The Small Open-Economy New Keynesian Phillips Curve: Empirical Evidence and Implied Inflation Dynamics

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The Small Open-Economy New Keynesian Phillips Curve: A First Empirical Test and Implied Inflation Dynamics

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Abstract

This paper is the first to subject the small open-economy New Keynesian Phillips Curve derived in Galí and Monacelli (2005) to the test of the data. Applying GMM to estimate alternative empirical specifications of our main theoretical equation over a quarterly sample of ten OECD small open economies from 1970 to 2007, we find moderate support for it. Notably, in our sample the small open-economy New Keynesian Phillips Curve does not overall perform worse than its closed-economy pure or hybrid counterparts. For most countries, the expected next-period relative change in the terms of trade emerges as a more relevant CPI inflation driver than the current-period domestic output gap. However, this does not seem to be a consequence of globalization, except for three countries where the role of external factors relative to domestic ones in inflation dynamics has increased over time.

Key words: New Keynesian Phillips Curve, small open economies, inflation dynamics, globalization, GMM estimation.

JEL classification codes: C32, C52, E31, F41.

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1 Introduction

The New Keynesian Phillips Curve (NKPC) is a key ingredient in what currently appears to be the workhorse model for business cycle analysis and evaluation of monetary policy, the so-called[1] New Keynesian policy model (NKPM).[2] In fact, the NKPC is just one of the structural-form equations in the NKPM.[3] It differs from the traditional Phillips Curve postulated in Phillips (1958)[4] in several important respects: first, it is derived from optimizing behavior; second, the intertemporal dimension of the firm's pricing decision is explicitly modeled; third, it does not imply a short-run tradeoff between output variability – originally, unemployment levels – and inflation variability – originally, nominal wage levels. Blanchard and Galí (2007) dub this latter property of the NKPM the 'divine coincidence': stabilizing the welfare-relevant output gap at the same time stabilizing inflation.[5]

Starting with Galí and Gertler (1999), many authors have advocated and estimated *hybrid closed-economy* specifications of the NKPC – see, e.g., Galí, Gertler and López-Salido (2001, 2003, 2005), Rudd and Whelan (2005, 2006) and Sbordone (2002, 2005, 2007).[6] The hybrid NKPC version features lagged terms as well as expectational terms of inflation, and – as Rudd and Whelan (2007) point out – can be theoretically motivated in at least three alternative ways.[7] Arguably, it appears to be a more realistic, 'inertial' specification that better fits the data. The usual practice has been to estimate the equations of the NKPM one-by-one and in separate studies.[8] Most available estimates in the literature involve precisely this hybrid NKPC and are inferred from a closed-economy context employing the generalized method of moments (GMM) of Hansen

[1] E.g., in Henry and Pagan (2004) among many others.

[2] The New Keynesian (NK) approach to macroeconomic modeling incorporates nominal rigidities and monopolistic competition that allow price-setting behavior and a role for monetary policy – although not necessarily for money demand and the ensuing LM curve – into the perfect-markets rational-expectations representative-agent dynamic stochastic general equilibrium models (DSGEMs) of the real business cycle (RBC) paradigm of the 1980s. For detailed discussions of the NK framework see, e.g., Yun (1996), Goodfriend and King (1997), Rotemberg and Woodford (1997), Clarida, Galí and Gertler (1999) and the books by Woodford (2003) and Galí (2008).

[3] The other commonly employed equations are a New Keynesian IS curve and an interest rate feedback rule, often of the simple (i.e., non-optimized) type recommended by Taylor (1993). In some versions of the NKPM with interest rate smoothing by policymakers, a fourth equation describes the partial adjustment dynamics of the actual interest rate.

[4] And from its commonly estimated reduced-form econometric counterparts.

[5] They explain it with the absence of real imperfections in the NK framework and show that once real wage rigidity is introduced the property holds no longer. The tradeoff at the centre of the ad-hoc backward-looking set-ups of the traditional macromodels that makes the monetary policy problem meaningful then re-emerges. Earlier modeling solutions to the same alleged shortcoming of the NKPM have been offered by Clarida *et al.* (1999), by appending an ad-hoc exogenous cost-push shock, and by Ravenna and Walsh (2006), who endogenize this shock by introducing a cost channel of monetary policy, present when marginal costs depend directly on the nominal interest rate. In the cannonical NKPM there is no unemployment either, and all variation in employment occurs along the intensive hours margin. Ravenna and Walsh (2007) and Blanchard and Galí (2008) model unemployment explicitly in the NK framework and show that the tradeoff between inflation and unemployment depends on labor market characteristics.

[6] Rudd and Whelan (2007) is a critical review of the more recent literature; Roberts (1995) synthesizes the earlier one.

[7] That is, (i) Fuhrer and Moore (1995) obtain a hybrid specification by assuming alternative contracting schemes when workers bargain over relative real wages; (ii) in Galí and Gertler (1999) the hybrid closed-economy NKPC results from introducing a proportion of backward-looking (non-optimizing) firms ('rule-of-thumb' price setters); (iii) Christiano *et al.* (2005) allow all prices to change each period but some are chosen optimally while the rest are simply indexed to observed inflation.

[8] Less frequently the system has been estimated jointly by full information maximum likelihood (FIML), e.g., in Ireland (2004), Dennis (2004), Giordani (2004) and Lindé (2005).

(1982) to handle the expectational terms.[9] More recent applications estimating hybrid NKPCs, even a few that explicitly include 'open-economy' in their titles, e.g., Leith and Malley (2007) and Rumler (2007), have ended up focusing on parameters such as the degree of backward- and forward-lookingness and of imperfect substitutability between domestic and foreign intermediate inputs, without examining in more detail the role of external-sector inflation drivers.[10]

The purpose of this paper is to provide a first empirical evaluation of the *small open-economy* (SOE) version of the NKPC derived in Galí and Monacelli (2005), henceforth the SOE NKPC. This latter microfounded equation takes into account the implications of external-sector macrovariables such as fluctuations in the multilateral terms of trade (ToT) – or, if alternatively written, the nominal (NER) or real (RER) effective exchange rate – for inflation dynamics (and, ultimately, for optimal monetary policy). The explicitly captured external influence in the theoretical SOE NKPC of Galí and Monacelli (2005) appears plausible empirically too, insofar the huge majority of the economies in the real world qualify to be small and open. A by-product of our first tests of this new, SOE specification of the NKPC is to check the support in the data, or the lack of it, for the divine coincidence property, as revealed by the sign of the statistically significant output gaps. Yet a deeper motivation – although based on the SOE NKPC estimates we obtain and, thus, sensitive to their robustness – attempts to go beyond the mere 'model testing' exercise. It is to compare and interpret across countries and time the relative weight of domestic versus global, rest-of-the-world (RoW) factors in determining consumer-price index (CPI) inflation in SOEs. Within this perspective, we add a few nuances to the debate on the potential consequences of globalization for inflation dynamics (and, ultimately, monetary policy). On one extreme of this debate, intuitively appealing explanations, e.g., in Borio and Filardo (2007) and White (2008) among others, claim that globalization should have increased the role of global factors relative to domestic ones, in inflation dynamics in particular. Hence, globalization has complemented monetary policy in slowing down the growth of prices and has even limited the power of central banks to adjust the short-term interest rate so as to achieve explicit or implicit inflation targets. However Woodford (2007) has taken the opposite stand, i.e., that globalization does not necessarily disable central banks to control domestic inflation.[11] He has presented solid arguments to support his views within a theoretical two-country framework of the transmission mechanism of monetary policy extending his own (Woodford, 2003) Neo-Wicksellian treatise to account for key features of a globalized world economy such as, notably, the degree of local currency pricing (LCP).[12] Along these lines, it is important to further try to learn from econometric measurement how far the trends of globalization have interfered, if at all, with inflation dynamics, to which we return in the analysis of our results.

In a preview, we find that the microfounded SOE NKPC of Galí and Monacelli (2005) is not overwhelmingly supported in our sample of 10 countries. Yet it enjoys overall support that appears stronger than the one for similar closed-economy 'pure' or

[9] An alternative, but not necessarily less problematic, approach is to obtain in one way or another forecasts for inflation, often on the basis of (bi-variate) VAR empirical models or through surveys of professional forecasters.

[10] Razin and Yuen (2002) have focused on the theoretical similarities and differences of closed- versus open-economy NKPC formulations. Razin and Binyamini (2007) have, more recently, investigated empirical issues related to the flattening of the inflation-output tradeoff and whether this could be assigned to monetary policy or globalization.

[11] Rogoff (2003, 2006), to a lesser extent, as well as Ball (2006) and Mishkin (2007, 2008), categorically enough, all essentially share most of the key arguments and conclusions in Woodford (2007).

[12] The implicit or explicit assumption in the NK framework, including Galí and Monacelli (2005), has been of full producer's currency pricing (PCP).

'hybrid' NKPC specifications or for slightly modified SOE NKPC versions on empirical grounds. This leads us to conclude that the empirical fit of the Galí and Monacelli (2005) SOE NKPC is reasonably good for a theoretically derived equation.[13] A second result is that in only a few cases across our many specifications the divine coincidence property does not hold; it holds, though, in more cases in our sample; but much more frequently we cannot say anything definite on it because the output gap term is not statistically significant. Given such mixed econometric evidence, we would not offer here strong views on the inflation-globalization nexus debate. We can, nevertheless, suggest an apparently robust interpretation of our GMM estimates of the SOE NKPC, overall across the sample, with respect to the relative importance of domestic versus external inflation drivers. In particular, for most countries the theoretically-relevant expected change in the terms of trade *relative to* the observed one comes out as a more important determinant of CPI inflation dynamics than our imperfect empirical proxies for the theoretically-relevant current-period domestic output gap. However, this does not seem to be a consequence of globalization in general: it is only for Italy, the Netherlands and the UK out of the ten countries in our sample where the role of external factors relative to domestic ones in inflation dynamics has increased in the 1990s and the 2000s compared to the 1970s and the 1980s.[14] This finding points out to a novel, we hope, aspect in the ongoing debate: the likely relevance of country-specific features such as, perhaps, production and trade structures (or policy and institutional frameworks too), among the many other facets to consider, when the possible effects of globalization on inflation dynamics (or, further, on monetary policy) are to be carefully examined. The highlighted partially contradictory evidence when taken on a general, cross-country, level versus a specific, individual-country, level makes us cautious in attempting to pronounce here overhastily any definitive broad conclusions on the (monetary policy-) inflation-globalization nexus.

The paper is structured as follows. The next section outlines our empirical strategy and derives the main testable equation. Section 3 introduces our data and estimation method. Section 4 summarizes and interprets our results, and the last section concludes. Three appendixes follow. Appendix A derives the theoretically expected sign of the coefficients we estimate. Appendix B provides a detailed justification of the way we interpret the expected relative change in the terms of trade in our main test equation. Finally, Appendix C lists the instrumental variables used in estimating each econometric specification by country.

2 Empirical Strategy

Our analysis is based on the model described in Galí and Monacelli (2005). They show that in a small open economy consumer-price (CPI) inflation, $\pi_t \equiv p_t - p_{t-1}$, with $p_t \equiv \ln P_t$, is determined by domestic-price inflation, $\pi_{H,t} \equiv p_{H,t} - p_{H,t-1}$, and the change in the terms of trade, $\Delta s_t \equiv s_t - s_{t-1}$, with $s_t \approx p_{F,t} - p_{H,t}$, where s_t is the (natural) log of the effective ToT of the SOE *vis-à-vis* the RoW and $p_{H,t}$ and $p_{F,t}$ are the (natural) logs of its domestic price index and import price index, respectively.

In particular, the following equation holds as a log-linear approximation around the

[13] Rudd and Whelan (2007), p. 163, note: "it should be kept in mind that the NKPC is a structural model and should be expeced to fit worse than a reduced-form econometric model"; and on p. 169 they conclude that "there is little evidence at present that structural modeling of inflation in a rational expectations framework provides an adequeate description of the empirical inflation process."

[14] In that our results essentially agree with the summarized conclusions in Rogoff (2003, 2006), Ball (2006), Woodford (2007) and Mishkin (2007, 2008).

steady state:[15]

$$\pi_t = \pi_{H,t} + \alpha \Delta s_t, \tag{1}$$

where $\alpha \in [0, 1]$ is inversely related to the degree of home bias in consumption preferences. The equation states that the gap between consumer- and domestic-price inflation is proportional to the per cent change of the terms of trade, with the coefficient of proportionality given by the index of openness. In other words, CPI inflation can be viewed as determined by two major factors, domestic-price inflation, a domestic cause, and changes in the terms of trade, which matter more the more open the economy is.

As Galí and Monacelli (2005) point out, equation (1) holds in approximation since the *effective* (i.e., multilateral) terms of trade of the SOE are, more precisely, defined by

$$S_t \equiv \frac{P_{F,t}}{P_{H,t}} = \left(\int_0^1 S_{i,t}^{1-\gamma} di \right)^{\frac{1}{1-\gamma}},$$

where $\gamma > 0$ measures the substitutability between goods produced in different countries other than the SOE indexed by i (and, thus, entering its import-price index), which can be approximated (up to first order) by the log-linear expression

$$s_t = \int_0^1 s_{i,t} di.$$

Moreover, *log-linearization* of the CPI Dixit–Stiglitz (1977) constant elasticity of substitution (CES) aggregator common to such frameworks,

$$P_t \equiv \left[(1-\alpha) P_{H,t}^{1-\eta} + \alpha P_{F,t}^{1-\eta} \right]^{\frac{1}{1-\eta}},$$

where $\eta > 0$ is the substitutability between the SOE's domestically-produced and imported goods (i.e., those produced in the RoW), around a *symmetric* steady state satisfying the purchasing power parity (PPP) condition, $P_{H,t} = P_{F,t}$ under assumed full producer currency pricing (PCP) and $\overline{S} = 1$, implies

$$\begin{aligned} p_t &\equiv (1-\alpha) p_{H,t} + \alpha p_{F,t} \\ &= p_{H,t} - \alpha p_{H,t} + \alpha p_{F,t} \\ &= p_{H,t} + \alpha (p_{F,t} - p_{H,t}) \\ &= p_{H,t} + \alpha s_t. \end{aligned}$$

The last expression above, taken in differences, in fact leads to (1).

A further implication of the Galí–Monacelli (2005) model is the following variant of the NKPC:

$$\pi_t = \beta E_t \pi_{H,t+1} + \lambda \widehat{mc}_t + \alpha \Delta s_t. \tag{2}$$

This equation follows directly from (14) and (32) in Galí and Monacelli (2005). Their (14) is (1) above, and their (32) is (3) below, an equation analogous to the one typically derived and estimated for a closed economy,

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \lambda \widehat{mc}_t, \tag{3}$$

[15] For a detailed derivation see Galí and Monacelli (2005).

where $\widehat{mc}_t$ is the SOE's real marginal cost in per cent deviation from its steady state value. In such frameworks $\widehat{mc}_t$ can be shown to be *proportional* to the SOE's output gap, x_t, so that a version of the NKPC for the SOE can also be expressed in terms of the output gap,[16] similarly to its closed-economy parallels:

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \kappa_\alpha x_t, \tag{4}$$

with the critical slope coefficient $\kappa_\alpha \equiv \lambda (\sigma_\alpha + \varphi)$, where $\lambda \equiv \frac{(1-\beta\theta)(1-\theta)}{\theta}$, $\sigma_\alpha \equiv \frac{\sigma}{(1-\alpha)+\alpha\omega}$, and $\omega \equiv \sigma\gamma + (1-\alpha)(\sigma\eta - 1)$; furthermore, σ is the inverse of the *inter*temporal elasticity of substitution in consumption and φ is an analogous parameter characterizing the *inter*temporal labor/leisure choice, θ is related to the degree of price stickiness (as $1-\theta$ is the probability of setting optimally in a Calvo (1983) fashion, i.e., in each period and independently of past history, a firm's price under monopolistic competition), $0 < \beta \equiv \frac{1}{1+\rho} < 1$ is the standard (subjective) time discount *factor*, with ρ being the (subjective) time discount *rate*), and $\eta > 0$ (as already mentioned) is the *intra*temporal substitutability in consumption between the SOE's domestically-produced and imported goods.

Equation (2), therefore, states that overall (or CPI) inflation is theoretically determined in the context of the SOE NKPM of Galí and Monacelli (2005) by expected domestic inflation, $E_t \pi_{H,t+1}$, domestic real marginal cost, $\widehat{mc}_t$, and the change in the SOE's ToT, Δs_t. Because of the proportionality between the real marginal cost (in deviation from its steady state value) and the output gap in this model – formally, $\widehat{mc}_t = (\sigma_\alpha + \varphi) x_t$ as on p. 718 in Galí and Monacelli (2005) – (2) can alternatively be written as[17]

$$\pi_t = \beta E_t \pi_{H,t+1} + \kappa_\alpha x_t + \alpha \Delta s_t. \tag{5}$$

Further algebraic substitutions, starting from (1), lead to a third version, as follows:

$$\begin{aligned} \pi_t &= \pi_{H,t} + \alpha \Delta s_t \Leftrightarrow \\ \pi_{H,t} &= \pi_t - \alpha \Delta s_t \\ \text{therefore, } E_t \pi_{H,t+1} &= E_t \pi_{t+1} - \alpha E_t \Delta s_{t+1}, \end{aligned}$$

and substituting out $E_t \pi_{H,t+1}$ in (2),

$$\begin{aligned} \pi_t &= \beta E_t \pi_{H,t+1} + \lambda \widehat{mc}_t + \alpha \Delta s_t \\ &= \beta (E_t \pi_{t+1} - \alpha E_t \Delta s_{t+1}) + \lambda \widehat{mc}_t + \alpha \Delta s_t \\ &= \beta E_t \pi_{t+1} - \alpha \beta E_t \Delta s_{t+1} + \lambda \widehat{mc}_t + \alpha \Delta s_t \\ &= \beta E_t \pi_{t+1} + \lambda \widehat{mc}_t - \alpha (\beta E_t \Delta s_{t+1} - \Delta s_t) \\ &= \beta E_t \pi_{t+1} + \lambda \widehat{mc}_t + \alpha (\Delta s_t - \beta E_t \Delta s_{t+1}). \end{aligned}$$

Sticking to the last specification above, as being the most intuitive and, perhaps, straightforward to estimate, we arrive at

[16] Theoretically defined as the deviation of the sticky-price output level from the output level when all prices are perfectly flexible; empirically measured most frequently as the deviation of actual output from 'potential' output proxied by trend output, as we do and explain further down.

[17] Similar CPI inflation dynamics arises also in two-country (large) open-economy models, e.g., in Benigno and Benigno (forthcoming) and McKnight and Mihailov (2007).

$$\pi_t = \beta E_t \pi_{t+1} + \lambda \widehat{mc}_t + \alpha \left(\Delta s_t - \beta E_t \Delta s_{t+1} \right). \tag{6}$$

Finally, replacing the marginal cost term above with the proportional output gap term, we end up with a fourth SOE NKPC version which is applied in our estimations:

$$\pi_t = \beta E_t \pi_{t+1} + \kappa_\alpha x_t + \alpha \left(\Delta s_t - \beta E_t \Delta s_{t+1} \right). \tag{7}$$

Equation (7) closely resembles its closed-economy counterpart. However, (7) also shows that CPI inflation, a much more relevant measure of the growth of the overall price level for small open economies than domestic-price inflation, is not just driven by the current-period domestic output gap in addition to expected next-period CPI inflation, as in closed economies. In SOEs CPI inflation is also theoretically determined by the expected current-to-next-period (discounted) change in the terms of trade *relative to* the observed past-to-current period ToT change. More precisely, an expected *relative improvement* in the ToT would stimulate expenditure switching to foreign goods, so that CPI inflation would be under *upward* pressure arising from the demand for imports. This pressure is stronger the higher is the degree of openness to trade, α. Inversely, an expected *relative deterioration* of the ToT would stimulate expenditure switching to domestically-produced goods, so that CPI inflation would be under *downward* pressure arising from the demand for imports. This pressure is stronger the higher is the degree of openness to trade. To understand better what we mean by expected *relative* changes in the ToT the reader is referred to Appendix B.

Our main contribution here is to test up against the data the relationship captured theoretically by equation (7) and to also provide, in consequence, empirical estimates for α. We do so by estimating via GMM, as is standard in the NKPC context, the orthogonality conditions implied by our main test equation, (7). To check for robustness, we also estimate (6), as well as 'pure', 'hybrid' and 'empirically motivated' closed- and open-economy variations of these for the whole sample and by two subperiods. Our data, econometric specifications and instruments are discussed next.

3 Data Description

We estimate equations (7) and (6) for ten advanced OECD countries, most of which are typically classified as small open economies (and also selected according to data availability and to maximize comparability): Austria, Canada, France, Germany, Italy, the Netherlands, Spain, Sweden, Switzerland and the United Kingdom. We include France, Germany and the UK even if they are not small countries since they are fairly open and interdependent in terms of consumption habits, whereas we do not consider the US and Japan which have a much lower import share in consumption.

All data (for the CPI, GDP and the import and export prices for the construction of the terms of trade as well as compensation to employees) stem from the Economic Outlook (ECO) database of the OECD. In estimating specification (7), we employ two different proxies for the output gap, namely the deviation of real GDP from a Hodrick-Prescott (H-P) trend, and its deviation from a quadratic-polynomial (Q-P) trend.[18] To solve the well-known endpoint problem of any one-sided filtering method, the H-P and Q-P trend have been calculated including forecast values up to 2009:4 available at the

[18] These commonly applied empirical measures of the output gap are, certainly, only imperfect proxies to the theoretically relevant output gap. The underlying detrending procedures, which postulate a specific functional form to separate the trend (or potential) real GDP from the cyclical component, are sometimes referred to as 'naive' in the literature. The alternatives in applied work, though, are not obvious.

ECO database. The H-P output gap has additionally been normalized by its standard deviation to ensure comparable magnitudes across countries.

In line with the approaches implemented with respect to the closed-economy NKPC, notably following Galí and Gertler (1999) and Sbordone (2002), we also estimate specification (6) using average real unit labor costs as a proxy for real marginal costs instead of the output gap. Empirically, average real unit labor cost is proxied by the labor share in income, $\frac{Wl}{Py}$, where W is hourly compensation, l total hours worked, y real output and P a measure of the (relevant) price level.[19] We construct this variable by dividing total nominal compensation to employees by nominal GDP. As the detrending method we use the Q-P trend in this case.

To construct the effective ToT, s_t, which in our model corresponds to $p_{F,t} - p_{H,t}$, we calculate - assuming producer's currency pricing as said before - the log difference of the import prices (given by the import deflator) and the export prices (given by the export deflator) for each country. Implicitly, this ratio gives the effective ToT because the importance of the trading partners is automatically reflected in the deflators.

Our data covers the period from the first quarter of 1970 to the last quarter of 2007, where the samples vary somewhat due to limited data availability for some countries. All estimations are from 1970:1 to 2007:4, with the following exceptions. For Austria, all data are available only from 1980 on. Specification (6) is estimated from 1975 for Italy and from 1980 for Spain because compensation of employees is available only from these respective years on. For Switzerland, specification (6) could not be estimated due to the lack of data on compensation.

The instruments used in the GMM estimation have been chosen for each country individually. They mainly consist of various lags of the right-hand-side variables in each regression, which are selected according to experimentation with different lag combinations. In addition to lagged regressors, we used commodity prices and the bilateral USD/EUR exchange rate as instruments for some countries. The instruments are the same in the estimations of the two subsamples. The complete set of instrumental variables by country and econometric specification is provided in Appendix C.

The dependent variable in each regression is (seasonally unadjusted) quarter-on-quarter CPI inflation.

4 Results

In this section we present our empirical findings. We start, in the first subsection, by assessing the empirical fit of the SOE NKPC proposed in the theoretical set-up of Galí and Monacelli (2005) but not yet tested up against the data. Based on our GMM results we then, in the second subsection, attempt to go a bit further and summarize their implications as far as the role of external versus domestic factors as inflation drivers is concerned. We do so in the hope of adding to the current debate on the inflation-globalization nexus, whose more profound study remains outside the scope of our paper.

4.1 Empirical Fit of the Small Open-Economy NKPC

Table 1 shows the results from the estimation of our main specification, (7), where we proxy the output gap, x_t, by the deviation of real GDP from its H-P trend. The p-value

[19] Most empirical studies have found a negative correlation between the labor share in income and the traditional, 'naive' measures of the output gap. For that reason, the notorious problem with wrongly signed (i.e., statistically significant and negative) output gaps found in the data has been often avoided by employing the labor share as a proxy for real marginal costs. See Galí and Gertler (1999) and Galí, Gertler and López-Salido (2001).

associated with the J-test statistic reported in the last column implies that the null of the validity of the overidentifying restrictions imposed by the instruments cannot be rejected at standard levels of significance.

[Table 1 about here]

The table shows that the time discount factor β is statistically significant in all countries and the point estimate is slightly below unity, except for Italy and France. For these two countries we estimate β to be only marginally above unity.[20]

Turning to κ_α, the parameter that measures the impact of the output gap on inflation, we see that this parameter is significantly greater than zero only in France and the UK. For Sweden, the point estimate for κ_α is significantly negative. Intuitively, higher marginal costs give rise to an increase in the output gap, which should translate into price pressure. Therefore, one would expect κ_α to be generally positive. However, as we demonstrate in Appendix A, this need not be theoretically true in all possible cases in the context of the NKPM of Gali and Monacelli (2005). Moreover, several authors argue that a shortcoming of the standard New Keynesian framework is that it does not allow for a tradeoff between inflation and output stabilization. As mentioned, Blanchard and Galí (2007) notably argue that incorporating real rigidities in the NKPM framework generates such a tradeoff. Thus, it might be the case that despite the fact that our estimated equation is based on a model which does not generally allow for this type of tradeoff, our estimate for κ_α actually picks up the effect of real rigidities insofar these are present in the data. In any case, in the majority of the countries in our sample the output gap turns out to be insignificant, which casts some doubt on the importance of domestic factors on inflation dynamics in open economies relative to external factors, as we claim below. Yet, 'wrongly' (i.e., negatively) signed output gaps that are statistically significant as well as statistically insignificant output gaps are known to have plagued the closed-economy empirical NKPC literature too, both in its 'pure' and 'hybrid' strands.[21]

Recall that in Galí and Monacelli (2005) α corresponds to the share of domestic consumption allocated to imported goods in the steady state. Clearly, a negative estimate for α is inconsistent with this interpretation. And we see, next, that our estimates for α, the parameter we are mostly interested in, are positive and significant at standard levels for half of the countries in our sample: namely, at 1% level for Germany, the Netherlands, the UK and Switzerland, and at 10% level for Canada. Thus, external factors appear to be more relevant than the domestic output gap as inflation divers in the small open economies in our sample. The degree of trade openness we estimate ranges from 14% (Canada, which is, inversely, a home bias of 86%) to 48% (UK, i.e., a home bias of 52%). Note that the model in Galí and Monacelli (2005) may not fully capture all factors influencing the impact of terms of trade fluctuations on inflation dynamics. A particularly relevant such factor seems the pricing behavior of exporting firms. As mentioned, the Galí-Monacelli (2005) model is based on full producer currency pricing (PCP). However, if prices are actually set according to local currency pricing (LCP) in some proportion, then our estimates of α may be affected by this feature, itself likely to be highly country-specific.

In short, we conclude that expected *relative* variations in the terms of trade appear to be an important driver of CPI inflation in the majority of countries under consideration. Moreover, the impact of domestic factors on inflation dynamics, summarized by the

[20] This is not uncommon in the empirical NKPC literature employing GMM: e.g., Rudd and Whelan (2007), Table 1, p. 159, similarly report discount factors slightly higher than unity for quarterly US estimates over 1960:1–2004:3.

[21] See again the up-to-date summary in Rudd and Whelan (2007).

output gap, come out to be of less importance. To be more precise, the output gap is statistically significant at the 5% level for three economies in our sample out of ten, namely, France, the UK and Sweden. Only in the UK both the expected relative ToT change and the current output gap are simultaneously significant, together with expected next-period CPI inflation as the third factor in our main test equation (7). Nevertheless, for three SOEs, Austria, Italy and Spain, we find that neither the output gap, nor the terms of trade change turn out to be significant. Only for one country, Sweden, the sign of the estimated output gap coefficient does not conform to the NKPM property of divine coincidence. Thus, our results are largely, although not entirely, in line with the model in Galí and Monacelli (2005).

[Table 2 about here]

As a next step in our analysis, we re-estimate (7) but this time with the output gap calculated as deviation of real GDP from a quadratic-polynomial (Q-P) trend. Table 2 demonstrates a slight improvement of our results in terms of our estimates for α. In addition to being rather robust to this modification, the outcome from this latter estimation also yields a sixth country, Italy, where the expected relative ToT change now becomes statistically significant at the 10% level and acquires a plausible positive magnitude of 0.31. However, the above improvement comes at some cost: when estimating (7) with Q-P instead of H-P filtering, the output gap coefficient, κ_α, turns out to be insignificant in all countries in the sample except France. As before, the estimated β's are all significant at the 1% level and have plausible values.

'Wrongly' signed or insignificant output gaps have appeared in many contributions, as emphasized earlier and, notably, in the review of the literature by Rudd and Whelan (2007). Much more details as to the likely causes of this outcome are offered in the latter survey. It might be related to the fact the output gap and marginal costs do not need to be proportional, whereas our estimated equation (7) relies on the common assumption that they are indeed. As mentioned, Galí and Gertler (1999) and Sbordone (2002) were among the first to argue that a more general approach would be to use average real unit labor costs to proxy marginal costs.

[Table 3 about here]

Thus, we proceeded by estimating equation (6) directly, without replacing $\widehat{mc}_t$ by the (assumed) proportional output gap. We see from Table 3 that this modification leads to rather similar outcomes. Now λ is still insignificant (in 9 out of the 10 economies in our sample) or wrongly signed (for the UK, the only country where it comes out significant, at the 1% level). On the other hand, we get estimates for α that are statistically significant at the 1% level and plausible in 4 cases (Germany, Italy, the Netherlands and the UK). Overall, for the remaining 6 countries in the sample we find that neither the current-period labor share in income, nor the expected next-period change in the terms of trade relative to that observed since the past period matter for the dynamics of the CPI inflation rate. Thus, this specification performs relatively worse, which is in line with the criticism in Rudd and Whelan (2007).

[Table 4 about here]

Note that specification (7) imposes rather strong restrictions on how the terms of trade enter and influence inflation dynamics.[22] Since β is close to unity in most cases,

[22] Appendix B proposes our interpretation as to why this is so, from a *theoretical* open-economy perspective.

the last term in (7) closely resembles the second difference of the terms of trade. Empirically, the second difference of the ToT behaves very much like white noise in most countries. This could be one reason why the estimates of α turn out to be insignificant or negatively signed in some of the countries. Thus, regardless the theoretical justification in Galí and Monacelli (2005) and our corresponding interpretation in Appendix B, as an additional robustness analysis we estimate an alternative specification motivated on empirical grounds (only) which replaces $(\Delta s_t - \beta E_t \Delta s_{t+1})$ simply by Δs_t. Of course, this additional specification does not allow to interpret the coefficients on the output gap and on the terms of trade in a structural way. Table 4 shows the results. We see that this slightly less restrictive from an applied viewpoint specification delivers broadly similar results. In particular, now the first difference of the terms of trade comes out significant in 6 countries, whereas the output gap is significantly different from zero in 3 countries.

Let us stress, last but not least in the present context, an important aspect that reveals a rather successful empirical fit of the SOE NKPC we test here: whenever we find a statistically significant α across all our whole sample specifications in tables 1 through 4, it is always positive and of a plausible value between 0 and 1. Moreover, this regularity is preserved as well in our estimates of α by subperiod, as reported in tables 7 and 8 on which we comment in the next subsection.

[Tables 5 and 6 about here]

To further cross-check our findings, we also ran other empirically motivated regressions within our sample by testing the 'pure' and 'hybrid' closed-economy versions of the NKPC. The 'pure' closed economy NKPC in table 5 shows a positive and significant coefficient on the output gap for 4 out of 10 countries, which is a marginally better performance than in our baseline specification in Table 1. From this finding we may conclude that the inclusion of expected relative ToT fluctuations in the SOE specification of the NKPC may slightly contribute to the loss of significance of the output gap. For the hybrid model, in contrast, the results for the output gap – shown in Table 6 – do not improve compared to the SOE NKPC estimation in Table 1. Thus, in our sample including lagged inflation in the NKPC does not solve the problem of insignificant or wrongly signed output gap coefficients often found in the literature.

Overall, these cross-checks reassure us additionally that the empirical fit of the SOE NKPC we found was reasonable. We therefore would more generally interpret our empirical tests of the Galí–Monacelli (2005) SOE NKPC as providing first econometric evidence in favor of a moderate support of the underlying theory.

4.2 Inflation Dynamics in Small Open Economies and Globalization

As stated in the introduction, a number of recent studies – e.g., Rogoff (2003, 2006) among many others – attempt to gauge whether the ongoing process of globalization may have important consequences for inflation dynamics and, therefore, for the conduct of monetary policy. A general argument in one strand of this literature – e.g., Borio and Filardo (2007) and White (2008) – is that, due to increased openness and the resulting increase in trade and financial flows, traditional domestic factors have become less important in determining inflation. More specifically, this literature argues that global output gaps have taken over the role of domestic output gaps as a driving force behind inflation dynamics. The opposite strand of the literature – e.g., Ball (2006), Woodford (2007), Mishkin (2007, 2008) – concludes that there is no evidence for a considerably changed inflation dynamics, and for any particular strong effect of globalization in determining domestic inflation (and, further, for the ability of central banks to control it).

In this section we try to explore if and how our present empirical analysis reflects, or may offer insights into, these debates. In a narrower sense, we check to what extent globalization may have had an impact on the SOE NKPC specified by (7). Accordingly, to be able to judge in a straightforward fashion and following a commonly applied procedure, we split the sample and estimate (7) over two subsamples, 1970:1–1986:4 and 1987:1–2007:4. We choose this particular date since it splits our sample in equal halves and also because the late 1980s saw substantial financial liberalizations and increases in international trade. For Germany we chose the sample split date to be 1991, i.e., the two subsamples are 1970:1–1990:4 and 1991:1–2007:4, because of the natural (statistical and probably structural) break induced by the German re-unification. Since data for Austria start in 1980 and due to its close economic links with Germany, we chose the break date for Austria to be 1991 as well.

[Tables 7 and 8 about here]

Tables 7 and 8 show the results across subperiods. We report only the estimates for the specification with H-P detrended real GDP as a proxy for the output gap. Results obtained for the other specifications are qualitatively similar.[23] Comparing the estimates for κ_α across subsamples shows that the output gap appears to have become less important as a driving force behind inflation over time. In the first subsample κ_α is significantly different from zero in 5 countries at the 5% level. In the second subsample, we find that the output gap enters significantly at the 5% level only in 3 countries. In Switzerland the output gap is only significant at the 10% level. Thus, we confirm the existing literature which documents a reduced sensitivity of inflation to domestic output gaps, e.g., Borio and Filardo (2007) and White (2008).

For α, however, we find a similar pattern. In the later subsample α is significantly different form zero in 3 countries, compared to 5 countries in the earlier sample. Note as well that, numerically, we obtain *larger* point estimates in the second subsample for *all* 3 economies where α is significantly greater than zero. More precisely, in those remaining 3 economies of our sample where global factors such as expected relative ToT changes have been estimated to be statistically significant, globalization appears to have increased its magnitude of influence quite dramatically: α has risen across the subperiods studied from 0.07 in the 1970s and the 1980s to 0.14 in the 1990s and the 2000s in Italy, from 0.47 to 0.84 in the UK and from 0.21 to 0.27 in the Netherlands. The latter trends are indicative for a potential role of country-specific features at the level of production and trade structures as well as of policy and institutional mechanisms in explaining the divergence of the mentioned 3 countries from the other countries in our sample.

Overall, while we find that the impact of the domestic output gap on CPI inflation has declined over time, no clear pattern across countries is observable for the expected relative change in the terms of trade. In 3 countries, as already mentioned, it increased over time, in 2 countries (Austria and Germany) it actually decreased, in Sweden it increased but lost its significance, and in the other 4 countries it remained insignificant. Thus, although the economies in our sample may have increasingly become more open over time, we do not find that changes in the expected relative ToT have become a more important determinant for inflation dynamics in the majority of countries. Yet, whereas the number of countries for which the terms of trade are an important determinant of

[23] We also estimated specifications where GDP is detrended using a Q-P trend and where unit labor costs replace the output gap. These results are available upon request.

inflation dynamics has decreased, its relative importance in the economies of our sample where it remains relevant (3 cases) has considerably increased.

5 Concluding Remarks

In this paper we subjected for the first time the small open-economy version of the New Keynesian Phillips Curve derived in Galí and Monacelli (2005) to empirical assessment. Across the specifications we estimated by GMM, we looked mainly into the frequency with which each of the three theoretically defined coefficients was statistically significant and had the expected sign, a 'qualitative' pass of our test of the SOE NKPC, and also had a plausible significant magnitude, a 'quantitative' pass, in an econometrically 'valid' estimation as indicated by the J-statistics reported in the tables. Overall, we find some moderate support for it in our sample. In particular, the SOE NKPC does not perform worse than its closed-economy 'pure' or 'hybrid' counterparts or, still, empirically motivated alternative SOE specifications. The theoretically relevant expected current-to-next period discounted change in the terms of trade relative to the observed past-to-current period ToT change proved, in general, plausible on empirical grounds too as a key determinant of CPI inflation dynamics in small open economies. For most such economies in the sample we considered, expected relative changes in the ToT turned out to be even a more important inflation driver than the domestic output gap.

When embarking on this empirical study, we intended to address essentially two questions:

1. What is the empirical support for this theoretically derived SOE NKPC?
2. Given its specifications we tested and the results we obtained, do we find anything (unambiguous) to say about globalization and inflation dynamics in SOEs?

Our (provisional) answer to question 1. is: we do not find overwhelming support for the Galí–Monacelli (2005) SOE NKPC in our 10-country SOE sample; yet we find some moderate evidence in its favor, especially by subperiod. This weakly supportive evidence covers, roughly and across the board, one-third to two-thirds of the countries in the sample, depending on the particular aspect along which we would choose to interpret our results. Here is a summary of some explanations we can offer along the key dimensions of our estimation and the obtained mixed results.

a. Our estimates of the time discount factor proved always (i) statistically significant and (ii) correctly signed, and (iii), with a few marginal exceptions common to the literature, also of plausible magnitudes.

b. We did moderately well too on estimating the degree of import dependence (or trade openness, in a broader sense) in terms of (i) statistical significance, (ii) sign and (iii), generally speaking, plausible magnitudes of the significantly positive α's.

c. (i) We did worse on getting the output gap statistically significant. But this is also a problem of the literature, including the closed-economy specification, and may be a result consistent with the data that reflects some decreasing influence on CPI inflation arising from this particular domestic source. Moreover, it may be that the inclusion of expected relative ToT fluctuations in the SOE specification for the NKPC negatively affects the significance of the output gap. (ii) As we demonstrated in Appendix A, the sign of the output gap should be most of the time positive in the Galí–Monacelli (2005) model, but not in specific (rare) cases of parameter constellations. In addition, we discussed that Blanchard and Galí (2007) argue in favor of a tradeoff, i.e., negative output gap in the NKPC if real rigidities matter and are appropriately accounted for. Real imperfections are not explicit in the Galí–Monacelli (2005) model, yet they would certainly be captured in our data, insofar such rigidities most likely underlie the actually existing economies in our sample. For these reasons we do not discard theoretically the empirical possibility, confirmed in a few cases in our tables, for the output gap sign to come out as significantly negative. (iii) Lastly, comparing statistical significance and magnitudes across our sample and subperiods, we find that external factors play a non-negligible role as a major inflation determinant in SOEs.

This latter finding naturally raises the question if and how globalization may have influenced – and will likely continue to influence – inflation dynamics, as well as the ensuing implications for the conduct of monetary policy. Although a detailed analysis of this issue lies beyond the scope of this paper, we may still summarize briefly the seemingly relevant aspects of our conclusions in such a direction.

So, our (provisional) answer to question 2. is: the Galí–Monacelli (2005) SOE NKPC specification found only moderate empirical support in our sample. Therefore, our estimates do not capture any systematic or overwhelming evidence concerning the potential effects of globalization on inflation dynamics across *all* of our 10 countries. However, for about *one-third* of our sample the role of external factors does seem to have increased substantively in quantitative terms.

Can this result for a subset of our sample be interpreted as an outcome of globalization *only*? It is more likely that other factors such as the specific size, production structure and/or trade patterns of a particular country may have contributed, in addition to global trends, to stronger or weaker influence of external versus domestic factors. Separating out and quantifying the effects of these dimensions, as well as other refinements of our initial broad estimates reported here, constitute obvious avenues for further theoretical and empirical research. More disaggregated data, alternative modeling of the pricing behavior of firms or of real rigidities that annihilate the divine coincidence of the New Keynesian set-up are also among the areas for future exploration.

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A Theoretically Expected Signs of Estimated Coefficients

This appendix justifies on theoretical grounds what the expected signs of the estimated coefficients in our alternative SOE NKPC econometric specifications highlighted in the main text should be.

A.1 Sign of β

The most directly evident expected sign of the coefficients we estimate is that of β. Being the constant (subjective) time discount *factor* of the representative household in the NKPM, it is theoretically limited to be within the range of $0 < \beta \equiv \frac{1}{1+\rho} < 1$, where $\rho > 0$ defines the constant (subjective) time discount *rate*. Moreover, β should be really very close to 1. Given that our empirical specifications employ quarterly time series, the magnitude of β usually assumed in simulations is 0.99. Therefore, the theoretically expected sign of β is positive, and its likely magnitude is close to 0.99.

A.2 Sign of α

Within the context of the SOE version of the NKPM in Galí and Monacelli (2005) the theoretically expected sign as well as magnitude of α are both clear as well. That is, $0 < \alpha < 1$, since α is the weight of imported goods in the total CPI.

A.3 Sign of λ

One of our econometric specifications, replacing the output gap by a measure of the deviation of real marginal costs from their steady state value, is based on equation (6). Recall that in the context of the NK model λ is a function of the degree of price stickiness $0 < \theta < 1$, as $0 < 1 - \theta < 1$ is the probability of setting optimally in a Calvo (1983) fashion a firm's price under monopolistic competition, and of the discount factor $0 < \beta \equiv \frac{1}{1+\rho} < 1$. More precisely,

$$0 < \lambda \equiv \frac{(1 - \beta\theta)(1 - \theta)}{\theta},$$

and therefore λ has a theoretically expected positive sign.

A.4 Sign of κ_α

Note that in Galí–Monacelli's (2005) SOE version of the NK model, which we subject to empirical testing here, $\kappa_\alpha \equiv \lambda(\sigma_\alpha + \varphi)$, where $\lambda \equiv \frac{(1-\beta\theta)(1-\theta)}{\theta} > 0$, $\varphi > 0$, $\sigma_\alpha \equiv \frac{\sigma}{(1-\alpha)+\alpha\omega} \gtrless 0$, and $\omega \equiv \sigma\gamma + (1-\alpha)(\sigma\eta - 1) \gtreqless 0$. From the signs of the enumerated components in the definition of κ_α *two general cases* and *one special case* stand out.

The *first general case* is where $\sigma\eta > 1$, i.e., the *product* of the *inverse* of the intERtemporal substitutability in consumption of the aggregate SOE's consumption index, $\sigma > 0$, and the intRAtemporal substitutability in consumption between domestically-produced and imported goods entering that index, $\eta > 0$, is *larger than unity.* In this case,

$$\omega \equiv \sigma\gamma + (1-\alpha)\underbrace{(\sigma\eta - 1)}_{>1} > 0$$

so that

$$\sigma_\alpha \equiv \frac{\sigma}{(1-\alpha)+\alpha \underbrace{\omega}_{>0}} > 0$$

and clearly then

$$\kappa_\alpha \equiv \lambda \left(\underbrace{\sigma_\alpha}_{>0} + \quad \varphi \right) > 0.$$

The *special case* is where $\sigma\eta = 1$, implying $\omega \equiv \sigma\gamma > 0$ too and, hence, again $\sigma_\alpha > 0$ and finally $\kappa_\alpha > 0$. These two cases, the general and the special ones, both implying $\kappa_\alpha > 0$, yield the standard NKPM (result) where, as pointed out by Blanchard and Galí (2007), the *divine coincidence* property *eliminates* the tradeoff between inflation stabilization and output stabilization. In the context of such parameter values, namely, $\sigma\eta \geq 1$ leading to $\kappa_\alpha > 0$, therefore, the theoretically expected sign of the output gap is *unambiguously positive.*

However, the *second general case* arises where $\sigma\eta < 1$, i.e., the *product* of the *inverse* of the intERtemporal substitutability in consumption of the aggregate SOE's consumption index, $\sigma > 0$, and the intRAtemporal substitutability in consumption between domestically-produced and imported goods entering that index, $\eta > 0$, is *smaller than unity.* In this case,

$$\omega \equiv \underbrace{\sigma\gamma}_{+} + \underbrace{(1-\alpha)}_{+}\underbrace{(\sigma\eta - 1)}_{-}$$

so that if

$$\underbrace{\sigma\gamma}_{+} > \underbrace{(1-\alpha)}_{+}\underbrace{(1-\sigma\eta)}_{+}$$

$$\sigma\gamma > 1 - \sigma\eta - \alpha + \alpha\sigma\eta$$

$$\sigma\gamma + \sigma\eta - \alpha\sigma\eta > 1 - \alpha$$

$$\sigma\left[\gamma + (1-\alpha)\,\eta\right] > 1 - \alpha$$

$$\frac{\gamma + (1-\alpha)\,\eta}{1-\alpha} > \sigma^{-1}$$

$$\frac{\gamma}{1-\alpha} + \eta > \sigma^{-1}$$

then $\kappa_\alpha > 0$, as before, but if the opposite is true, i.e.,

$$\frac{\gamma}{1-\alpha} + \eta < \sigma^{-1}$$

then $\omega < 0$, so that

$$\sigma_\alpha \equiv \frac{\overbrace{\sigma}^{+}}{\underbrace{(1-\alpha)}_{+} + \underbrace{\alpha\omega}_{-}}$$

and if, further,

$$\underbrace{\alpha - 1}_{-} < \underbrace{\alpha\omega}_{-}$$

then $\sigma_\alpha > 0$ and so $\kappa_\alpha > 0$, as before, but if the opposite is true, i.e.,

$$\underbrace{\alpha - 1}_{-} > \underbrace{\alpha\omega}_{-}$$

then $\sigma_\alpha < 0$ and

$$\kappa_\alpha \equiv \underbrace{\lambda}_{+} \left(\underbrace{\sigma_\alpha}_{-} + \underbrace{\varphi}_{+} \right)$$

so that if

$$|\sigma_\alpha| < |\varphi|$$

then $\kappa_\alpha > 0$, as before, but if the opposite is true, i.e.,

$$|\sigma_\alpha| > |\varphi|$$

then $\kappa_\alpha < 0$ and the divine coincidence disappears even in the standard NKPM. As we can verify from the long chain of 'ifs' that need to be true in order to finally arrive at $\kappa_\alpha < 0$ in the Galí–Monacelli (2005) SOE version of the usual NK framework, the case of $\kappa_\alpha < 0$ would be theoretically (much) less probable – or may be even not plausible for appropriately chosen parameter values – than the case of $\kappa_\alpha > 0$.

However, in a more general set-up such as that in Blanchard and Galí (2007) or along similar lines, incorporating *real imperfections* which very likely characterize real-world economies as those in our sample, the theoretically expected sign of the output gap may well be *unambiguously negative*, and then the short-run tradeoff between inflation stabilization and output stabilization well-known from the practice of central banks and from the traditional macromodels is restored.

For that reason, we do not discard empirical results from our sample that come out with a *statistically significant negative* coefficient to the SOE NKPC output gap, that is, with estimated $\kappa_\alpha < 0$. Moreover, classifying and interpreting our findings by country and subperiod along the positivity or negativity of the output gap coefficients may tell us more about the heterogeneity of the SOEs studied in terms of their underlying degree of real rigidities.

B Interpretation of the Expected Relative ToT Change

This appendix justifies on theoretical grounds the economic interpretation we would offer for the appearance of the expected relative change in the terms of trade in our main SOE NKPC econometric specifications, (7) and (6), discussed in the main text. This latter ToT-related term is $s_t - s_{t-1} - \beta(E_t s_{t+1} - s_t)$. It is positive if $s_t - s_{t-1} > \beta(E_t s_{t+1} - s_t)$. There are *four cases* to consider, for further clarity, as follows.

Case 1: If $s_t - s_{t-1} > 0$ (past-to-current period ToT *deterioration* for the SOE examined) and $\beta(E_t s_{t+1} - s_t) < 0$ (expected discounted current-to-next period ToT *improvement*), then $s_t - s_{t-1} > \beta(E_t s_{t+1} - s_t)$ and a (*strong*) positive (*upward*) pressure on CPI inflation arises from this ToT-related term (multiplied by the degree of openness, $0 < \alpha < 1$, in the estimated specifications).

Case 2: If $s_t - s_{t-1} > 0$ (past-to-current period ToT *deterioration* for the SOE examined) and $\beta(E_t s_{t+1} - s_t) > 0$ too (expected discounted current-to-next period ToT *deterioration* too), then if further $s_t - s_{t-1} > \beta(E_t s_{t+1} - s_t)$, a (*weaker* than in case 1) positive (*upward*) pressure on CPI inflation arises from the ToT-related term. This means that if there has been a deterioration in the ToT observed, i.e., $s_t - s_{t-1} > 0$, and if agents expect a further deterioration, so that $\beta(E_t s_{t+1} - s_t) > 0$ too, then the second (next-period) deterioration must be of a *smaller* (discounted) size, i.e., $s_t - s_{t-1} > \beta(E_t s_{t+1} - s_t)$, *de facto* an expected *relative improvement* in the ToT between yesterday $(t-1)$, now (t) and tomorrow $(t+1)$, for a positive (*upward*) pressure on CPI inflation to arise from the ToT-related term (again, multiplied by the degree of openness in the specifications we estimate).

Summing up cases 1 and 2: One interpretation of the results in cases 1 and 2 above we adopt here is that the expected *relative improvement* in the ToT would stimulate expenditure switching to *foreign* goods, so that the analyzed SOE's CPI inflation would be under *upward* pressure arising from the *higher* demand for imports. This pressure is stronger the higher is the degree of openness to trade, $0 < \alpha < 1$.

Case 3: If $s_t - s_{t-1} < 0$ (past-to-current period ToT *improvement*) and $\beta(E_t s_{t+1} - s_t) > 0$ (expected discounted current-to-next period ToT *deterioration*), then $s_t - s_{t-1} < \beta(E_t s_{t+1} - s_t)$ and a (*strong*) negative (*downward*) pressure on CPI inflation arises from this ToT-related term.

Case 4: If $s_t - s_{t-1} < 0$ (past-to-current period ToT *improvement*) and $\beta(E_t s_{t+1} - s_t) < 0$ too (expected discounted current-to-next period ToT *improvement* too), then if further $s_t - s_{t-1} < \beta(E_t s_{t+1} - s_t)$, a (*weaker* than in case 3) negative (*downward*) pressure on CPI inflation arises from the ToT-related term. This means that if there has been an improvement in the ToT observed, i.e., $s_t - s_{t-1} < 0$, and if agents expect a further improvement, so that $\beta(E_t s_{t+1} - s_t) < 0$ too, then the second (next-period) improvement must be of a *smaller in absolute value* (discounted) size, i.e., $s_t - s_{t-1} < \beta(E_t s_{t+1} - s_t)$ (*both* the LHS and the RHS here are now *negative* values), *de facto* an expected *relative deterioration* in the ToT between yesterday $(t-1)$, now (t) and tomorrow $(t+1)$, for a negative (*downward*) pressure on the analyzed SOE's CPI inflation to arise from the ToT-related term.

Summing up cases 3 and 4: The corresponding interpretation of the results in cases 3 and 4 would be that the expected *relative deterioration* in the SOE's ToT would stimulate expenditure switching to *domestically-produced* goods, so that its CPI inflation would be under *downward* pressure arising from the *lower* demand for imports. Again, this pressure is stronger the higher is the degree of openness to trade, $0 < \alpha < 1$.

Thus, an economic interpretation which is theoretically-coherent across all four possible cases above of the ToT-related term in our test equation specifications has been justified here. The main text uses it directly.

C Instrumental Variables Used in the Estimations

This appendix provides a full list of the instrumental variables used in our GMM estimation by specification (i.e., table) and country. In addition to the instruments below, each instrument set includes also a constant.

In Table 1:

Austria: CPI inflation lags 1 to 4, H-P filtered output gap lags 1 to 4, change in terms of trade lags 1 to 6;
Germany: CPI inflation lags 1 to 6, H-P filtered output gap lags 1 to 4, change in terms of trade lags 1 to 4;
Italy: CPI inflation lags 1 to 4, H-P filtered output gap lags 1 to 4, change in terms of trade lags 1 to 4;
France: CPI inflation lags 1 to 4, real unit labor costs lags 1 to 6, change in terms of trade lags 1 to 4;
Spain: CPI inflation lags 1 to 4, H-P filtered output gap lags 1 to 6, change in terms of trade lags 1 to 4;
Netherlands: CPI inflation lags 1 to 4, H-P filtered output gap lags 1 to 4, change in terms of trade lags 1 to 6;
UK: CPI inflation lags 1 to 6, H-P filtered output gap lags 1 to 6, change in terms of trade lags 1 to 4;
Canada: CPI inflation lags 1 to 4, H-P filtered output gap lags 1 to 6, change in terms of trade lags 1 to 6;
Sweden: CPI inflation lags 1 to 6, H-P filtered output gap lags 1 to 4, change in terms of trade lags 1 to 4;
Switzerland: CPI inflation lags 1 to 6, H-P filtered output gap lags 1 to 4, change in terms of trade lags 1 to 4.

In Table 2:

As in Table 1, except with Q-P filtered output gap instead of H-P filtered output gap.

In Table 3:

As in Table 1, except with real unit labor costs instead of H-P filtered output gap.

In Table 4:

As in Table 1.

In Table 5:

Austria: CPI inflation lags 1 to 6, H-P filtered output gap lags 1 to 6, change in the bilateral USD/EUR (national currency before 1999) exchange rate lags 1 to 4;
Germany: CPI inflation lags 1 to 6, H-P filtered output gap lags 1 to 4, change in the HWWA commodity price index lags 1 to 4;
Italy: CPI inflation lags 1 to 4, H-P filtered output gap lags 1 to 4, terms of trade lags 1 to 4;
France: CPI inflation lags 1 to 4, real unit labor costs lags 1 to 6, change in terms of trade lags 1 to 4;

Spain: CPI inflation lags 1 to 4, real unit labor costs lags 1 to 6, change in the HWWA commodity price index lags 1 to 4;
Netherlands: CPI inflation lags 1 to 6, H-P filtered output gap lags 1 to 4, change in the bilateral USD/EUR (national currency before 1999) exchange rate lags 1 to 4;
UK: CPI inflation lags 1 to 6, H-P filtered output gap lags 1 to 6, change in terms of trade lags 1 to 4;
Canada: CPI inflation lags 1 to 6, H-P filtered output gap lags 1 to 6, change in import prices lags 1 to 6;
Sweden: CPI inflation lags 1 to 6, real unit labor costs lags 1 to 6, change in the bilateral USD/SEK exchange rate lags 1 to 6;
Switzerland: CPI inflation lags 1 to 6, H-P filtered output gap lags 1 to 4, change in the bilateral USD/CHF exchange rate lags 1 to 4.

In Table 6:

As in Table 5, except that CPI inflation starts at lag 2 instead of 1.

In Table 7:

As in Table 1.

In Table 8:

As in Table 1.

Table 1: GMM Estimates of the SOE NKPC with H-P Filtered Output Gap

	β		p-value	κ_α		p-value	α		p-value	p(J-stat)
Austria	0,87	***	0,00	0,00		1,00	-0,27		0,10	0,20
Germany	0,97	***	0,00	0,02		0,53	0,17	***	0,00	0,26
Italy	1,01	***	0,00	0,06		0,26	0,06		0,10	0,25
France	1,05	***	0,00	0,19	**	0,02	-0,08		0,31	0,18
Spain	0,99	***	0,00	0,01		0,70	-0,01		0,54	0,48
Netherlands	0,94	***	0,00	0,01		0,79	0,28	***	0,00	0,12
UK	0,87	***	0,00	0,18	**	0,02	0,48	***	0,00	0,24
Canada	0,99	***	0,00	0,04		0,28	0,14	*	0,07	0,44
Sweden	0,93	***	0,00	-0,14	**	0,03	0,01		0,60	0,29
Switzerland	0,93	***	0,00	0,02		0,67	0,24	***	0,03	0,15

Notes: Coefficients are estimated according to equation (7). The estimation period is 1970:1–2007:4 (except for Austria: 1980:1–2007:4). The stars attached to the coefficients estimates show significance levels, where * denotes significance at the 10%, ** at the 5% and *** at the 1% level. The Hansen's J-test tests the validity of the overidentifying restrictions imposed by the instruments with the null hypothesis that the overidentifying restrictions are satisfied (the instruments are valid). Standard errors are robust with respect to heteroskedasticity and autocorrelation.

Table 2: GMM Estimates of the SOE NKPC with Q-P Filtered Output Gap

	β		p-value	κ_α		p-value	α		p-value	p(J-stat)
Austria	0,89	***	0,00	0,02		0,52	-0,26		0,12	0,21
Germany	0,98	***	0,00	0,00		0,94	0,18	***	0,00	0,28
Italy	1,01	***	0,00	0,02		0,31	0,06	*	0,08	0,31
France	1,01	***	0,00	0,12	*	0,01	-0,06		0,40	0,18
Spain	0,99	***	0,00	0,00		0,83	0,00		0,70	0,51
Netherlands	0,94	***	0,00	0,01		0,36	0,29	***	0,00	0,13
UK	0,86	***	0,00	0,04		0,23	0,47	***	0,00	0,17
Canada	0,99	***	0,00	0,01		0,44	0,15	*	0,07	0,43
Sweden	0,95	***	0,00	-0,02		0,20	0,01		0,62	0,27
Switzerland	0,91	***	0,00	0,01		0,47	0,25	***	0,02	0,15

Notes: Coefficients are estimated according to equation (7). The estimation period is 1970:1–2007:4 (except for Austria: 1980:1–2007:4). The stars attached to the coefficients estimates show significance levels, where * denotes significance at the 10%, ** at the 5% and *** at the 1% level.

Table 3: GMM Estimates of the SOE NKPC with Labor Income Share (as RMC Proxy)

	β		p-value	λ		p-value	α		p-value	p(J-stat)	
Austria	0,89	***	0,00	-0,02		0,72	-0,02		0,91	0,19	
Germany	0,97	***	0,00	0,00		0,91	0,17	***	0,00	0,28	
Italy	1,02	***	0,00	0,00		0,76	0,23	***	0,02	0,47	
France	0,98	***	0,00	0,01		0,27	-0,04		0,52	0,07	*
Spain	1,00	***	0,00	0,00		0,33	0,01		0,38	0,82	
Netherlands	0,96	***	0,00	0,01		0,54	0,28	***	0,00	0,07	*
UK	0,81	***	0,00	-0,10	***	0,00	0,53	***	0,00	0,12	
Canada	0,99	***	0,00	0,00		0,81	0,00		0,98	0,47	
Sweden	0,93	***	0,00	-0,02		0,24	0,01		0,61	0,23	

Notes: Coefficients are estimated according to equation (6). The estimation period is 1970:1–2007:4 (except for Austria: 1980:1–2007:4; Italy: 1975:1–2007:4; Spain: 1980:1–2007:4). The stars attached to the coefficients estimates show significance levels, where * denotes significance at the 10%, ** at the 5% and *** at the 1% level.

Table 4: GMM Estimates of the SOE NKPC with H-P Filtered Output Gap but Differenced ToT

	β_Δ		p-value	$\kappa_{\alpha\Delta}$		p-value	α_Δ		p-value	p(J-stat)	
Austria	0.89	***	0.00	0.02		0.65	0.35	**	0.02	0.22	
Germany	0.95	***	0.00	0.03		0.29	0.18	***	0.00	0.14	
Italy	1.01	***	0.00	0.08		0.10	0.05		0.29	0.17	
France	1.06	***	0.00	0.15	**	0.02	0.09	**	0.02	0.40	
Spain	0.99	***	0.00	0.01		0.60	0.01		0.54	0.46	
Netherlands	0.96	***	0.00	-0.01		0.84	0.31	***	0.00	0.09	*
UK	0.83	***	0.00	0.30	***	0.00	0.55	***	0.00	0.14	
Canada	1.00	***	0.00	0.03		0.34	0.04		0.42	0.39	
Sweden	0.92	***	0.00	-0.14	**	0.03	0.02		0.61	0.30	
Switzerland	0.81	***	0.00	-0.04		0.43	0.16	**	0.03	0.10	

Notes: Coefficients are estimated from $\pi_t = \beta_\Delta E_t \pi_{t+1} + \kappa_{\alpha\Delta} x_t + \alpha_\Delta \Delta s_t$. The estimation period is 1970:1–2007:4 (except for Austria: 1980:1–2007:4). The stars attached to the coefficients estimates show significance levels, where * denotes significance at the 10%, ** at the 5% and *** at the 1% level.

Table 5: GMM Estimates of the Pure Closed Economy NKPC with H-P Filtered Output Gap

	β		p-value	κ		p-value	p(J-stat)
Austria	0.91	***	0.00	0.04		0.28	0.38
Germany	0.99	***	0.00	0.05	*	0.08	0.31
Italy	1.00	***	0.00	0.12	**	0.02	0.25
France	1.03	***	0.00	0.13	**	0.02	0.18
Spain	1.02	***	0.00	0.05		0.22	0.70
Netherlands	0.97	***	0.00	0.01		0.66	0.15
UK	0.81	***	0.00	0.48	***	0.00	0.12
Canada	1.00	***	0.00	0.05		0.10	0.65
Sweden	1.00	***	0.00	0.11		0.42	0.36
Switzerland	0.95	***	0.00	-0.01		0.74	0.13

Notes: Coefficients are estimated from $\pi_t = \beta E_t \pi_{t+1} + \kappa x_t$. The estimation period is 1970:1–2007:4 (except for Austria: 1980:1–2007:4). The stars attached to the coefficients estimates show significance levels, where * denotes significance at the 10%, ** at the 5% and *** at the 1% level.

Table 6: GMM Estimates of the Hybrid Closed Economy NKPC with H-P Filtered Output Gap

	γ_f		p-value	γ_b		p-value	κ		p-value	p(J-stat)	
Austria	0.71	***	0.00	0.29	***	0.00	0.01		0.66	0.23	
Germany	0.55	***	0.00	0.44	***	0.00	0.02		0.19	0.09	*
Italy	0.62	***	0.00	0.38	***	0.00	0.07	**	0.04	0.09	*
France	0.40	***	0.00	0.60	***	0.00	-0.01		0.75	0.08	*
Spain	0.79	***	0.00	0.23		0.32	0.06		0.10	0.46	
Netherlands	0.54	***	0.00	0.46	***	0.00	0.01		0.75	0.06	*
UK	0.58	***	0.00	0.23	***	0.01	0.32	***	0.00	0.04	**
Canada	0.67	***	0.00	0.33	***	0.00	0.04	*	0.07	0.41	
Sweden	0.69	***	0.00	0.33	***	0.00	0.14		0.32	0.20	
Switzerland	0.34	***	0.00	0.62	***	0.00	0.00		0.92	0.04	**

Notes: Coefficients are estimated from $\pi_t = \gamma_f E_t \pi_{t+1} + \gamma_b \pi_{t-1} + \kappa x_t$. The estimation period is 1970:1–2007:4 (except for Austria: 1980:1–2007:4). The stars attached to the coefficients estimates show significance levels, where * denotes significance at the 10%, ** at the 5% and *** at the 1% level.

Table 7: GMM Estimates of the SOE NKPC with H-P Filtered Output Gap: Earlier Subsample (1970:1–1986:4)

	β		p-value	κ_α		p-value	α		p-value	p(J-stat)
Austria	0,30	***	0,00	-0,56	***	0,00	0,33	*	0,09	0,45
Germany	0,99	***	0,00	0,07	**	0,03	0,07	**	0,04	0,50
Italy	1,00	***	0,00	0,08		0,38	0,04		0,23	0,49
France	1,03	***	0,00	0,10	**	0,03	-0,04		0,37	0,46
Spain	0,98	***	0,00	0,08		0,47	0,00		0,79	0,35
Netherlands	0,97	***	0,00	0,20		0,11	0,21	**	0,01	0,32
UK	0,90	***	0,00	0,24		0,03	0,47	***	0,00	0,58
Canada	0,98	***	0,00	0,09		0,18	0,08		0,10	0,73
Sweden	0,91	***	0,00	-0,44	***	0,00	0,04	**	0,06	0,36
Switzerland	0,86	***	0,00	-0,14	**	0,01	0,10		0,41	0,43

Notes: Coefficients are estimated according to equation (7). The estimation period is 1970:1–1986:4 (except for Austria: 1980:1–1990:4; Germany: 1970:1–1990:4). The stars attached to the coefficients estimates show significance levels, where * denotes significance at the 10%, ** at the 5% and *** at the 1% level.

Table 8: GMM Estimates of the SOE NKPC with H-P Filtered Output Gap: Later Subsample (1987:1–2007:4)

	β		p-value	κ_α		p-value	α		p-value	p(J-stat)
Austria	0,96	***	0,00	0,00		0,99	0,12		0,58	0,51
Germany	0,83	***	0,00	-0,03		0,44	0,06		0,25	0,22
Italy	1,04	***	0,00	0,01		0,80	0,14	**	0,05	0,17
France	0,96	***	0,00	0,01		0,71	0,01		0,91	0,10
Spain	0,99	***	0,00	-0,05	**	0,02	0,01		0,65	0,73
Netherlands	0,86	***	0,00	-0,07	**	0,03	0,27	***	0,00	0,11
UK	0,72	***	0,00	0,24	**	0,03	0,84	***	0,00	0,42
Canada	0,97	***	0,00	0,02		0,65	0,05		0,40	0,74
Sweden	0,95	***	0,00	0,01		0,89	0,05		0,48	0,32
Switzerland	1,03	***	0,00	0,10	*	0,07	0,12		0,13	0,11

Notes: Coefficients are estimated according to equation (7). The estimation period is 1987:1–2007:4 (except for Austria and Germany: 1991:1–2007:4). The stars attached to the coefficients estimates show significance levels, where * denotes significance at the 10%, ** at the 5% and *** at the 1% level.