002) and Woodford (2007) assumption of no home bias in consumption, $\xi = \xi^*$, the coefficients on the output gap terms simplify to,

$$\Psi_{\pi,x} = \xi(\gamma + \varphi) > 0 \tag{21}$$

$$\Psi_{\pi,x^*} = (1 - \xi)(\gamma + \varphi) > 0. \tag{22}$$

That is, the foreign output gap will matter for domestic CPI inflation, and there is no ambiguity about the sign of the effect. Note also that the importance of the foreign output gap activity is greater, the greater the importance of foreign goods in the consumption bundle, $1 - \xi$. Thus, in the context of this simple model at least, two key features of the global slack hypothesis are apparent. First, the output gap in the foreign country, as measured by the deviation of output from its frictionless level, matters for domestic CPI inflation. Second, the Phillips curve will be flatter (relative to the domestic output gap), the more important are foreign goods in the domestic consumption bundle.

2.2 Local currency pricing

The second case that we need to consider is the assumption of local currency pricing (LCP), where the law of one price no longer holds. When the general expression for the open economy Phillips Curve in (4) is rewritten in terms of real marginal costs, we obtain,

$$\widehat{\pi}_t = \beta \mathbb{E}_t \left(\widehat{\pi}_{t+1}\right) + \lambda \left[\xi \left(\widehat{mc}_t - \widehat{p}_t^H\right) + (1 - \xi) \left(\widehat{mc}_t^* - \widehat{p}_t^{F*} + \widehat{d}_t^*\right)\right], \tag{23}$$

where $\widehat{d}_t^* \equiv \left(\widehat{s}_t + \widehat{p}_t^{F*} - \widehat{p}_t^F\right)$ is a measure of the deviation from the law of one price for foreign goods.

The log-linearized expressions for marginal costs under the local currency pricing assumption are,

$$\widehat{mc}_t - \widehat{p}_t^H = \gamma \widehat{c}_t + \varphi \widehat{y}_t + (1-\xi)\,\widehat{tot}_t - (1-\xi)\,\widehat{d}_t - (1+\varphi)\,\widehat{a}_t, \tag{24}$$

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

where $\widehat{d}_t \equiv \left(\widehat{p}_t^H - \widehat{s}_t - \widehat{p}_t^{H*}\right)$ is a measure of the deviation from the law of one price for domestic goods. Under local currency pricing, an important distinction needs to be made between the terms of trade and the relative price of foreign goods. The terms of trade are still defined as $\widehat{tot}_t = \widehat{p}_t^F - \widehat{s}_t - \widehat{p}_t^{H*}$ in log-deviations but are no longer equal to $\widehat{p}_t^F - \widehat{p}_t^H$ due to the fact that the law of one price no longer holds in general. As before, the potential or frictionless level of output of the domestic and foreign economies 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 $\widehat{\overline{mc}}_t^* - \widehat{\overline{p}}_t^{F*} = 0$ respectively. This gives us the following pair of equations to characterize the frictionless allocation,

$$0 = \gamma \widehat{\overline{c}}_t + \varphi \widehat{\overline{y}}_t + (1-\xi)\,\widehat{\overline{tot}}_t - (1+\varphi)\,\widehat{a}_t, \tag{26}$$

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

which are identical to (8) and (9) since $\widehat{\overline{d}}_t = \widehat{\overline{d}}_t^* = 0$ (because, by definition, the law of one price holds in the frictionless equilibrium).

We can use these relationships to rewrite the expressions for real marginal costs in terms of gaps as before,

$$\widehat{mc}_t - \widehat{p}_t^H = \gamma\left(\widehat{c}_t - \widehat{\overline{c}}_t\right) + \varphi\left(\widehat{y}_t - \widehat{\overline{y}}_t\right) + (1-\xi)\left(\widehat{tot}_t - \widehat{\overline{tot}}_t\right) - (1-\xi)\,\widehat{d}_t, \tag{28}$$

$$\widehat{mc}_t^* - \widehat{p}_t^{F*} = \gamma\left(\widehat{c}_t^* - \widehat{\overline{c}}_t^*\right) + \varphi\left(\widehat{y}_t^* - \widehat{\overline{y}}_t^*\right) - \xi^*\left(\widehat{tot}_t - \widehat{\overline{tot}}_t\right) - \xi^* \widehat{d}_t^*. \tag{29}$$

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 Phillips Curve in terms of output gaps, the terms of trade and the real exchange rate as,

$$\widehat{\pi}_t = \beta \mathbb{E}_t\left(\widehat{\pi}_{t+1}\right) + \lambda\left[\Psi_{\pi,x}\left(\widehat{y}_t - \widehat{\overline{y}}_t\right) + \Psi_{\pi,x^*}\left(\widehat{y}_t^* - \widehat{\overline{y}}_t^*\right) + \Psi_{\pi,rp}\left(\left(\xi - \xi^*\right)\widehat{tot}_t - \widehat{rs}_t\right)\right], \tag{30}$$

where $\Psi_{\pi,x}$ and Ψ_{π,x^*} are defined exactly as in (19) and (20), while the new composite parameter, $\Psi_{\pi,rp}$, is defined as,

$$\begin{aligned}\Psi_{\pi,rp} \equiv\ & \gamma\sigma\left(\tfrac{1-(\xi-\xi^{*})(\eta-\eta^{*})}{(\xi-\xi^{*})(1+(\xi-\xi^{*}))}\right)\left(\tfrac{\sigma(1-\xi)+\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^{*})(1-\eta)}{\sigma-\left(\sigma-\frac{1}{\gamma}\right)(\xi-\xi^{*})(\eta-\eta^{*})}\right)- \\ & -\gamma\sigma\left(\tfrac{(1-\xi^{*})-\eta(\xi-\xi^{*})}{(\xi-\xi^{*})(1+(\xi-\xi^{*}))}\right).\end{aligned} \tag{31}$$

But this characterization of the Phillips Curve is well-defined only if $\xi \neq \xi^{*}$.

Imposing the assumption of no home bias in consumption (as do Clarida *et al.* (2002) and Woodford (2007)), i.e. $\xi = \xi^{*}$, we can derive an expression for the Phillips Curve in the following terms,

$$\widehat{\pi}_t = \beta\mathbb{E}_t\left(\widehat{\pi}_{t+1}\right) + \lambda\left[\xi\left(\gamma+\varphi\right)\left(\widehat{y}_t - \widehat{\overline{y}}_t\right) + \left(1-\xi\right)\left(\gamma+\varphi\right)\left(\widehat{y}^{*}_t - \widehat{\overline{y}}^{*}_t\right) + (1-n)\widehat{rs}_t\right], \tag{32}$$

where $(1-n)$ denotes the foreign population size. In this special case, it suffices to use the real exchange rate to account for the deviations from the law of one price without having to subtract the effect of the terms of trade. The coefficients on the domestic and foreign output gaps can be obtained from the more general composite parameters $\Psi_{\pi,x}$ and $\Psi_{\pi,x^{*}}$ defined in (19) and (20) under the assumption of no home bias, but the same is not true of the composite parameter $\Psi_{\pi,rp}$.

The two propositions we stated above continue to hold: First, the output gap in the foreign country, as measured by the deviation of output from its frictionless level, matters for domestic CPI inflation. Second, the Phillips Curve will be flatter (relative to the domestic output gap), the more important are foreign goods in the domestic consumption bundle. The only difference with the Phillips Curve expression we derived under the assumption of producer current pricing is the presence of a term involving the real exchange rate (net of terms of trade effects) that captures the contribution of deviations of the law of one price, whose importance increases with the size of the population of the foreign country (rather than with its openness to foreign trade).

2.3 Hybrid case

Recall the characterization of CPI inflation under the assumption of producer currency pricing in equation (18) and the characterization of CPI inflation under the assumption of local currency pricing (whenever $\xi \neq \xi^{*}$) in equation (30). If we assume that a constant fraction of firms $0 \leq \epsilon \leq 1$ price according to the local currency pricing rule in each country, CPI inflation will then be determined as,

$$\widehat{\pi}_t = \left(1-\epsilon\right)\widehat{\pi}^{PCP}_t + \epsilon\widehat{\pi}^{LCP}_t, \tag{33}$$

with the Phillips Curve then being given by,

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

On top of the usual assumptions, this result defines the inflation dynamics under the assumption that the fraction of local currency pricing firms is exogenously given, does not change over time, and is identical in both countries.

While this expression has its conceptual limitations, it is useful in the sense that it suggests that deviations from the law of one price as reflected in international relative prices (the real exchange rate net of terms of trade effects) cannot be excluded and ignored in the Phillips Curve except in the polar case where all firms in all countries engage in producer currency pricing (the implicit assumption in Clarida *et al.* (2002)).

2.4 Discussion

The key parameter determining the quantitative significance of foreign factors for domestic CPI inflation developments in this and related models is the share parameter for foreign goods in the consumption basket, $1 - \xi$. It might be argued that given the composition of the consumption bundle of the representative U.S. household, and specifically the fact that it seems to be heavily skewed towards goods and services that are either nontraded or nontradable, this puts a significant limit on how important, in a quantitative sense, foreign economic activity is likely to be for U.S. inflation developments. As Figure 1 shows, while the share of imports of goods and services in 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 smaller economies.

However, we think such a conclusion would be premature. There are a number of other channels through which foreign economic activity may matter for domestic inflation dynamics that are absent from the model outlined above, such as trade in intermediate products and commodities, and immigration and outsourcing. Leith and Malley (2007) and Rumler (2007) explore extensions of the basic model sketched out above that allow for trade in intermediate inputs. The analysis above was conducted in the context of an environment where goods are mobile across national borders, but labor is not.[6] Engler (2009) examines the effect of labor mobility in the standard New Keynesian model. Engler's analysis is motivated by the observation that in many cases migration is not a once and for all decision but instead

[6] Woodford (2007) also considers a version of the model where there is assumed to be a single global market for labor, and shows that in such a case the global output gap matters not just for the evolution of CPI inflation, $\widehat{\pi}_t$, but for the evolution of domestic product price inflation, $\widehat{\pi}^H_t$, as well.

has a significant high frequency component as well. Engler's analysis is conducted from the perspective of the source country – that is, he looks at how the Phillips Curve relationship in a small open economy is affected by the possibility that domestic workers can supply effort to foreign as well as domestic firms - and he shows that the opening of the labor market tends to flatten the domestic Phillips Curve. Razin and Binyamini (2008) further extend Engler's framework to consider the impact of immigration from the perspective of the receiving country, albeit in the two-country setting of Clarida *et al.* (2002), and show that this too leads to a flattening of the Phillips Curve for the domestic economy.[7]

3 Evidence that foreign activity affects U.S. inflation

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 G7 group of 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 U.S.' largest trading partner, but again found no effect.

Tootell (1998) was a more comprehensive assessment of whether resource utilization in the G7 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 G7 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 to include the past decade, they found that the estimated coefficient on the domestic slack variable declined in magnitude and statistical

[7] Bentolila et al. (2008) also consider the implications of immigration for inflation dynamics.

significance (as many other studies have shown), while that on the foreign slack variable increased. Global slack, at least in the other G7 countries, seems to matter for U.S. inflation after all.

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 G7, but several of the U.S.' other top trading partners 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.

Taking these earlier studies as a point of reference, we decided to investigate whether we can detect any relationship between inflation in the U.S. and domestic and foreign resource slack. We consider three very standard measures of resource slack to begin with, namely capacity utilization in manufacturing, the unemployment rate and the output gap. We start by looking at the G7 group of countries (for reasons that will become apparent later), defining foreign slack as a simple import-weighted average of the various slack measures. Figures 2-4 plot capacity utilization in U.S. manufacturing, the U.S. unemployment rate and the U.S. output gap along with the foreign equivalents for the other countries in the G7. Two points are immediately obvious. First, the short historical coverage of some of the series: our foreign capacity utilization series only starts in 1985 (the earliest date for which a capacity utilization measure for U.K. manufacturing is available), while the foreign output gap series is only available from 1991 (due to German reunification). Second, the U.S. and foreign measures of resource utilization are highly correlated, suggesting that it may be difficult to discern a distinct effect on U.S. inflation from resource utilization outside the U.S.[8]

Table 1 reports the results of a series of simple least squares regressions of headline and core inflation on the three measures of resource utilization in the U.S. and the other

[8] Note that while capacity utilization rates in the U.S. and the rest of the G7 seem to move in tandem most of the time, there are episodes when the two diverge. The striking discrepancy between capacity utilization rates in the U.S. and the rest of the G7 in the early 1990s was what motivated Orr's (1994) analysis.

G7 countries. The simple specifications we start with are motivated by the theoretical analysis above that assumes producer currency pricing, and specifically, equation (18). Our objective here is not to come up with a comprehensive model of U.S. inflation dynamics, but rather to simply explore whether there are any hints in the data that foreign influences may be important. Note that for five of the six specifications reported, the coefficient on the foreign resource utilization variable is statistically significant at conventional levels, and of the right sign. By contrast, the sign on the U.S. resource utilization variable is always of the wrong sign, and is never statistically significant. The explanatory power of these very simple specifications, as measured by the $\overline{R}^2$, is surprisingly high in some cases, and especially where core inflation is used as the dependent variable. But the results of the Breusch-Godfrey test for serial correlation in the residuals suggest that all but one of the estimated models are potentially misspecified.

Recall that the Phillips Curve expressions that we derived above were in terms of deviations from a steady state. The New Keynesian analytical framework provides an account of inflation dynamics around a (possibly time-varying) steady state, so it seems logical, therefore, when looking for patterns in the data, that we might want to focus on the cyclical components of different variables.[9] We measure the cyclical components of headline and core (ex. food and energy) PCE inflation using the Hodrick-Prescott filter with smoothing parameter $\lambda = 1600$ and Figures 5 and 6 show the time series for the overall, trend and cyclical components of our two inflation measures. Table 2 reports the results we obtain when we re-estimate the specifications in Table 1 using detrended headline and core inflation as the dependent variable.[10] Again, the estimated coefficients on the foreign resource utilization variables are always of the right sign, and in many cases are statistically significant. The coefficient estimates on the U.S. resource utilization variables are also of the correct sign (except in the specification with core inflation and the output gap), but only statistically significant in one case. While the explanatory power of these specifications is somewhat lower than for the specifications that use the raw inflation measures, there no longer appears to be a problem with serial correlation in the residuals (as determined by the Breusch-Godfrey test) for the specifications that use core inflation as the dependent variable.

What if we estimate simple specifications motivated by the expression we derived for the open economy Phillips Curve relationship under the assumption of local currency pricing in

[9] Carlstrom and Fuerst (2008) also emphasize the importance of controlling for changes in trend inflation when looking at the relationship between economic slack and inflation. Balakrishnan and Ouliaris (2006) argue that changes in external trade and global factor markets tend to impact inflation primarily over the business cycle.

[10] In a slight abuse of notation, in our empirical work we use hats "^" to denote the cyclical component of a series rather than the (log) deviation of the series from a steady state value.

equation (30) above? These specifications include the terms of trade and the real exchange rate on the right hand side, and as such resemble the specifications estimated by Ihrig *et al.* (2007).[11] Table 3 reports the results. The coefficient on foreign slack as measured by the unemployment rate is not statistically significant in either the specification for headline or core inflation. The coefficient on foreign slack as measured by capacity utilization is significant at the 10% level in the specification for headline inflation, but the strongest results are obtained when we use the output gap measures. The coefficient on the U.S. output gap is not significant for either headline or core inflation, but the foreign output gap is, and is significant at the 1% level in the estimated equation for core inflation. However, note that all of the estimated equations seem to have serially correlated residuals, although as in Tables 1 and 2, the problem seems less severe for the specifications for core inflation.

To summarize, if we define the world as consisting of just the G7 economies, ordinary least squares estimates of simple linear Phillips Curve specifications motivated by a standard open economy extension of the New Keynesian model are consistent with the global slack hypothesis. That is, there seems to be a more significant relationship (in a statistical sense) between slack in the other economies of the G7 and inflation in the U.S., than between slack in the U.S. and inflation in the U.S. The evidence is fragile, to be sure, but it does suggest that there is empirical content to the global slack hypothesis.

So far we have limited ourselves to reporting results where the rest of the world is defined as the other members of the G7. However, while the G7 group still accounts for a significant share of world GDP and of U.S. imports, these shares are declining, as Figure 7 shows. A more comprehensive empirical evaluation of the global slack hypothesis would look at a larger group of countries to measure global slack. However we immediately run into severe data problems, even if we limit ourselves to the economies of the G20, or our largest trading partners. For example, estimates of the unemployment rate for China are only available from 2000, and then only for urban areas. Estimates of capacity utilization in Chinese manufacturing are only available from 2002, and there are still no official estimates of the level of Chinese real GDP on a quarterly basis that could be used to estimate an output gap for China.

Figures 8-10 illustrate the data challenge in graphical form. Referring back to the basic theory, it suggests that the relevant measure of slack in an estimated Phillips Curve is some sort of trade weighted average of slack in each of our trading partners. Figures 8-10 plot time series of,

$$x_t(\upsilon) = \sum\nolimits_{i \in G26} \frac{imp_t^i}{\sum\nolimits_{i \in G26} imp_t^i} \times \iota_t^i(\upsilon), \tag{35}$$

[11] Ihrig et al. (2007) specify inflation as a function of lagged inflation, domestic and foreign slack, and import, energy and food prices.

where $\upsilon \in$ {capacity utilization rate in manufacturing, unemployment rate, output gap}, imp_t^i is nominal U.S. imports from country i at date t for the 26 countries (where the euro area is counted as a single country) that are included in the Federal Reserve Board's broad trade weighted value of the dollar index, and $\iota_t^i(\upsilon) = 1$ if the slack measure υ is available for country i as of date t, and $\iota_t^i(\upsilon) = 0$ otherwise. For example, if we were interested in slack as measured by the unemployment rate and it were possible to obtain a measure of unemployment for all of our trading partners for the entire sample period, then $x_t = 1$ at all dates t. If at the beginning of the period we can only obtain estimates of the unemployment rate for countries that account for half of our imports, then $x_t = 0.5$ initially. As more countries start reporting unemployment on a regular basis, x_t would rise over time. As our trade shifts towards countries for which we are unable to obtain the necessary data, x_t will fall. In addition to capturing the availability of slack measures for our various trading partners, this measure also captures the shifting composition of our imports.

Examination of the Figures shows that over the period since 1970, we can at best measure the degree of capacity utilization in manufacturing in countries that account for about three quarters of our imports. Prior to 1985, the best we can do is just over 50 percent. For unemployment we can do better, but only towards the end of the period. For the output gap, the situation is in between, with coverage of countries accounting for more than 80 percent of our imports towards the end of the sample.

With these caveats about the coverage of various slack measures in mind, we re-estimated the simple Phillips Curve specifications for the broader G26 group of countries that supply most of the U.S.' imports. We limited ourselves to the output gap as the measure of slack, and the results are reported in Table 4. Figure 11 shows how this measure compares with the measure for the U.S. and the other countries of the G7. We addressed the tradeoff between sample size and country coverage by including all countries for which real GDP estimates are available on a quarterly basis from 1996 on. Note that the coefficient on the foreign slack measure is statistically significant in three of the four specifications we report, while the coefficient on the domestic slack measure is not significant in any of the specifications. Note that our estimate of the foreign output gap in these regressions does not include China, due to the idiosyncrasies of China's national accounts, nor, indeed, measures of the output gap for about 20 to 30 percent (depending on the year) of our trading partners.

So far we have reported simple ordinary least squares estimates of the Phillips Curve to evaluate the global slack hypothesis, taking lagged inflation as a proxy for expected future inflation in the various specifications. We can also use the fact that under rational expectations the forecast error $\widehat{\pi}_{t+1} - \mathbb{E}_t\widehat{\pi}_{t+1}$ will be uncorrelated with information dated t and earlier to obtain a set of orthogonality conditions that allow us to estimate our most general specification of the Phillips Curve (equation (34) above) using the generalized method of moments (GMM) under the assumption that a fraction $(1-\epsilon)$ of firms engage in producer currency pricing, while the remainder engage in local currency pricing,

$$E_t\left\{\left(\widehat{\pi}_t-\beta\widehat{\pi}_{t+1}-\lambda\left[\Psi_{\pi,x}\left(\widehat{y}_t-\widehat{\overline{y}}_t\right)+\Psi_{\pi,x^*}\left(\widehat{y}_t^*-\widehat{\overline{y}}_t^*\right)\left(\left(\xi-\xi^*\right)\widehat{tot}_t-\widehat{rs}_t\right)\ldots\right.\right.\right.$$
$$\left.\left.\left.+\epsilon\Psi_{\pi,rp}\left(\left(\xi-\xi^*\right)\widehat{tot}_t-\widehat{rs}_t\right)\right)\right]\right)z_t\right\}=0, \tag{36}$$

where z_t is a vector of variables dated t and earlier. Table 5 reports the results of estimating the model using GMM, where the vector of instruments z_t includes four lags of the headline PCE inflation rate, four lags of the cyclical component of the labor share in the U.S., four lags of the import-weighted labor share in the other G7 countries, one lag of the output gap in the U.S., one lag of the trade weighted output gap in our main trading partners and four lags of the relative price of oil in the U.S. For six of the eight specifications, the estimated coefficient on the foreign output gap is statistically significant at the 1% level and of the correct sign, while for only three of the eight specifications is the coefficient on the U.S. output gap statistically significant. Note also that the coefficients on the foreign output gaps are statistically significant in two of the four specifications that include the terms of trade and the real exchange rate as additional explanatory variables, specifically the specifications for core inflation.

3.1 Discussion

The evidence presented here suggests that the global slack hypothesis has some empirical content, but it is equally clear that the empirical relationship between the cyclical component of inflation in the U.S. and measures of foreign slack is fragile. There are a number of possible reasons for this. There is an element of arbitrariness to the measurement of the cyclical components of statistical series, and well-known end-of-sample problems that may be particularly important for the short post-1990 sample period that we focus on for most of our empirical results. 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 such an important role in the pricing decisions of U.S. firms nowadays, 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.

It is also not clear what the relationship is between the conventional statistical measures of slack we have employed in our empirical analysis and the measures suggested by the modern literature. The gap concept in the model outlined above was the deviation of output from its frictionless level. It is intuitive that the frictionless 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, 2005) show that there is a *negative* relationship between the New Keynesian concept of the output gap (the deviation of output from its frictionless level) and the measure commonly used in empirical research (the deviation of output from a smooth, possibly time varying, trend).

By way of illustration of the potential importance of the difference between the two concepts of potential output (the statistical one and the model-consistent one), we simulated the full model as described in Tables A1-A4 of the Appendix under the producer currency pricing assumption, and then computed the frictionless level of output implied by the model and the potential output as measured by the application of the Hodrick-Prescott filter to the output series generated by the model.[12] Figure 12 is an illustrative scatter plot of the two series of the foreign gap for a sample of 100 periods. For the particular set of parameter values used to generate these data and a larger sample of 5000 periods, the correlation between the two series is only 0.05, while the volatility of the model-consistent foreign output gap is merely 0.27 compared with a standard deviation of 0.64 for the Hodrick-Prescott filtered foreign output. A fuller evaluation of the global slack hypothesis would complete the specification of the demand side of the model outlined above, include a specification of a rule for monetary policy, and then take the full system to the data.

In light of the conceptual and measurement challenges associated with estimating Phillips Curves in terms of domestic and foreign output gaps, it is worth asking whether we can derive specifications that rely on more easily measured variables such as the terms of trade. Under the producer currency pricing assumption it is possible to write the terms of trade gap as a function of domestic and foreign output gaps as follows,

$$\widehat{tot}_t - \widehat{\overline{tot}}_t = \left[\frac{1}{\sigma - \left(\sigma - \frac{1}{\gamma}\right)(\xi - \xi^*)(\eta - \eta^*)} \right] \left[\left(\widehat{y}_t - \widehat{\overline{y}}_t\right) - \left(\widehat{y}^*_t - \widehat{\overline{y}}^*_t\right) \right]. \tag{37}$$

[12] 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 essentially taken from Chari *et al.* (2002) and very similar to the set-up for the closed-economy model of Neiss and Nelson (2003, 2005). Countries are of equal size, i.e. $n = \frac{1}{2}$, and we maintain home bias in consumption, i.e. $(1 - \xi) = \xi^*$. We assume that the Taylor rule is symmetric in both countries, inertial, and takes 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 0.25 as in Chari *et al.* (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 innovations at 0.5 as in Chari *et al.* (2002).

Using this expression to eliminate the foreign output gap term from the Phillips Curve in equation (18) above, we obtain,

$$\begin{aligned} \widehat{\pi}_t &= \beta \mathbb{E}_t\left(\widehat{\pi}_{t+1}\right) + \lambda\Big[(\varphi+\gamma)\left(\widehat{y}_t - \widehat{\overline{y}}_t\right) ... \\ & -\Psi_{\pi,x^*}\left(\sigma - \left(\sigma - \frac{1}{\gamma}\right)(\xi-\xi^*)(\eta-\eta^*)\right)\left(\widehat{tot}_t - \widehat{\overline{tot}}_t\right)\Big]. \end{aligned} \quad (38)$$

That is, the effects of foreign slack on domestic inflation can be fully captured in principle by movements in the terms of trade gap. Note that the slope of the Phillips Curve with respect to domestic slack, $\lambda(\varphi+\gamma)$, is *exactly the same* in the open economy and closed economy specifications (i.e., when $\xi = \xi^* = 1$ which defines the closed economy case) when the open economy version of the Phillips Curve includes the terms of trade gap instead of the foreign output gap. The expression for the Phillips Curve can be further simplified to,

$$\widehat{\pi}_t = \beta \mathbb{E}_t\left(\widehat{\pi}_{t+1}\right) + \lambda(\varphi+\gamma)\left[\left(\widehat{y}_t - \widehat{\overline{y}}_t\right) - \sigma(1-\xi)\left(\widehat{tot}_t - \widehat{\overline{tot}}_t\right)\right], \quad (39)$$

if we assume no home bias in consumption, $\xi = \xi^*$, as Clarida *et al.* (2002) and Woodford (2007) do. Note that the terms of trade gap enters with a *negative* coefficient whose size depends on the share of foreign goods in the consumption basket, $(1-\xi)$, and the elasticity of substitution between home and foreign goods, σ.

If instead we assume local currency pricing, the relationship between the terms of trade gap and the output gaps in the domestic and foreign countries includes a term measuring deviations from the law of one price for foreign goods in the domestic market,

$$\begin{aligned} \widehat{tot}_t - \widehat{\overline{tot}}_t = & \left[\frac{1}{\sigma - \left(\sigma - \frac{1}{\gamma}\right)(\xi-\xi^*)(\eta-\eta^*)}\right]\left[\left(\widehat{y}_t - \widehat{\overline{y}}_t\right) - \left(\widehat{y}^*_t - \widehat{\overline{y}}^*_t\right)\right] ... \\ & + \left[1 + \frac{\frac{1}{\gamma}(\eta-\eta^*)}{\sigma - \left(\sigma - \frac{1}{\gamma}\right)(\xi-\xi^*)(\eta-\eta^*)}\right]\widehat{d}_t. \end{aligned} \quad (40)$$

This relationship depends on $\widehat{d}_t$ exclusively because in our framework it can be shown that $\left(\widehat{p}^F_t - \widehat{p}^H_t\right) = \left(\widehat{p}^{F*}_t - \widehat{p}^{H*}_t\right)$ (see, e.g., Engel (2009)) implying that $\widehat{d}_t = -\widehat{d}^*_t$. Moreover, we can derive from the definition of the real exchange rate and the consumption price indexes the following relationship,

$$\widehat{rs}_t = (\xi-\xi^*)\widehat{tot}_t - (1+(\xi-\xi^*))\widehat{d}_t, \quad (41)$$

along with the fact that in the frictionless equilibrium $\widehat{\overline{rs}}_t = (\xi - \xi^*)\widehat{\overline{tot}}_t$. Hence, whenever $\xi \neq \xi^*$, we can rewrite the 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,

$$\begin{aligned}
\widehat{\pi}_t = \beta \mathbb{E}_t \left(\widehat{\pi}_{t+1}\right) + \lambda \Big[(\varphi + \gamma) \left(\widehat{y}_t - \widehat{\overline{y}}_t\right) - \\
- \Psi_{\pi,x^*} \left(\sigma - \left(\sigma - \frac{1}{\gamma}\right) (\xi - \xi^*) (\eta - \eta^*) \right) \left(\widehat{tot}_t - \widehat{\overline{tot}}_t\right) + \\
+ \Xi_\pi \left((\xi - \xi^*) \left(\widehat{tot}_t - \widehat{rs}_t\right) \right) \Big],
\end{aligned} \tag{42}$$

where the composite parameter Ξ_π is defined as,

$$\begin{aligned}
\Xi_\pi &\equiv \left(\varphi (1 - \xi) + \gamma \left(\tfrac{\sigma(1-\xi) + \left(\sigma - \frac{1}{\gamma}\right)(\xi - \xi^*)(1-\eta)}{\sigma - \left(\sigma - \frac{1}{\gamma}\right)(\xi - \xi^*)(\eta - \eta^*)} \right) \right) \left(\tfrac{\sigma - \left(\sigma - \frac{1}{\gamma}\right)(\xi - \xi^*)(\eta - \eta^*) + \frac{1}{\gamma}(\eta - \eta^*)}{1 + (\xi - \xi^*)} \right) + \Psi_{\pi,rp} \\
&= \left(\varphi (1 - \xi) + \gamma \left(\tfrac{\sigma(1-\xi) + \left(\sigma - \frac{1}{\gamma}\right)(\xi - \xi^*)(1-\eta)}{\sigma - \left(\sigma - \frac{1}{\gamma}\right)(\xi - \xi^*)(\eta - \eta^*)} \right) \right) \left(\tfrac{\sigma - \left(\sigma - \frac{1}{\gamma}\right)(\xi - \xi^*)(\eta - \eta^*) + \frac{1}{\gamma}(\eta - \eta^*)}{1 + (\xi - \xi^*)} \right) + \\
&+ \gamma\sigma \left(\tfrac{\sigma(1-\xi) + \left(\sigma - \frac{1}{\gamma}\right)(\xi - \xi^*)(1-\eta)}{\sigma - \left(\sigma - \frac{1}{\gamma}\right)(\xi - \xi^*)(\eta - \eta^*)} \right) \left(\tfrac{1 - (\xi - \xi^*)(\eta - \eta^*)}{(\xi - \xi^*)(1 + (\xi - \xi^*))} \right) - \gamma\sigma \left(\tfrac{(1 - \xi^*) - \eta(\xi - \xi^*)}{(\xi - \xi^*)(1 + (\xi - \xi^*))} \right),
\end{aligned} \tag{43}$$

and $\Psi_{\pi,rp}$ was defined in (31). The composite parameters on the domestic output gap and the terms of trade gap are the same as under producer currency pricing, as can be observed in equation (38).

If we make the additional assumption that there is no home bias in consumption (as do Clarida *et al.* (2002) and Woodford (2007)), $\xi = \xi^*$, we can derive the corresponding Phillips Curve in terms of the terms of trade gap as,

$$\begin{aligned}
\widehat{\pi}_t &= \beta \mathbb{E}_t \left(\widehat{\pi}_{t+1}\right) + \lambda (\gamma + \varphi) \Big[\left(\widehat{y}_t - \widehat{\overline{y}}_t\right) - \sigma (1 - \xi) \left(\widehat{tot}_t - \widehat{\overline{tot}}_t\right) \dots \\
&\quad - \left(\sigma (1 - \xi) - \frac{1 - n}{\gamma + \varphi} \right) \widehat{rs}_t \Big].
\end{aligned} \tag{44}$$

The composite parameters on the domestic output gap and the terms of trade gap are the same that follow from equation (42) under no home bias and identical to those of the producer currency pricing specification in (39), but here the real exchange rate suffices to summarize the contribution of the deviations of the law of one price.

Once again, the responsiveness of CPI inflation to the domestic output gap is exactly the same as in the closed economy case (i.e., $\xi = \xi^* = 1$), and the importance of the terms of trade gap is directly proportional to the importance of foreign goods in the consumption basket, $(1 - \xi)$, while the importance of real exchange rate movements that account for deviations of the law of one price depends on the foreign population size, $(1 - n)$.

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 will be 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 dynamics for a long time. More importantly, it tells us that the validity of the global slack hypothesis cannot be determined solely on the basis of simple least squares regressions of the sort reported here and elsewhere in the literature. Ultimately what is needed is a more structural evaluation of the factors influencing inflation dynamics in the open economy.

4 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 dynamics in open economies. 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 share of consumption devoted to foreign-produced goods increases. We also provided some empirical support for the global slack hypothesis, and showed that abstracting from fluctuations in trend inflation (as the theory suggests is appropriate) is important when evaluating the hypothesis. We also noted the conceptual 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 by-pass some of those measurement problems.

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 which would be worth modelling. Two that spring to mind are migration, and international trade in raw materials and intermediate inputs. Recent work by Cortes (2008) and Lach (2007) 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 which are arguably at the heart of the debate about the implications of globalization for inflation and monetary policy, and therein lies another potentially fruitful avenue for future research. In our empirical 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.

We used theory to motivate very simple ordinary least squares and GMM estimates of the Phillips Curve, and there is considerable scope for more sophisticated empirical work. For example, we did not impose any of the parameter restrictions suggested by the theory, nor did we employ theory-consistent measures of slack in our estimates. We also limited ourselves to examining the impact of global slack on inflation dynamics in the United States - a fuller test of the theory would include an analysis of the determinants of inflation in more open economies as well.

Data Appendix

All data were obtained from HAVER Analytics database. Below we use the HAVER mnemonics to describe the exact series we use.

United States:

Personal Consumption Expenditures Price Index - JCBM@USECON;

Personal Consumption Expenditures less Food and Energy Price Index - JCXFEBM@USECON;

Real GDP - GDPH@USECON;

Unemployment rate - LR@USECON;

Capacity utilization rate in manufacturing - C158BCU@OECDMEI;

Real Exchange rate - FXTWBC@USECON;

Terms of trade - JX@USNA/JM@USNA;

Labor share - YCOMPD@USNA/GDP@USECON;

Relative price of oil - JMMP@USNA/JCBM@USECON.

Japan:

Real GDP - C158GDP@OECDNAQ;

Unemployment rate - C158UR@OECDMEI;

Capacity utilization rate in manufacturing - C158BCU@OECDMEI;

U.S. imports from Japan - M111F158@IMFDOTM;

Share of U.S. imports from Japan - FXWIJAP@USECON.

Germany:

Real GDP- C134GDPC@OECDNAQ;

Unemployment rate - C134UR@OECDMEI;

Capacity utilization rate in manufacturing - C134BCU@OECDMEI;

U.S. imports from Germany - M111F134@IMFDOTM.

France:

Real GDP - C132GDPC@OECDNAQ;

Unemployment rate - C132UR@OECDMEI;

Capacity utilization rate in manufacturing - C132BCU@OECDMEI;

U.S. imports from France - M111F132@IMFDOTM.

United Kingdom:

Real GDP - C112GDPC@OECDNAQ;

Unemployment rate - S112ELRQ@G10;

Capacity utilization rate in manufacturing - C112BCU@OECDMEI;

U.S. imports from th eUnited kingdom - M111F112@IMFDOTM;

Share of U.S. imports from the United Kingdom - FXWIUK@USECON.

Italy:

Real GDP - C136GDPC@OECDNAQ;

Unemployment rate - C136UR@OECDMEI;

Capacity utilization rate in manufacturing - C136BCU@OECDMEI;

U.S. imports from Italy - M111F136@IMFDOTM

Canada:

Real GDP - C156GDPC@OECDNAQ;

Unemployment rate - C156UR@OECDMEI;

Capacity utilization rate in manufacturing - C156BCUN@OECDMEI;

U.S. imports from Canada - M111F156@IMFDOTM;

Share of U.S. imports from Canada - FXWICAN@USECON.

Euro area:

Real GDP - J025GDPT@EUROSTAT;

Share of U.S. imports from euro area - FXWIEUR@USECON.

Taiwan:

Real GDP - S528NGPC@EMERGEPR:

Share of U.S. imports from Taiwan - FXWITWN@USECON.

Hong Kong:

Real GDP - F532NGPC@EMERGEPR;

Share of U.S. imports from Hong Kong - FXWIHK@USECON.

Malaysia:

Real GDP - F548NGPC@EMERGEPR;

Share of U.S. imports from Malaysia - FXWIMAL@USECON.

Brazil:

Real GDP - S223GPI@EMERGELA;

Share of U.S. imports from Brazil - FXWIBRZ@USECON.

Switzerland:

Real GDP - S146NGPC@G10;

Share of U.S. imports from Switzerland - FXWISW@USECON.

Thailand:

Real GDP - S578NGPC@EMERGEPR;

Share of U.S. imports from Thailand - FXWITHA@USECON.

Philippines:

Real GDP - F566NGPC@EMERGEPR;

Share of U.S. imports from the Philippines - FXWIPHL@USECON.

Australia:

Real GDP - C193GDPC@OECDNAQ;

Share of U.S. imports from Australia - FXWIAUS@USECON.

Indonesia:

Real GDP - F536NGPC@EMERGEPR;

Share of U.S. imports from Indonesia - FXWIIN@USECON.

India:

Real GDP - H534NGEC@EMERGEPR;

Share of U.S. imports from India - FXWIIND@USECON.

Israel:

Real GDP - S436NGPC@EMERGEMA;

Share of U.S. imports from Israel - FXWIISR@USECON.

Sweden:

Real GDP - C144GDPC@OECDMEI;

Share of U.S. imports from Sweden - FXWISWD@USECON.

Argentina:

Real GDP - S213GPC@EMERGELA;

Share of U.S. imports from Argentina - FXWIARG@USECON.

Chile:

Real GDP - S228GPC@EMERGELA;

Share of U.S. imports from Chile - FXWICHL@USECON.

Colombia:

Real GDP - S233GPC@EMERGELA;

Share of U.S. imports from Colombia - FXWICOL@USECON.

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	Table 1
	Phillips Curve regressions for headline and core inflation
(1)	$\pi_t = \underset{(0.187)}{0.064}\pi_{t-1} - \underset{(0.036)}{0.013}CU_t^{US} + \underset{(0.071)^{**}}{0.220}\ CU_t^{G6}$
	Sample period: 1985:I to 2009:II; $\overline{R}^2 = 0.30; NR^2 = 15.57^{***}$
(2)	$\pi_t^{Core} = \underset{(0.064)^{***}}{0.723}\ \pi_{t-1}^{Core} - \underset{(0.015)}{0.009}CU_t^{US} + \underset{(0.028)}{0.043}CU_t^{G6}$
	Sample period = 1985:I to 2009:II; $\overline{R}^2 = 0.64; NR^2 = 15.84^{***}$
(3)	$\pi_t = \underset{(0.076)^{***}}{0.687}\ \pi_t + \underset{(0.081)}{0.127}UR_t^{US} - \underset{(0.162)^{***}}{0.452}\ UR_t^{G6}$
	Sample period = 1971:I to 2009:II; $\overline{R}^2 = 0.69$; $NR^2 = 18.90^{***}$
(4)	$\pi_t^{Core} = \underset{(0.061)^{***}}{0.831}\ \pi_{t-1}^{Core} + \underset{(0.074)}{0.067}UR_t^{US} - \underset{(0.117)^{**}}{0.231}\ UR_t^{G6}$
	Sample period = 1971:I to 2009:II; $\overline{R}^2 = 0.84$; $NR^2 = 9.07^{*}$
(5)	$\pi_t = \underset{(0.197)}{0.039}\pi_{t-1} - \underset{(0.159)}{0.018}\widehat{y}_t^{US} + \underset{(0.398)^{*}}{0.726}\,\widehat{y}_t^{G6}$
	Sample period = 1991:I to 2009:II; $\overline{R}^2 = 0.20; NR^2 = 21.80^{***}$
(6)	$\pi_t^{Core} = \underset{(0.104)^{***}}{0.539}\ \pi_{t-1}^{Core} - \underset{(0.112)}{0.126}\widehat{y}_t^{US} + \underset{(0.099)^{*}}{0.197}\,\widehat{y}_t^{G6}$
	Sample period = 1991:I to 2009:II; $\overline{R}^2 = 0.39; NR^2 = 7.16$

Notes to Table 1: All regressions include a constant (not reported). Newey-West HAC standard errors in parentheses. *** denotes significance at the 1% level; ** denotes significance at the 5% level; * denotes significance at the 10% level. π_t is measured as the annualized quarterly change in the PCE deflator. π_t^{Core} is measured as the annualized quarterly change in the PCE deflator excluding food and energy. CU^{US} is measured as the rate of capacity utilization in US manufacturing. CU^{G6} is measured as an import-weighted average of the rates of capacity utilization in manufacturing in the other G7 countries. UR^{US} is measured as the unemployment rate in the US. UR^{G6} is measured as an import-weighted average of the unemployment rates in the other G7 countries. $\widehat{y}_t^{US}$ is measured as the cyclical component of US GDP. $\widehat{y}_t^{G6}$ is measured as an import-weighted average of the cyclical component of GDP in the other G7 countries. Cyclical components are defined using the Hodrick-Prescott filter with smoothing parameter $\lambda = 1600$. NR^2 is the Breusch-Godfrey Lagrange multiplier test statistic for serial correlation up to order 4 which has an asymptotic $\chi^2(4)$ distribution under the null hypothesis of no serial correlation.

Table 2

Phillips Curve regressions for cyclical components of inflation

(1) $$\widehat{\pi}_t = \underset{(0.142)}{-0.132}\widehat{\pi}_{t-1} + \underset{(0.068)}{0.088}\widehat{CU}_t^{US} + \underset{(0.101)^{*}}{0.176}\,\widehat{CU}_t^{G6}$$

Sample period: 1985:I to 2009:II; $\overline{R}^2$ =0.17; NR^2 =19.36***

(2) $$\widehat{\pi}_t^{Core} = \underset{(0.107)}{0.049}\widehat{\pi}_{t-1}^{Core} + \underset{(0.035)}{0.023}\widehat{CU}_t^{US} + \underset{(0.034)}{0.047}\widehat{CU}_t^{G6}$$

Sample period: 1985:I to 2009:II; $\overline{R}^2$ =0.10; NR^2 =6.19

(3) $$\widehat{\pi}_t = \underset{(0.110)^{***}}{0.307}\ \widehat{\pi}_t - \underset{(0.161)^{**}}{0.403}\ \widehat{UR}_t^{US} - \underset{(0.368)}{0.525}\widehat{UR}_t^{G6}$$

Sample period: 1971:I to 2009:II; $\overline{R}^2$ =0.28; NR^2 =12.13**

(4) $$\widehat{\pi}_t^{Core} = \underset{(0.146)^{***}}{0.473}\ \widehat{\pi}_{t-1}^{Core} - \underset{(0.138)}{0.012}\widehat{UR}_t^{US} - \underset{(0.268)^{**}}{0.603}\ \widehat{UR}_t^{G6}$$

Sample period: 1971:I to 2009:II; $\overline{R}^2$ =0.38; NR^2 =2.23

(5) $$\widehat{\pi}_t = \underset{(0.177)}{-0.205}\widehat{\pi}_{t-1} + \underset{(0.122)}{0.182}\widehat{y}_t^{US} + \underset{(0.316)^{**}}{0.764}\ \widehat{y}_t^{G6}$$

Sample period: 1991:I to 2009:II; $\overline{R}^2$ =0.29; NR^2 =18.57***

(6) $$\widehat{\pi}_t^{Core} = \underset{(0.106)^{*}}{-0.202}\widehat{\pi}_{t-1}^{Core} - \underset{(0.073)}{0.091}\widehat{y}_t^{US} + \underset{(0.083)^{***}}{0.374}\ \widehat{y}_t^{G6}$$

Sample period: 1991:I to 2009:II; $\overline{R}^2$ =0.28; NR^2 =8.09*

Notes to Table 2: All regressions include a constant (not reported). Newey-West HAC standard errors in parentheses. *** denotes significance at the 1% level; ** denotes significance at the 5% level; * denotes significance at the 10% level. $\widehat{\pi}_t$ is measured as the cyclical component of the annualized quarterly change in the PCE deflator. $\widehat{\pi}_t^{Core}$ is measured as the cyclical component of the annualized quarterly change in the PCE deflator. $\widehat{CU}^{US}$ is measured as the cyclical component of the rate of capacity utilization in US manufacturing. $\widehat{CU}^{G6}$ is measured as the cyclical component of an import-weighted average of the rates of capacity utilization in manufacturing in the other G7 countries. $\widehat{UR}^{US}$ is measured as the cyclical component of the unemployment rate in the US. $\widehat{UR}^{G6}$ is measured as the cyclical component of an import-weighted average of the unemployment rates in the other G7 countries. $\widehat{y}_t^{US}$ is measured as the cyclical component of US GDP. $\widehat{y}_t^{G6}$ is measured as an import-weighted average of the cyclical component of GDP in the other G7 countries. Cyclical components are defined using the Hodrick-Prescott filter with smoothing parameter $\lambda = 1600$. Breusch-Godfrey NR^2 is the Breusch-Godfrey Lagrange multiplier test statistic for serial correlation up to order 4 which has an asymptotic $\chi^2(4)$ distribution under the null hypothesis of no serial correlation.

Table 3

Phillips Curve regressions including terms of trade and real exchange rate

(1) $\widehat{\pi}_t = \underset{(0.152)^{**}}{-0.332}\widehat{\pi}_{t-1} + \underset{(0.067)}{0.097}\widehat{CU}_t^{US} + \underset{(0.072)^{*}}{0.120}\widehat{CU}_t^{G6} - \underset{(0.069)^{***}}{0.330}\widehat{tot}_t - \underset{(0.043)}{0.010}\widehat{rer}_t$

Sample period: 1985:I to 2009:II; $\overline{R}^2$ =0.31; NR^2 =37.98***

(2) $\widehat{\pi}_t^{Core} = \underset{(0.126)}{-0.007}\widehat{\pi}_{t-1}^{Core} - \underset{(0.032)}{0.001}\widehat{CU}_t^{US} + \underset{(0.036)}{0.055}\widehat{CU}_t^{G6} + \underset{(0.031)}{0.014}\widehat{tot}_t - \underset{(0.017)^{**}}{0.035}\widehat{rer}_t$

Sample period: 1985:I to 2009:II; $\overline{R}^2$ =0.12; NR^2 =9.26*

(3) $\widehat{\pi}_t = \underset{(0.112)}{-0.008}\widehat{\pi}_{t-1} - \underset{(0.247)^{***}}{0.906}\widehat{UR}_t^{US} + \underset{(0.508)}{0.574}\widehat{UR}_t^{G6} - \underset{(0.066)^{***}}{0.289}\widehat{tot}_t - \underset{(0.037)}{0.034}\widehat{rer}_t$

Sample period: 1973:I to 2009:II; $\overline{R}^2$ =0.39; NR^2 =23.15***

(4) $\widehat{\pi}_t^{Core} = \underset{(0.144)}{0.219}\widehat{\pi}_{t-1}^{Core} - \underset{(0.174)}{0.165}\widehat{UR}_t^{US} - \underset{(0.330)}{0.088}\widehat{UR}_t^{G6} - \underset{(0.049)^{***}}{0.167}\widehat{tot}_t + \underset{(0.021)}{0.003}\widehat{rer}_t$

Sample period: 1973:I to 2009:II; $\overline{R}^2$ =0.46; NR^2 =2.54

(5) $\widehat{\pi}_t = \underset{(0.175)^{***}}{-0.472}\widehat{\pi}_{t-1} + \underset{(0.150}{0.072}\widehat{y}_t^{US} + \underset{(0.331)^{*}}{0.639}\widehat{y}_t^{G6} - \underset{(0.090)^{***}}{0.265015}\widehat{tot}_t - \underset{(0.063)^{**}}{0.138}\widehat{rer}_t$

Sample period:1991:I to 2009:II; $\overline{R}^2$ =0.47; NR^2 =27.85***

(6) $\widehat{\pi}_t^{Core} = \underset{(0.107)^{**}}{-0.221}\widehat{\pi}_{t-1}^{Core} - \underset{(0.071)}{0.102}\widehat{y}_t^{US} + \underset{(0.074)^{***}}{0.350}\widehat{y}_t^{G6} + \underset{(0.036)}{0.011}\widehat{tot}_t - \underset{(0.014)^{**}}{0.040}\widehat{rer}_t$

Sample period: 1991:I to 2009:II; $\overline{R}^2$ =0.31; NR^2 =7.96*

Notes to Table 3: All regressions include a constant (not reported). Newey-West HAC standard errors in parentheses. *** denotes significance at the 1% level; ** denotes significance at the 5% level; * denotes significance at the 10% level. $\widehat{\pi}_t$ is measured as the cyclical component of the annualized quarterly change in the PCE deflator. $\widehat{\pi}_t^{Core}$ is measured as the cyclical component of the annualized quarterly change in the PCE deflator. $\widehat{CU}^{US}$ is measured as the cyclical component of the rate of capacity utilization in US manufacturing. $\widehat{CU}^{G6}$ is measured as the cyclical component of an import-weighted average of the rates of capacity utilization in manufacturing in the other G7 countries. $\widehat{tot}_t$ is measured as the cyclical component of the US terms of trade (defined as the ratio of the deflator for exports of goods and services to the deflator for imports of goods and services in the national income and product accounts). $\widehat{rer}_t$ is measured as the cyclical component of the real trade weighted value of the dollar. $\widehat{UR}^{US}$ is measured as the cyclical component of the unemployment rate in the US. $\widehat{UR}^{G6}$ is measured as the cyclical component of an import-weighted average of the unemployment rates in the other G7 countries. $\widehat{y}_t^{US}$ is measured as the cyclical component of US GDP. $\widehat{y}_t^{G6}$ is measured as an import-weighted average of the cyclical component of GDP in the other G7 countries. Cyclical components are defined using the Hodrick-Prescott filter with smoothing parameter $\lambda = 1600$. Breusch-Godfrey NR^2 is the Breusch-Godfrey Lagrange multiplier test statistic for serial correlation up to order 4 which has an asymptotic $\chi^2(4)$ distribution under the null hypothesis of no serial correlation.

Table 4

Phillips Curve regressions including broadest measure of global slack

(1) $$\widehat{\pi}_t = \underset{(0.190)}{-0.217}\widehat{\pi}_{t-1} + \underset{(0.228)}{0.124}\widehat{y}_t^{US} + \underset{(0.591)^{**}}{1.236}\,\widehat{y}_t^{G26}$$

Sample period: 1996:II to 2009:I; $\overline{R}^2$ =0.30; NR^2 =18.68***

(2) $$\widehat{\pi}_t^{Core} = \underset{(0.108)^{**}}{-0.225}\widehat{\pi}_{t-1}^{Core} + \underset{(0.082)}{0.020}\widehat{y}_t^{US} + \underset{(0.121)^{***}}{0.347}\,\widehat{y}_t^{G26}$$

Sample period: 1996:II to 2009:I; $\overline{R}^2$ =0.23; NR^2 =10.30**

(3) $$\widehat{\pi}_t = \underset{(0.178)^{**}}{-0.430}\widehat{\pi}_{t-1} + \underset{(0.261)}{0.090}\widehat{y}_t^{US} + \underset{(0.620)}{0.782}\widehat{y}_t^{G26} - \underset{(0.114)^{**}}{0.260}\,\widehat{tot}_t - \underset{(0.067)^{**}}{0.143}\,\widehat{rer}_t$$

Sample period: 1996:II to 2009:I; $\overline{R}^2$ =0.43; NR^2 =27.25***

(4) $$\widehat{\pi}_t^{Core} = \underset{(0.122)^{*}}{-0.223}\widehat{\pi}_{t-1}^{Core} + \underset{(0.084)}{0.005}\widehat{y}_t^{US} + \underset{(0.133)^{**}}{0.286}\,\widehat{y}_t^{G26} - \underset{(0.036)}{0.009}\widehat{tot}_t - \underset{(0.017)^{*}}{0.030}\,\widehat{rer}_t$$

Sample period: 1996:II to 2009:I; $\overline{R}^2$ =0.23; NR^2 =9.86**

Notes to Table 4: All regressions include a constant (not reported). Newey-West HAC standard errors in parentheses. *** denotes significance at the 1% level; ** denotes significance at the 5% level; * denotes significance at the 10% level. $\widehat{\pi}_t$ is measured as the cyclical component of the annualized quarterly change in the PCE deflator. $\widehat{\pi}_t^{Core}$ is measured as the cyclical component of the annualized quarterly change in the PCE deflator. $\widehat{y}_t^{US}$ is measured as the cyclical component of U.S. GDP. $\widehat{y}_t^{G26}$ is measured as an import-weighted average of the cyclical component of GDP in the U.S.' main trading partners. We include all trading partners with quarterly real GDP series available from 1996, and allow the weights to change over time to reflect changing trade patterns. The countries included are the euro area, Canada, Japan, U.K., Taiwan, Hong Kong, Malaysia, Brazil, Switzerland, Thailand, Philippines, Australia, Indonesia, India, Israel, Sweden, Argentina, Chile and Colombia. $\widehat{tot}_t$ is measured as the cyclical component of the U.S. terms of trade (defined as the ratio of the deflator for exports of goods and services to the deflator for imports of goods and services in the national income and product accounts). $\widehat{rer}_t$ is measured as the cyclical component of the real trade weighted value of the dollar. Cyclical components are defined using the Hodrick-Prescott filter with smoothing parameter $\lambda = 1600$. Breusch-Godfrey NR^2 is the Breusch-Godfrey Lagrange multiplier test statistic for serial correlation up to order 4 which has an asymptotic $\chi^2(4)$ distribution under the null hypothesis of no serial correlation.

Table 5

GMM estimates of Phillips Curve

(1) $$\widehat{\pi}_t = \underset{(0.155)^{***}}{0.659}\ \mathbb{E}_t\widehat{\pi}_{t+1} - \underset{(0.127)}{0.048}\widehat{y}_t^{US} + \underset{(0.389)^{***}}{0.402}\ \widehat{y}_t^{G6}$$

(2) $$\widehat{\pi}_t^{Core} = \underset{(0.163)^{**}}{0.492}\ \mathbb{E}_t\widehat{\pi}_{t+1}^{Core} + \underset{(0.055)}{0.012}\widehat{y}_t^{US} + \underset{(0.039)^{***}}{0.231}\ \widehat{y}_t^{G6}$$

(3) $$\widehat{\pi}_t = \underset{(0.170)^{***}}{0.453}\ \mathbb{E}_t\widehat{\pi}_{t+1} + \underset{(0.140)^{*}}{0.285}\,\widehat{y}_t^{US} + \underset{(0.129)}{0.161}\widehat{y}_t^{G6} + \underset{(0.063)}{0.052}\widehat{tot}_t - \underset{(0.049)^{**}}{0.127}\ \widehat{rer}_t$$

(4) $$\widehat{\pi}_t^{Core} = \underset{(0.215)}{0.246}\mathbb{E}_t\widehat{\pi}_{t+1}^{Core} - \underset{(0.054)}{0.015}\widehat{y}_t^{US} + \underset{(0.053)^{***}}{0.248}\ \widehat{y}_t^{G6} + \underset{(0.034)^{***}}{0.105}\ \widehat{tot}_t - \underset{(0.023)^{***}}{0.077}\ \widehat{rer}_t$$

(5) $$\widehat{\pi}_t = \underset{(0.165)^{***}}{0.765}\ \mathbb{E}_t\widehat{\pi}_{t+1} + \underset{(0.143)^{*}}{0.276}\,\widehat{y}_t^{US} + \underset{(0.113)^{***}}{0.379}\ \widehat{y}_t^{G26}$$

(6) $$\widehat{\pi}_t^{Core} = \underset{(0.153)}{-0.100}\mathbb{E}_t\widehat{\pi}_{t+1}^{Core} + \underset{(0.046)^{**}}{0.111}\ \widehat{y}_t^{US} + \underset{(0.037)^{***}}{0.202}\ \widehat{y}_t^{G26}$$

(7) $$\widehat{\pi}_t = \underset{(0.183)^{***}}{0.573}\ \mathbb{E}_t\widehat{\pi}_{t+1} + \underset{(0.167)^{***}}{0.472}\ \widehat{y}_t^{US} + \underset{(0.181)}{0.242}\widehat{y}^{G26} + \underset{(0.088)}{0.101}\widehat{tot}_t - \underset{(0.056)^{**}}{0.121}\ \widehat{rer}_t$$

(8) $$\widehat{\pi}_t^{Core} = \underset{(0.222)}{-0.363}\mathbb{E}_t\widehat{\pi}_{t+1}^{Core} + \underset{(0.055)}{0.076}\widehat{y}_t^{US} + \underset{(0.080)^{***}}{0.400}\ \widehat{y}_t^{G26} + \underset{(0.042)^{***}}{0.124}\ \widehat{tot}_t - \underset{(0.026)^{***}}{0.102}\ \widehat{rer}_t$$

Notes to Table 5: Sample period for equations (1)-(4) is 1992:1 to 2009:I, for equations (5)-(8) is 1996:III to 2009:I. *** denotes significance at the 1% level; ** denotes significance at the 5% level; * denotes significance at the 10% level. $\widehat{\pi}_t$ is measured as the cyclical component of the annualized quarterly change in the PCE deflator. $\widehat{\pi}_t^{Core}$ is measured as the cyclical component of the annualized quarterly change in the PCE deflator. $\widehat{y}_t^{US}$ is measured as the cyclical component of U.S. GDP. $\widehat{y}_t^{G26}$ is measured as an import-weighted average of the cyclical component of GDP in the U.S.' main trading partners. We include all trading partners with quarterly real GDP series available from 1996, and allow the weights to shift over time to reflect changing trade patterns. The countries included are the euro area, Canada, Japan, U.K., Taiwan, Hong Kong, Malaysia, Brazil, Switzerland, Thailand, Philippines, Australia, Indonesia, India, Israel, Sweden, Argentina, Chile and Colombia. $\widehat{tot}_t$ is measured as the cyclical component of the U.S. terms of trade (defined as the ratio of the deflator for exports of goods and services to the deflator for imports of goods and services in the national income and product accounts). $\widehat{rer}_t$ is measured as the cyclical component of the real trade weighted value of the dollar. Cyclical components are defined using the Hodrick-Prescott filter with smoothing parameter $\lambda = 1600$. The instrument set for equations (1)-(4) consists of four lags of the headline PCE inflation rate, four lags of the cyclical component of the labor share in the US, four lags of the import-weighted labor share in the other G7 countries, one lag of the output gap in the US, one lag of the output gap in the other G7 countries and four lags of the relative price of oil in the US. We use the same instruments for equations (5)-(8), except that we replace the lag of output gap in the other G7 countries with one lag of the trade weighted output gap in the broader group of countries.

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 the home and foreign bundles	$\sigma > 0$
Preference of the domestic consumer for home goods	$0 < \xi < 1$
Preference of the foreign consumer for home goods	$0 < \xi^* < 1$
Domestic population size	$0 < n < 1$
Foreign population size	$0 < 1 - n < 1$
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	$\psi_x > 1$

Table A1- Notation

	Home	Foreign
	Real variables	
Output of domestic variety h	$Y_t(h)$	-
Output of foreign variety f	-	$Y_t^*(f)$
Potential output of domestic variety h	$\overline{Y}_t(h)$	-
Potential output of foreign variety f	-	$\overline{Y}_t^*(f)$
Labor demand for domestic variety h	$L_t\,(h)$	-
Labor demand for foreign variety f	-	$L_t^*\,(f)$
Aggregate labor supply	nL_t	$(1-n)\,L_t^*$
Consumption of domestic variety h	$C_t(h)$	$C_t^*(h)$
Consumption of foreign variety f	$C_t(f)$	$C_t^*(f)$
	Nominal variables	
Price of domestic variety h	$P_t(h)$	$P_t^*(h)$
Price of foreign variety f	$P_t(f)$	$P_t^*(f)$
Optimal re-optimzing price of domestic variety h	$\widetilde{P}_t(h)$	$\widetilde{P}_t^*(h)$
Optimal re-optimzing price of foreign variety f	$\widetilde{P}_t(f)$	$\widetilde{P}_t^*(f)$
Demand of domestic contingent bonds	$B^H\,(\omega_t \mid \omega_{t-1})$	$B^{H*}\,(\omega_t \mid \omega_{t-1})$
Demand of foreign contingent bonds	$B^F\,(\omega_t \mid \omega_{t-1})$	$B^{F*}\,(\omega_t \mid \omega_{t-1})$
Contingent bond prices	$Q\,(\omega_t \mid \omega_{t-1})$	$Q^*\,(\omega_t \mid \omega_{t-1})$
Nominal exchange rate	S_t	$\frac{1}{S_t}$
Profits from domestic variety h	$\Pi_t\,(h)$	-
Profits from foreign variety f	-	$\Pi_t^*\,(f)$
Nominal wage of domestic variety h	$W_t\,(h) = W_t$	-
Nominal wage of foreign variety f	-	$W_t^*\,(f) = W_t^*$
Lump sum taxes	T_t	T_t^*
	Shocks	
Total factor productivity	A_t	A_t^*
Monetary policy shocks	Z_t	Z_t^*
	Useful definitions	
Real exchange rate	$RS_t \equiv \frac{S_t P_t^*}{P_t}$	$\frac{1}{RS_t}$
Terms of trade	$ToT_t \equiv \frac{P_t^F}{S_t P_t^{H*}}$	$\frac{1}{ToT_t}$
Marginal costs (after subsidies)	$MC_t\,(h) = MC_t \equiv \frac{(1-\phi_t)W_t}{A_t}$	$MC_t^*\,(f) = MC_t^* \equiv \frac{(1-\phi_t)W_t}{A_t}$
Aggregate profits	$n\Pi_t \equiv \int_0^n \Pi_t\,(h)\,dh$ $= \int_0^n \left[\begin{array}{c} P_t\,(h)\,nC_t\,(h) + S_t P_t^*\,(h)\,(1-n)\,C_t^*\,(h) - \\ -\,(1+\phi_t)\,W_t L_t\,(h) \end{array} \right] dh$	$(1-n)\,\Pi_t^* \equiv \int_n^1 \Pi_t^*\,(f)\,df$ $= \int_n^1 \left[\begin{array}{c} \frac{1}{S_t} P_t\,(f)\,nC_t\,(f) + P_t^*\,(f)\,(1-n)\,C_t^*\,(f) - \\ -\,(1+\phi_t^*)\,W_t^* L_t^*\,(f) \end{array} \right] df$
Aggregate output	$nY_t \equiv \int_0^n Y_t\,(h)\,dh$	$(1-n)\,Y_t^* \equiv \int_n^1 Y_t^*\,(f)\,df$
Aggregate potential output	$n\overline{Y}_t \equiv \int_0^n \overline{Y}_t\,(h)\,dh$	$(1-n)\,\overline{Y}_t^* \equiv \int_n^1 \overline{Y}_t^*\,(f)\,df$
Intertemporal marginal rate of substitution	$m_{t,t+\tau} \equiv \beta^\tau \left(\frac{C_{t+\tau}}{C_t}\right)^{-\gamma} \frac{P_t}{P_{t+\tau}}$	$m_{t,t+\tau}^* \equiv \beta \left(\frac{C_{t+\tau}^*}{C_t^*}\right)^{-\gamma} \frac{P_t^*}{P_{t+\tau}^*}$
Short-term (gross) interest rates	$1 + i_t \equiv \frac{1}{\int_{\omega_{t+1}\in\Omega} Q(\omega_{t+1}\vert\omega_t)}$	$1 + i_t^* \equiv \frac{1}{\int_{\omega_{t+1}\in\Omega} Q^*(\omega_{t+1}\vert\omega_t)}$

Table A2 - Households

	Home	Foreign
Optimization		
Lifetime utility	$\mathbb{E}_t \sum_{\tau=0}^{+\infty} \beta^{\tau} \left[\frac{1}{1-\gamma}(C_{t+\tau})^{1-\gamma} - \frac{1}{1+\varphi}\left(L_{t+\tau}\right)^{1+\varphi}\right]$	$\mathbb{E}_t \sum_{\tau=0}^{+\infty} \beta^{\tau} \left[\frac{1}{1-\gamma}\left(C^*_{t+\tau}\right)^{1-\gamma} - \frac{1}{1+\varphi}\left(L^*_{t+\tau}\right)^{1+\varphi}\right]$
Aggregate consumption	$C_t \equiv \left[\xi^{\frac{1}{\sigma}}\left(C_t^H\right)^{\frac{\sigma-1}{\sigma}} + (1-\xi)^{\frac{1}{\sigma}}\left(C_t^F\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$	$C^*_t \equiv \left[(\xi^*)^{\frac{1}{\sigma}}\left(C_t^{H*}\right)^{\frac{\sigma-1}{\sigma}} + (1-\xi^*)^{\frac{1}{\sigma}}\left(C_t^{F*}\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$
Consumption bundle of domestic varieties	$C_t^H \equiv \left[\left(\frac{1}{n}\right)^{\frac{1}{\theta}} \int_0^n C_t(h)^{\frac{\theta-1}{\theta}}\, dh\right]^{\frac{\theta}{\theta-1}}$	$C_t^{H*} \equiv \left[\left(\frac{1}{n}\right)^{\frac{1}{\theta}} \int_0^n C^*_t(h)^{\frac{\theta-1}{\theta}}\, dh\right]^{\frac{\theta}{\theta-1}}$
Consumption bundle of foreign varieties	$C_t^F \equiv \left[\left(\frac{1}{1-n}\right)^{\frac{1}{\theta}} \int_n^1 C_t(f)^{\frac{\theta-1}{\theta}}\, df\right]^{\frac{\theta}{\theta-1}}$	$C_t^{F*} \equiv \left[\left(\frac{1}{1-n}\right)^{\frac{1}{\theta}} \int_n^1 C^*_t(f)^{\frac{\theta-1}{\theta}}\, df\right]^{\frac{\theta}{\theta-1}}$
Budget constraint	$P_t C_t + \int_{\omega_{t+1}\in\Omega} Q\left(\omega_{t+1} \mid \omega_t\right) B^H\left(\omega_{t+1} \mid \omega_t\right) +$ $+S_t \int_{\omega_{t+1}\in\Omega} Q^*\left(\omega_{t+1} \mid \omega_t\right) B^F\left(\omega_{t+1} \mid \omega_t\right)$ $\leq \frac{1}{S_t} B^H\left(\omega_t \mid \omega_{t-1}\right) + B^F\left(\omega_t \mid \omega_{t-1}\right) + W_t L_t + \Pi_t - T_t$	$P^*_t C^*_t + \frac{1}{S_t}\int_{\omega_{t+1}\in\Omega} Q\left(\omega_{t+1} \mid \omega_t\right) B^{H*}\left(\omega_{t+1} \mid \omega_t\right) +$ $+\int_{\omega_{t+1}\in\Omega} Q^*\left(\omega_{t+1} \mid \omega_t\right) B^{F*}\left(\omega_{t+1} \mid \omega_t\right)$ $\leq \frac{1}{S_t} B^{H*}\left(\omega_t \mid \omega_{t-1}\right) + B^{F*}\left(\omega_t \mid \omega_{t-1}\right) + W^*_t L^*_t + \Pi^*_t - T^*_t$
Equilibrium conditions		
Consumption price level	$P_t = \left[\xi\left(P_t^H\right)^{1-\sigma} + (1-\xi)\left(P_t^F\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}$	$P^*_t = \left[\xi^*\left(P_t^{H*}\right)^{1-\sigma} + (1-\xi^*)\left(P_t^{F*}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}$
Price sub-index of the bundle of domestic varieties	$P_t^H = \left[\frac{1}{n}\int_0^n P_t(h)^{1-\theta}\, dh\right]^{\frac{1}{1-\theta}} = \left[\alpha\left(P_{t-1}^H\right)^{1-\theta} + (1-\alpha)\left(\tilde{P}_t(h)\right)^{1-\theta}\right]^{\frac{1}{1-\theta}}$	$P_t^{H*} = \left[\frac{1}{n}\int_0^n P^*_t(h)^{1-\theta}\, dh\right]^{\frac{1}{1-\theta}} = \left[\alpha\left(P_{t-1}^{H*}\right)^{1-\theta} + (1-\alpha)\left(\tilde{P}^*_t(h)\right)^{1-\theta}\right]^{\frac{1}{1-\theta}}$
Price sub-index of the bundle of foreign varieties	$P_t^F = \left[\frac{1}{1-n}\int_n^1 P_t(f)^{1-\theta}\, df\right]^{\frac{1}{1-\theta}} = \left[\alpha\left(P_{t-1}^F\right)^{1-\theta} + (1-\alpha)\left(\tilde{P}_t(f)\right)^{1-\theta}\right]^{\frac{1}{1-\theta}}$	$P_t^{F*} = \left[\frac{1}{1-n}\int_n^1 P^*_t(f)^{1-\theta}\, df\right]^{\frac{1}{1-\theta}} = \left[\alpha\left(P_{t-1}^{F*}\right)^{1-\theta} + (1-\alpha)\left(\tilde{P}^*_t(f)\right)^{1-\theta}\right]^{\frac{1}{1-\theta}}$
Demand for domestic variety h	$C_t(h) = \frac{1}{n}\left(\frac{P_t(h)}{P_t^H}\right)^{-\theta} C_t^H = \frac{\xi}{n}\left(\frac{P_t(h)}{P_t^H}\right)^{-\theta}\left(\frac{P_t^H}{P_t}\right)^{-\sigma} C_t$	$C^*_t(h) = \frac{1}{n}\left(\frac{P^*_t(h)}{P_t^{H*}}\right)^{-\theta} C_t^{H*} = \frac{\xi^*}{n}\left(\frac{P^*_t(h)}{P_t^{H*}}\right)^{-\theta}\left(\frac{P_t^{H*}}{P^*_t}\right)^{-\sigma} C^*_t$
Demand for foreign variety f	$C_t(f) = \frac{1}{1-n}\left(\frac{P_t(f)}{P_t^F}\right)^{-\theta} C_t^F = \frac{1-\xi}{1-n}\left(\frac{P_t(f)}{P_t^F}\right)^{-\theta}\left(\frac{P_t^F}{P_t}\right)^{-\sigma} C_t$	$C^*_t(f) = \frac{1}{1-n}\left(\frac{P^*_t(f)}{P_t^{F*}}\right)^{-\theta} C_t^{F*} = \frac{1-\xi^*}{1-n}\left(\frac{P^*_t(f)}{P_t^{F*}}\right)^{-\theta}\left(\frac{P_t^{F*}}{P^*_t}\right)^{-\sigma} C^*_t$
Intratemporal efficiency condition	$\frac{W_t}{P_t} = (C_t)^{\gamma}(L_t)^{\varphi}$	$\frac{W^*_t}{P^*_t} = \left(C^*_t\right)^{\gamma}\left(L^*_t\right)^{\varphi}$
Intertemporal efficiency condition	$Q\left(\omega_{t+1} \mid \omega_t\right) = \beta\left(\frac{C\left(\omega_{t+1}\right)}{C\left(\omega_t\right)}\right)^{-\gamma}\frac{P\left(\omega_t\right)}{P\left(\omega_{t+1}\right)}\mu\left(\omega_{t+1} \mid \omega_t\right),$	$Q^*\left(\omega_{t+1} \mid \omega_t\right) = \beta\left(\frac{C^*\left(\omega_{t+1}\right)}{C^*\left(\omega_t\right)}\right)^{-\gamma}\frac{P^*\left(\omega_t\right)}{P^*\left(\omega_{t+1}\right)}\mu\left(\omega_{t+1} \mid \omega_t\right)$
International perfect risk-sharing condition	$RS_t = \left(\frac{C^*_t}{C_t}\right)^{-\gamma}$	

Table A3 - Firms

	Home	Foreign
Optimization (potential, without nominal rigidities)		
Profits for firm h	$\left(nC_t^d(h)+(1-n)C_t^{d*}(h)\right)(P_t(h)-MC_t)$	-
Profits for firm f	-	$\left(nC_t^d(f)+(1-n)C_t^{d*}(f)\right)\left(P_t^*(f)-MC_t^*\right)$
Technology	$Y_t(h)=A_tL_t(h)$	$Y_t^*(f)=A_t^*L_t^*(f)$
Aggregate demand constraint	$nC_t^d(h)+(1-n)C_t^{d*}(h) = \left(\frac{P_t(h)}{P_t^H}\right)^{-\theta}\left(n\frac{\xi}{n}\left(\frac{P_t^H}{P_t}\right)^{-\sigma}C_t+(1-n)\frac{\xi^*}{n}\left(\frac{P_t^{H*}}{P_t^*}\right)^{-\sigma}C_t^*\right)$	$nC_t^d(f)+(1-n)C_t^{d*}(f) = \left(\frac{P_t^*(f)}{P_t^{F*}}\right)^{-\theta}\left(n\frac{1-\xi}{1-n}\left(\frac{P_t^F}{P_t}\right)^{-\sigma}C_t+(1-n)\frac{1-\xi^*}{1-n}\left(\frac{P_t^{F*}}{P_t^*}\right)^{-\sigma}C_t^*\right)$
Equilibrium conditions (potential, without nominal rigidities)		
Optimal pricing of firm h	$P_t(h)=\frac{\theta}{\theta-1}MC_t$	$P_t^*(h)=\frac{1}{S_t}P_t(h)$
Optimal pricing of firm f	$P_t(f)=S_tP_t^*(f)$	$P_t^*(f)=\frac{\theta}{\theta-1}MC_t^*$
Potential output for firm h	$\overline{Y}_t(h)=nC_t^d(h)+(1-n)C_t^{d*}(h)$	-
Potential output for firm f	-	$\overline{Y}_t^*(f)=nC_t^d(f)+(1-n)C_t^{d*}(f)$
Optimization (PCP)		
Present discounted value of profits for re-optimizing h	$\mathbb{E}_t\sum_{\tau=0}^{+\infty}\alpha^\tau m_{t,t+\tau}\left[\left(n\widetilde{C}_{t,t+\tau}^d(h)+(1-n)\widetilde{C}_{t,t+\tau}^{d*}(h)\right)\left(\widetilde{P}_t(h)-MC_{t+\tau}\right)\right]$	-
Present discounted value of profits for re-optimizing f	-	$\mathbb{E}_t\sum_{\tau=0}^{+\infty}\left[\alpha^\tau m_{t,t+\tau}^*\left(n\widetilde{C}_{t,t+\tau}^d(f)+(1-n)\widetilde{C}_{t,t+\tau}^{d*}(f)\right)\left(\widetilde{P}_t^*(f)-MC_{t+\tau}^*\right)\right]$
Technology	$Y_t(h)=A_tL_t(h)$	$Y_t^*(f)=A_t^*L_t^*(f)$
Aggregate demand constraint	$n\widetilde{C}_{t,t+\tau}^d(h)+(1-n)\widetilde{C}_{t,t+\tau}^{d*}(h) = \left(\frac{\widetilde{P}_t(h)}{P_{t+\tau}^H}\right)^{-\theta}\left(n\frac{\xi}{n}\left(\frac{P_{t+\tau}^H}{P_{t+\tau}}\right)^{-\sigma}C_{t+\tau}+(1-n)\frac{\xi^*}{n}\left(\frac{P_{t+\tau}^{H*}}{P_{t+\tau}^*}\right)^{-\sigma}C_{t+\tau}^*\right)$	$n\widetilde{C}_{t,t+\tau}^d(f)+(1-n)\widetilde{C}_{t,t+\tau}^{d*}(f) = \left(\frac{\widetilde{P}_t^*(f)}{P_{t+\tau}^{F*}}\right)^{-\theta}\left(n\frac{1-\xi}{1-n}\left(\frac{P_{t+\tau}^F}{P_{t+\tau}}\right)^{-\sigma}C_{t+\tau}+(1-n)\frac{1-\xi^*}{1-n}\left(\frac{P_{t+\tau}^{F*}}{P_{t+\tau}^*}\right)^{-\sigma}C_{t+\tau}^*\right)$
Equilibrium conditions (PCP)		
Optimal pricing of firm h	$\widetilde{P}_t(h)=\frac{\theta}{\theta-1}\frac{\sum_{\tau=0}^{+\infty}\alpha^\tau\mathbb{E}_t\left[m_{t,t+\tau}\left(n\widetilde{C}_{t,t+\tau}^d(h)+(1-n)\widetilde{C}_{t,t+\tau}^{d*}(h)\right)MC_{t+\tau}\right]}{\sum_{\tau=0}^{+\infty}\alpha^\tau\mathbb{E}_t\left[m_{t,t+\tau}\left(n\widetilde{C}_{t,t+\tau}^d(h)+(1-n)\widetilde{C}_{t,t+\tau}^{d*}(h)\right)\right]}$	$\widetilde{P}_t^*(h)=\frac{1}{S_t}\widetilde{P}_t(h)$
Optimal pricing of firm f	$\widetilde{P}_t(f)=S_t\widetilde{P}_t^*(f)$	$\widetilde{P}_t^*(f)=\frac{\theta}{\theta-1}\frac{\sum_{\tau=0}^{+\infty}\alpha^\tau\mathbb{E}_t\left[m_{t,t+\tau}^*\left(n\widetilde{C}_{t,t+\tau}^d(f)+(1-n)\widetilde{C}_{t,t+\tau}^{d*}(f)\right)MC_{t+\tau}^*\right]}{\sum_{\tau=0}^{+\infty}\alpha^\tau\mathbb{E}_t\left[m_{t,t+\tau}^*\left(n\widetilde{C}_{t,t+\tau}^d(f)+(1-n)\widetilde{C}_{t,t+\tau}^{d*}(f)\right)\right]}$
Optimization (LCP)		
Present discounted value of profits for h	$\mathbb{E}_t\sum_{\tau=0}^{+\infty}\alpha^\tau m_{t,t+\tau}\left[\begin{array}{c}n\widetilde{C}_{t,t+\tau}^d(h)\left(\widetilde{P}_t(h)-MC_{t+\tau}\right)+\\+(1-n)\widetilde{C}_{t,t+\tau}^{d*}(h)\left(S_{t+\tau}\widetilde{P}_t^*(h)-MC_{t+\tau}\right)\end{array}\right]$	-
Present discounted value of profits for f	-	$\mathbb{E}_t\sum_{\tau=0}^{+\infty}\alpha^\tau m_{t,t+\tau}^*\left[\begin{array}{c}n\widetilde{C}_{t,t+\tau}^d(f)\left(\frac{1}{S_{t+\tau}}\widetilde{P}_t(f)-MC_{t+\tau}^*\right)+\\+(1-n)\widetilde{C}_{t,t+\tau}^{d*}(f)\left(\widetilde{P}_t^*(f)-MC_{t+\tau}^*\right)\end{array}\right]$
Technology	$Y_t(h)=A_tL_t(h)$	$Y_t^*(f)=A_t^*L_t^*(f)$
Demand constraint in home market	$\widetilde{C}_{t,t+\tau}^d(h)=\frac{\xi}{n}\left(\frac{\widetilde{P}_t(h)}{P_{t+\tau}^H}\right)^{-\theta}\left(\frac{P_{t+\tau}^H}{P_{t+\tau}}\right)^{-\sigma}C_{t+\tau}$	$\widetilde{C}_{t,t+\tau}^d(f)=\frac{1-\xi}{1-n}\left(\frac{\widetilde{P}_t(f)}{P_{t+\tau}^F}\right)^{-\theta}\left(\frac{P_{t+\tau}^F}{P_{t+\tau}}\right)^{-\sigma}C_{t+\tau}$
Demand constraint in foreign market	$\widetilde{C}_{t,t+\tau}^{d*}(h)=\frac{\xi^*}{n}\left(\frac{\widetilde{P}_t^*(h)}{P_{t+\tau}^{H*}}\right)^{-\theta}\left(\frac{P_{t+\tau}^{H*}}{P_{t+\tau}^*}\right)^{-\sigma}C_{t+\tau}^*$	$\widetilde{C}_{t,t+\tau}^{d*}(f)=\frac{1-\xi^*}{1-n}\left(\frac{\widetilde{P}_t^*(f)}{P_{t+\tau}^{F*}}\right)^{-\theta}\left(\frac{P_{t+\tau}^{F*}}{P_{t+\tau}^*}\right)^{-\sigma}C_{t+\tau}^*$
Equilibrium conditions (LCP)		
Optimal pricing of firm h	$\widetilde{P}_t(h)=\frac{\theta}{\theta-1}\frac{\sum_{\tau=0}^{+\infty}\alpha^\tau\mathbb{E}_t\left[m_{t,t+\tau}\widetilde{C}_{t,t+\tau}^d(h)MC_{t+\tau}\right]}{\sum_{\tau=0}^{+\infty}\alpha^\tau\mathbb{E}_t\left[m_{t,t+\tau}\widetilde{C}_{t,t+\tau}^d(h)\right]}$	$\widetilde{P}_t^*(h)=\frac{\theta}{\theta-1}\frac{\sum_{\tau=0}^{+\infty}\alpha^\tau\mathbb{E}_t\left[m_{t,t+\tau}\widetilde{C}_{t,t+\tau}^{d*}(h)MC_{t+\tau}\right]}{\sum_{\tau=0}^{+\infty}\alpha^\tau\mathbb{E}_t\left[m_{t,t+\tau}\widetilde{C}_{t,t+\tau}^{d*}(h)S_{t+\tau}\right]}$
Optimal pricing of firm f	$\widetilde{P}_t(f)=\frac{\theta}{\theta-1}\frac{\sum_{\tau=0}^{+\infty}\alpha^\tau\mathbb{E}_t\left[m_{t,t+\tau}^*\widetilde{C}_{t,t+\tau}^d(f)MC_{t+\tau}^*\right]}{\sum_{\tau=0}^{+\infty}\alpha^\tau\mathbb{E}_t\left[m_{t,t+\tau}^*\widetilde{C}_{t,t+\tau}^d(f)\frac{1}{S_{t+\tau}}\right]}$	$\widetilde{P}_t^*(f)=\frac{\theta}{\theta-1}\frac{\sum_{\tau=0}^{+\infty}\alpha^\tau\mathbb{E}_t\left[m_{t,t+\tau}^*\widetilde{C}_{t,t+\tau}^{d*}(f)MC_{t+\tau}^*\right]}{\sum_{\tau=0}^{+\infty}\alpha^\tau\mathbb{E}_t\left[m_{t,t+\tau}^*\widetilde{C}_{t,t+\tau}^{d*}(f)\right]}$

Table A4 - Policy rules and market clearing conditions

	Home	Foreign
	Policy rules	
Fiscal policy	$\phi_t = \frac{-1}{\theta}$	$\phi_t^* = \frac{-1}{\theta}$
Monetary policy (Taylor rule)	$1 + i_t = \beta^{\rho-1} Z_t \left(1 + i_{t-1}\right)^{\rho} \left[\left(\frac{P_t}{P_{t-1}}\right)^{\psi_\pi} \left(\frac{Y_t}{\overline{Y}_t}\right)^{\psi_x} \right]^{1-\rho}$	$1 + i_t^* = \beta^{\rho-1} Z_t^* \left(1 + i_{t-1}^*\right)^{\rho} \left[\left(\frac{P_t^*}{P_{t-1}^*}\right)^{\psi_\pi} \left(\frac{Y_t^*}{\overline{Y}_t^*}\right)^{\psi_x} \right]^{1-\rho}$
	Market clearing conditions	
Market clearing for domestic variety h	$Y_t\left(h\right) = nC_t\left(h\right) + \left(1-n\right) C_t^*\left(h\right)$	
Market clearing for foreign variety f	$Y_t^*\left(f\right) = nC_t\left(f\right) + \left(1-n\right) C_t^*\left(f\right)$	
Market clearing for domestic labor market	$nL_t = \int_0^n L_t\left(h\right) dh$	-
Market clearing for foreign labor market	-	$\left(1-n\right) L_t^* = \int_n^1 L_t^*\left(f\right) df$
Domestic (contingent) bonds market clearing	$nB^H\left(\omega_{t+1} \mid \omega_t\right) + \left(1-n\right) B^{H*}\left(\omega_{t+1} \mid \omega_t\right) = 0$	
Foreign (contingent) bonds market clearing	$nB^F\left(\omega_{t+1} \mid \omega_t\right) + \left(1-n\right) B^{F*}\left(\omega_{t+1} \mid \omega_t\right) = 0$	

Figure 1
US imports as a share of GDP

Figure 2
Capacity utilization rates in the US and other G7 countries

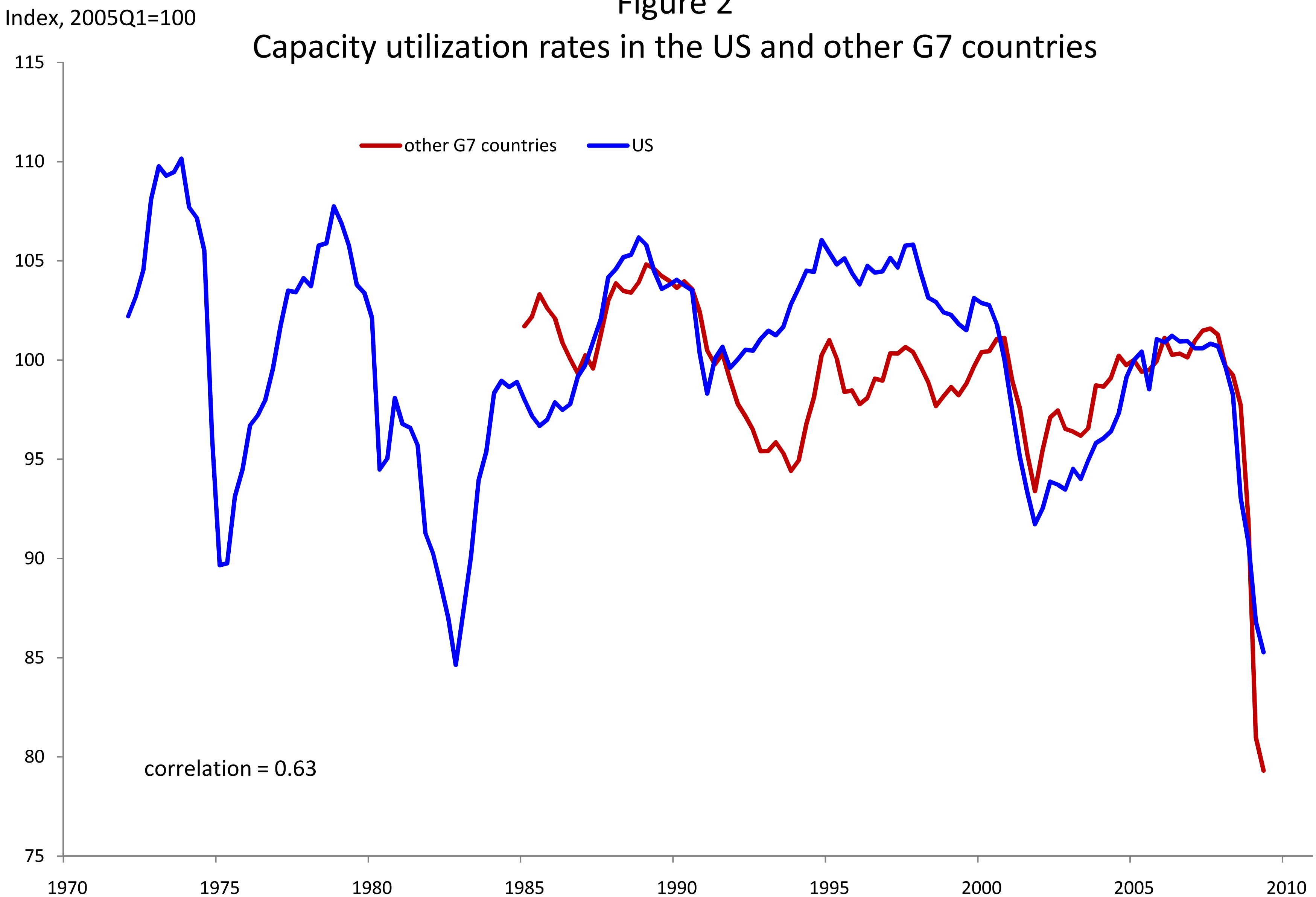


Figure 3
Unemployment rates in the US and other G7 countries

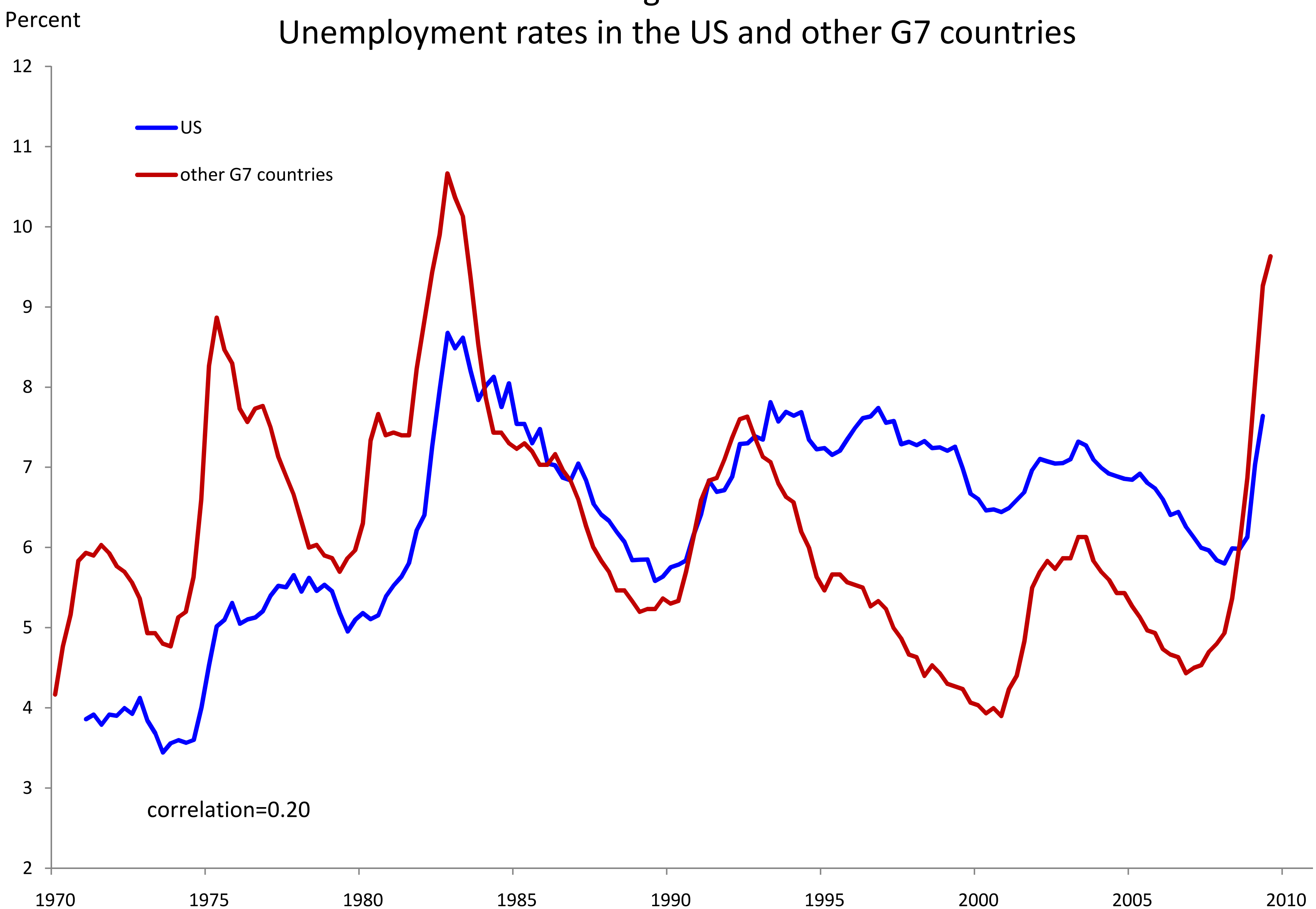


Figure 4
Output gap in the US and other G7 countries

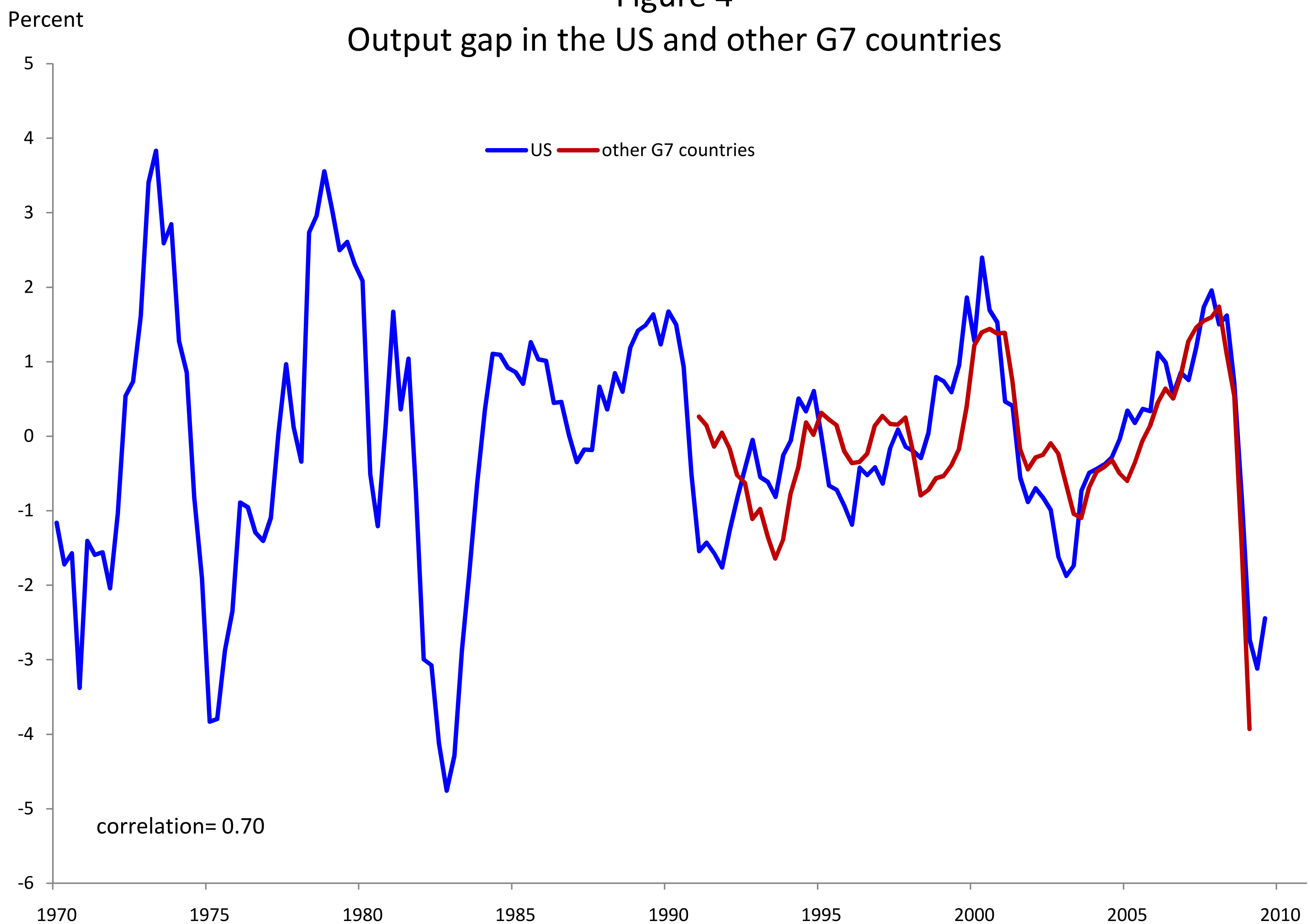
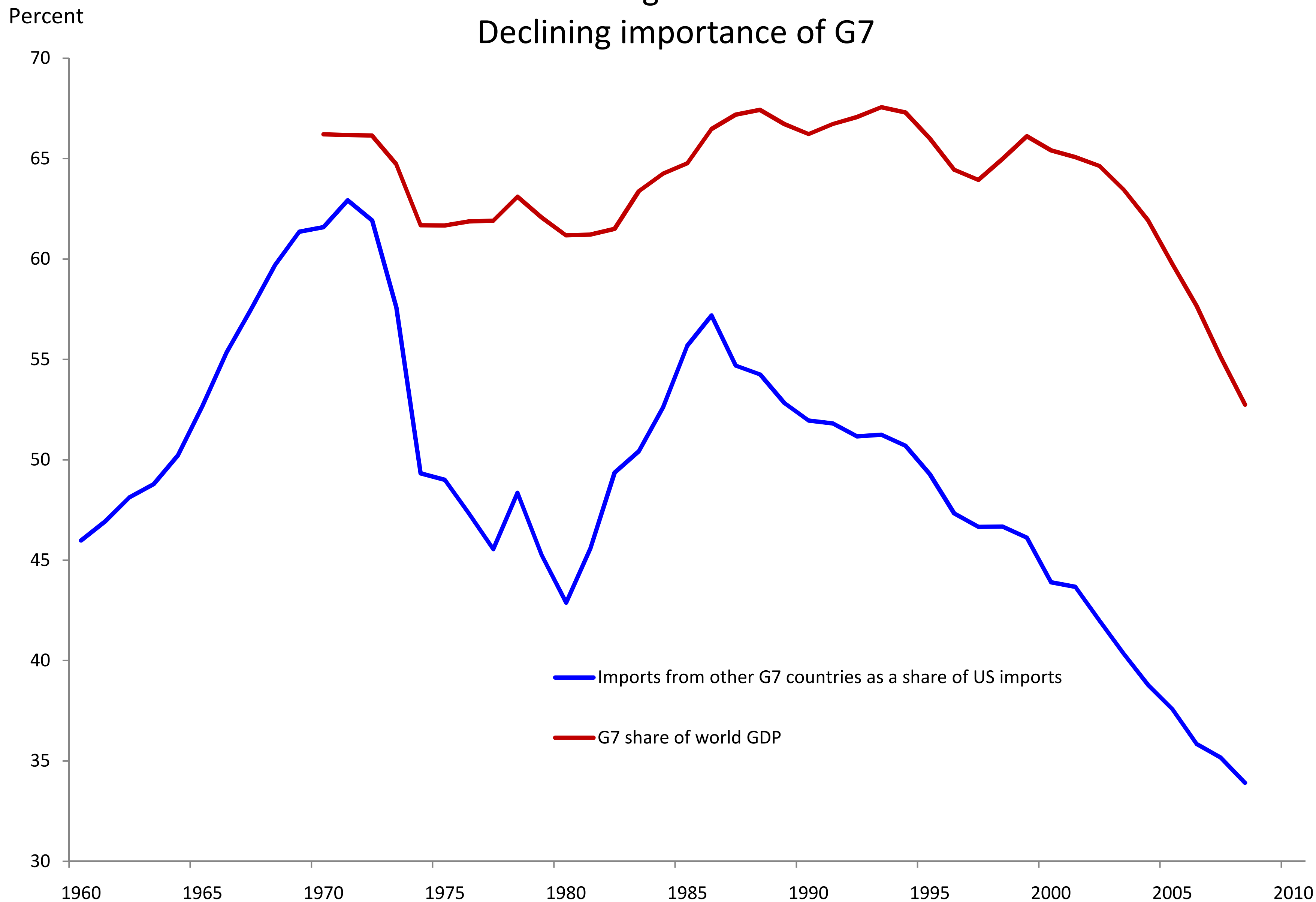


Figure 5
Declining importance of G7



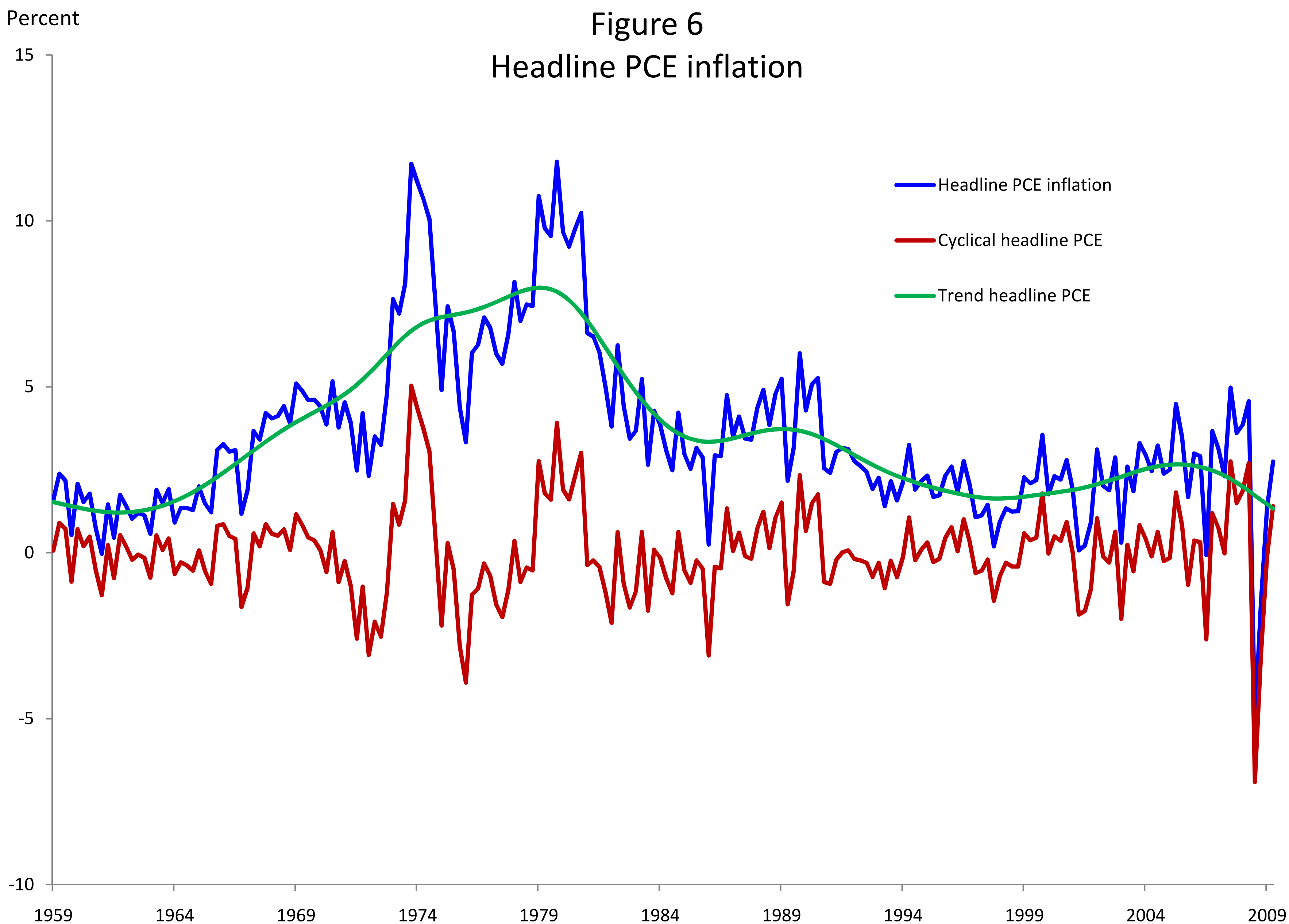

Percent
Figure 6
Headline PCE inflation
15
10
5
0
-5
-10
1959
1964
1969
1974
1979
1984
1989
1994
1999
2004
2009
Headline PCE inflation
Cyclical headline PCE
Trend headline PCE

Figure 7
Core PCE inflation

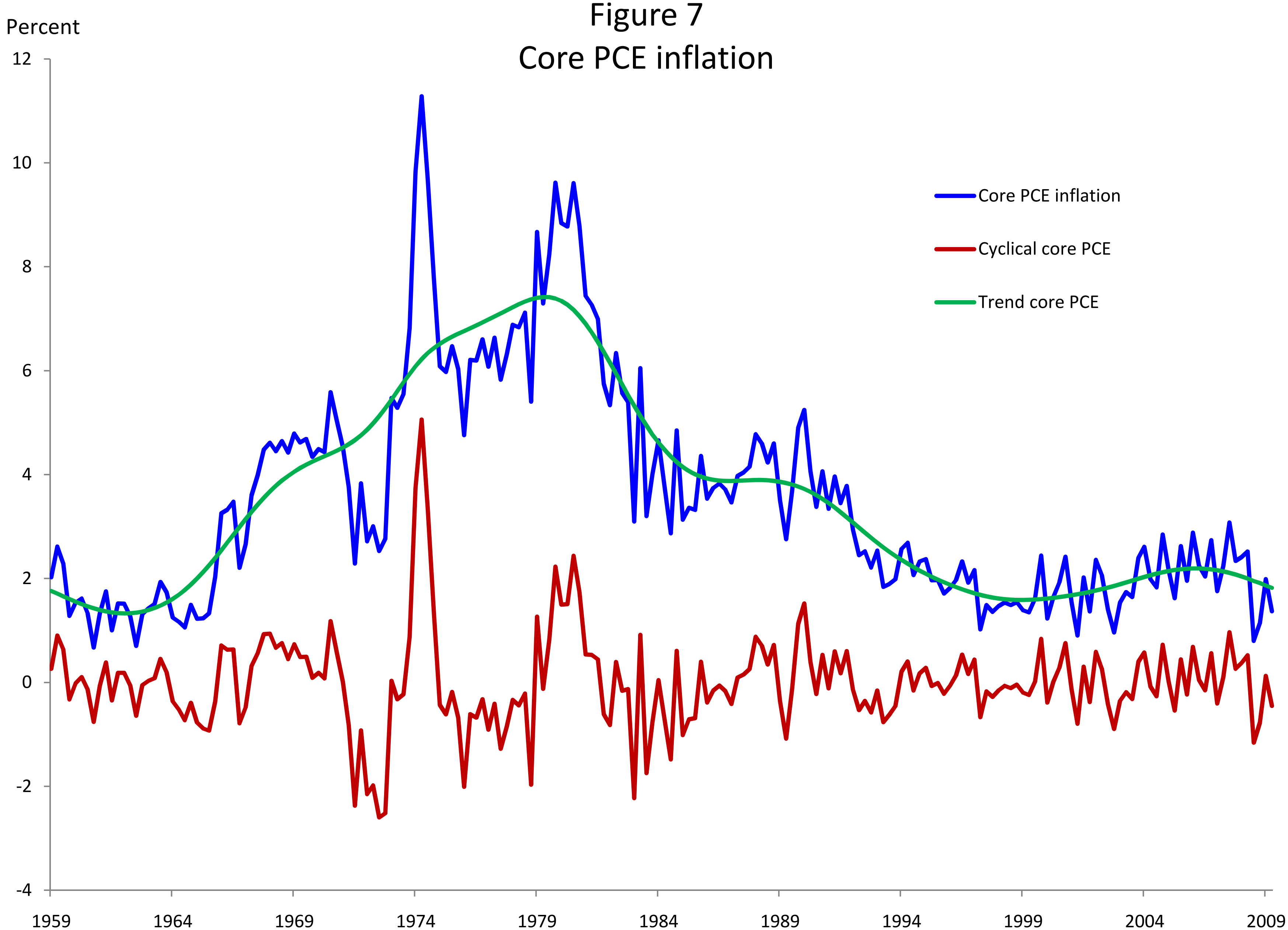


Figure 8
Capacity utilization rate

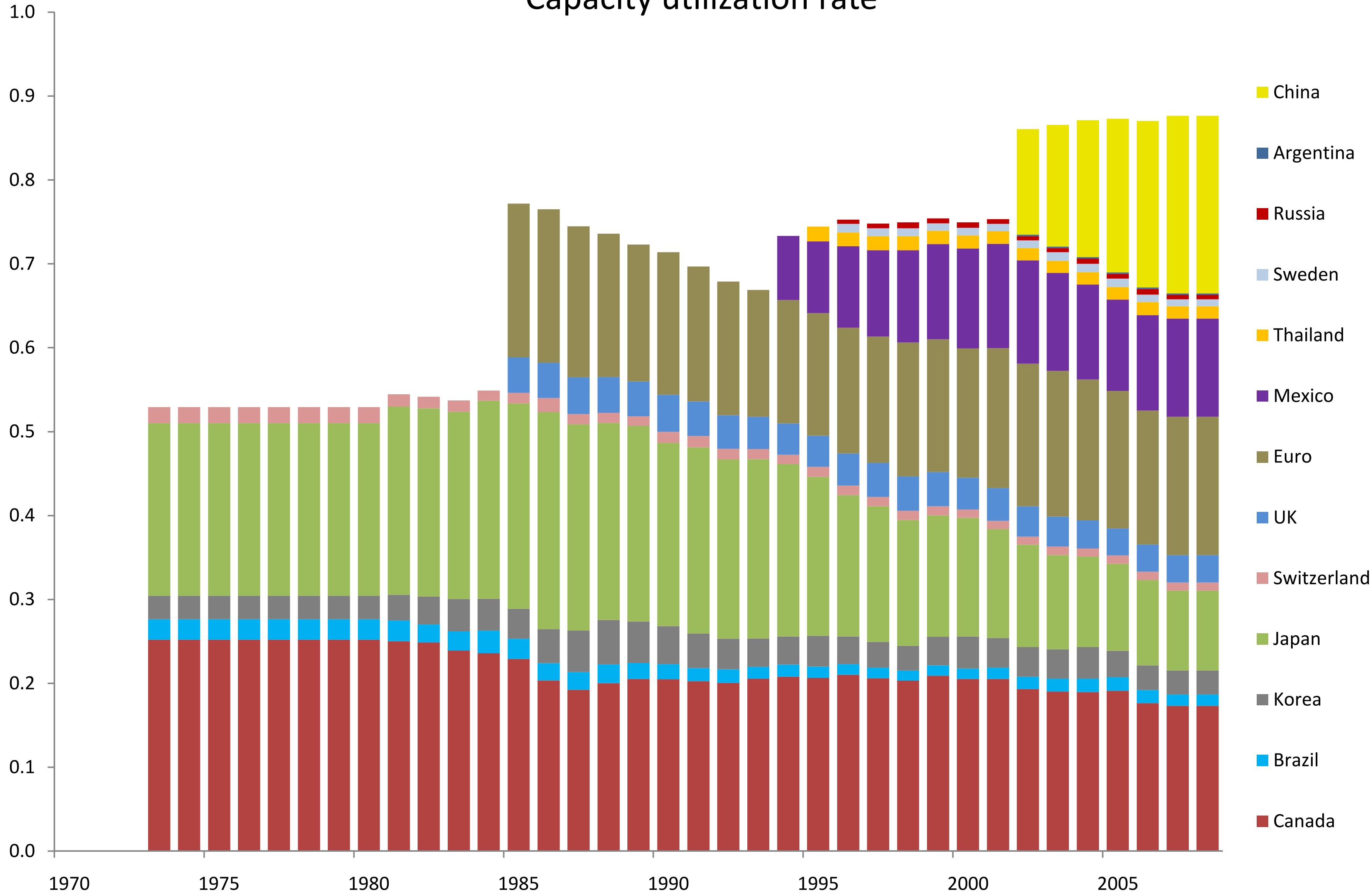
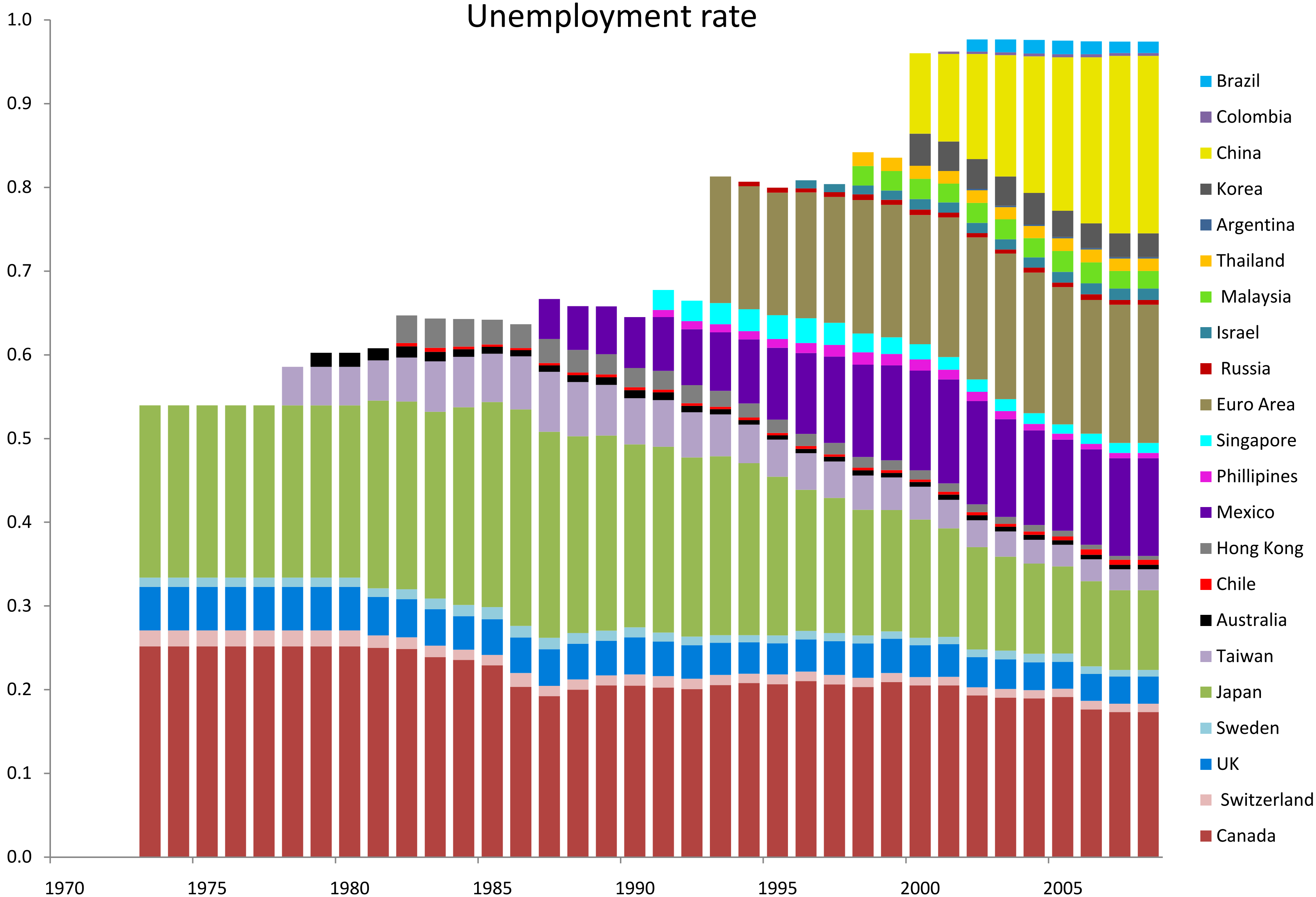


Figure 9
Unemployment rate



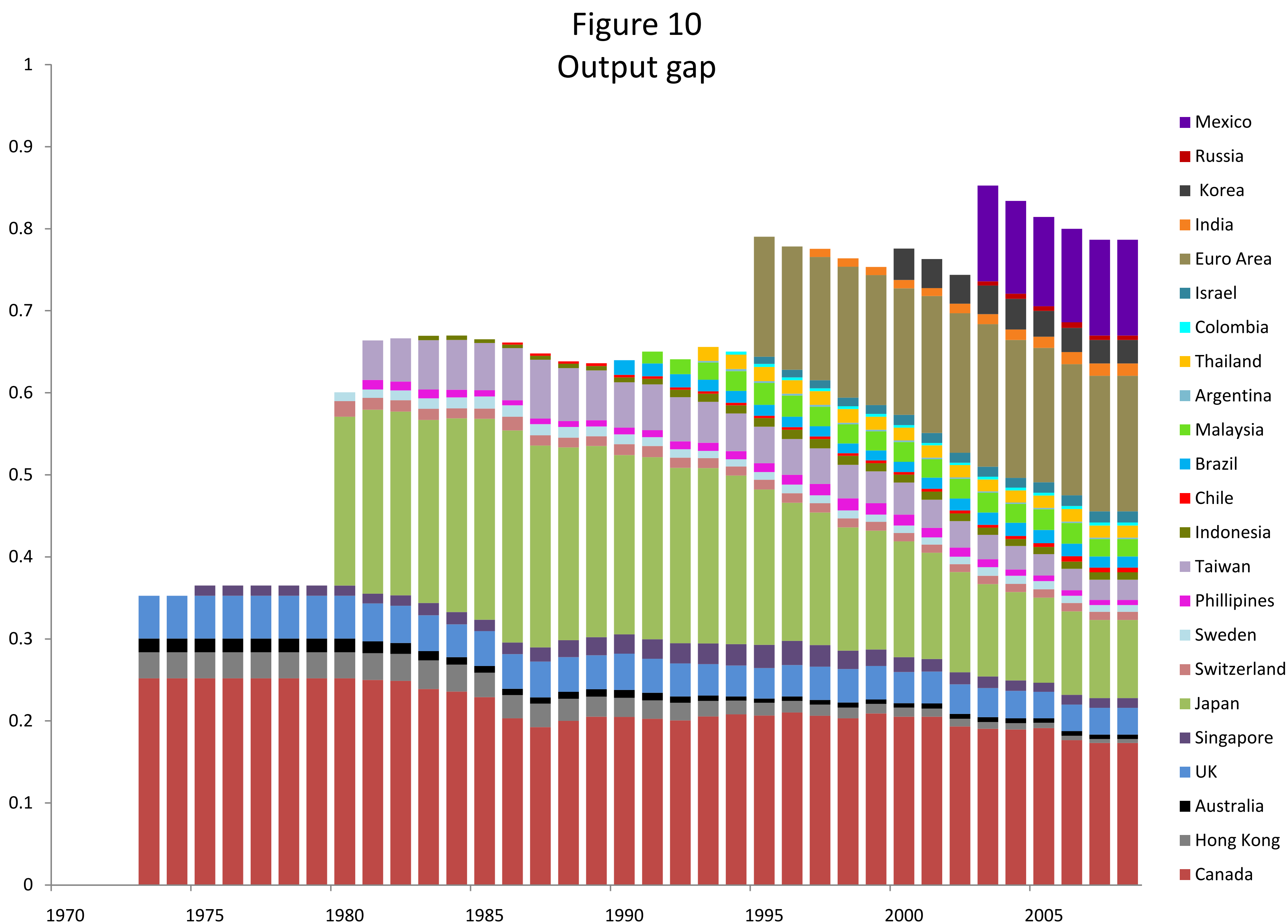


Figure 10
Output gap
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1970
1975
1980
1985
1990
1995
2000
2005
Mexico
Russia
Korea
India
Euro Area
Israel
Colombia
Thailand
Argentina
Malaysia
Brazil
Chile
Indonesia
Taiwan
Phillipines
Sweden
Switzerland
Japan
Singapore
UK
Australia
Hong Kong
Canada

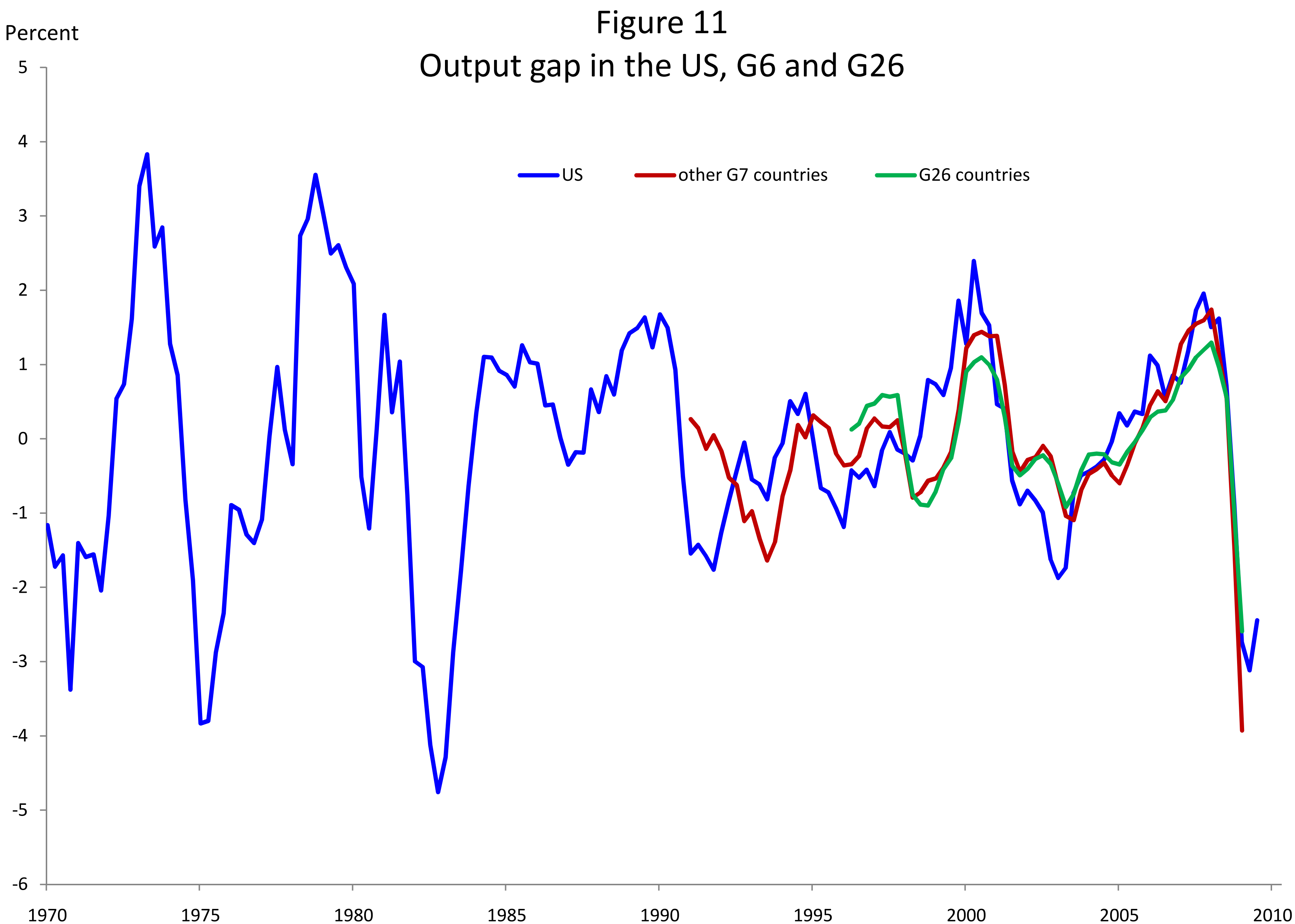

Percent
Figure 11
Output gap in the US, G6 and G26
US
other G7 countries
G26 countries
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
1970
1975
1980
1985
1990
1995
2000
2005
2010

Figure 12
Relationship between statistical and model-consistent measures of foreign slack