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Revisiting the exchange rate pass through: A general equilibrium perspective

Javier García-Cicco [b,*], Mariana García-Schmidt [a]

[a] Banco Central de Chile, Agustinas 1180, Santiago, Chile
[b] Banco Central de la República Argentina, Reconquista 266, Buenos Aires, Argentina

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ABSTRACT

A large literature estimates the exchange rate pass-through to prices (ERPT) using reduced-form approaches, whose results are an important input for Central Banks. We show two shortcomings of these empirical measures for monetary policy analysis, which are quantitatively important and may lead to imprecise and biased inflation predictions. First, while the literature describes a single ERPT, which we will label *unconditional*, there are different ERPT *conditional* on each shock that hits the economy. Second, these crucially depend on *expected* monetary policy, so that empirical ERPT measures should not be taken as given in evaluating policy actions. We use a simple model of a small and open economy to understand the intuition behind these two critiques, showing that these results seem to hold under many alternative specifications. We then highlight the quantitative relevance of these distinctions using a large-scale DSGE model of a small open economy.

1. Introduction

The exchange-rate pass-through (ERPT) measures the evolution of a price after a change in the nominal exchange rate (NER). Estimates from reduced-form empirical approaches, such as vector auto-regressions (VAR) or single-equation models, are a relevant input for monetary policymakers.[1] In this paper, we highlight two shortcomings with these empirical estimates that may lead to incomplete and biased inflation forecasts and show how a structural approach can help to prevent them.

The first shortcoming is based on the observation that different shocks affect the NER and prices differently. Empirical estimates are based on isolating "exogenous" or "unforecastable" movements in the NER, producing a single ERPT for different horizons (which we call *unconditional* or *aggregate*, UERPT for short). In contrast, in general equilibrium models it is natural to differentiate among alternative shocks, allowing to compute a *conditional* ERPT for each shock (labeled CERPT). While some studies have documented that the ERPT might differ depending on the shock (as discussed below) we provide a novel analytical characterization of the relationship between CERPT and UERPT; allowing for a clear assessment of the biases emerging from reduced-form estimates. Indeed, we show that the differences can be large.

* Corresponding author.
E-mail addresses: javier.garcia@bcra.gob.ar, (J. García-Cicco), mcgarcia@bcentral.cl. (M. García-Schmidt).

[1] Some examples are Devereux and Engel (2002), Campa and Goldberg (2005), Campa and Minguez (2006), Choudhri and Hakura (2006), Ca' Zorzi et al. (2007), Gopinath et al. (2010), among many others. Burstein and Gopinath (2014) and Aron et al. (2014) provide extensive surveys. Throughout, we use the terms "reduced-form" and "empirical" interchangeably to refer to this literature.

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The second shortcoming is that all ERPTs depend on how monetary policy reacts and, crucially, is expected to behave. This generates a second source of bias for empirical approaches, which can be quantitatively important as well. ERPT estimates from reduced-form approaches are generally taken as a given input for policymakers. However, the realized ERPT will in part be an outcome of both current and expected policy. Reduced-form methodologies are ill-suited to deal with this distinction. In contrast, a general-equilibrium analysis can produce a different ERPT for each alternative policy path under consideration; greatly improving the analysis presented to decision-makers.[2]

We begin by analyzing the information lost in using UERPT measures relative to CERPT. We show analytically that, under certain assumptions –in the context of linear, dynamic and stochastic models– the UERPT obtained using a VAR is a weighted average of the CERPTs. We then propose UERPT measures that are comparable to the empirical ones, useful to quantitatively evaluate possible biases.

We show that CERPTs and UERPTs are indeed very different using a simple dynamic stochastic general equilibrium (DSGE) model of a small and open economy with nominal rigidities. For instance, the one-year ahead inflation forecast can be less than half or more than double when using CERPTs as compared to the forecasts when using UERPTs. These distinctions arise because each shock propagates through different channels.

We then highlight the role of monetary policy in shaping both CERPTs and UERPTs by running several experiments. One of them contrasts the baseline setup –in which policy follows Taylor rule– with an alternative that maintains the rate at its pre-shock level for a given number of periods, returning to the Taylor rule afterward. This attempts to mimic what would happen if a policymaker, guided by an estimated ERPT that is relatively low, convinces herself that the likely effect on inflation will be small; deciding not to change the policy stance. We show that important differences may arise, depending also on the shock hitting the economy.

We finally check that our main results remain robust to different specifications and are overall quantitatively relevant. To that end, we first explore alternative specifications of the baseline model such as indexation, differences in the pricing and invoicing-currency for tradables, financial frictions, and variations in parameter values. We then check the quantitative relevance by running the same exercises using a large-scale DSGE model, estimated with Chilean data, to see a practical application. In all these cases the differences between CERPTs and UERPTs, as well as their dependence on expected monetary policy, remain relevant.

In terms of the related literature, three previous papers using VAR models, Shambaugh (2008) and Forbes et al. (2017, 2018), recognize the existence of different ERPTs depending on shocks. They use alternative identification assumptions to estimate how several sources of fluctuations might generate different ERPTs; in the same spirit as our definition of CERPTs. Our work deepens their analysis in two ways. First, these studies do not show how these CERPTs compare with unconditional measures; a comparison that we explicitly perform to understand the bias implicit in UERPTs. Second, the identified shocks in these structural VARs might still be too general compared to those in a DSGE model, allowing us to provide a relatively more precise description of the relevant CERPTs.[3] Importantly, our analysis does not hinge on DSGE models providing a better fit to the data than VARs; nor do we claim this is the case. We just stress that DSGE models allow to calculate ERPTs conditional on well-specified structural shocks and to control for alternative policies, which cannot be done with empirical models, including VARs.

Two related papers using DSGEs are Bouakez and Rebei (2008) and Corsetti et al. (2008). The former is, to the best of our knowledge, the only one that uses an estimated DSGE (fitted to Canadian data) to compute CERPTs, providing also a measure that would qualify as UERPT. Our paper differs from theirs since we provide an UERPT measure that is directly comparable to those estimated in the empirical literature, allowing a better understanding of the produced biases. Corsetti et al. (2008) explores the structural determinants of the ERPT to import prices from a DSGE perspective, assessing possible biases in single-equation empirical methodologies. While our paper shares common points with this study, we distinguish between CERPTs and UERPTs, characterize ERPTs for several prices, and provide a quantitative evaluation of the biases. Still, none of these studies explore the second shortcoming we highlight regarding expected monetary policy.

The relationship between monetary policy and the ERPT has been studied in several papers, but none has explored how alternative *expected* policy paths affect the ERPT. For instance, Taylor (2000), Gagnon and Ihrig (2004) and Devereux et al. (2004) use DSGE models to see how monetary policy can alter the ERPT, proposing that a greater focus on inflation stabilization can explain why the empirical measures of ERPT seem to have declined over time in many countries. Others have analyzed how monetary policy should differ depending on structural characteristics associated with the ERPT, such as the currency in which international prices are set, the degree of nominal rigidities, among others. Some examples are Devereux et al. (2006), Engel (2009), Devereux and Yetman (2010), and Corsetti et al. (2010). The point we want to stress, although related to these previous papers, is however different: the expected policy path can have an important influence in realized ERPTs. In a way, the ERPT that will materialize after a shock is to a large extent a policy option, not a policy-invariant parameter as it is many times treated both in policy and academic discussions. Moreover, given the increased emphasis on communicating the expected policy path by central banks, our work highlights that ERPT discussions should also be framed in a similar forward-looking manner.[4]

[2] It might be argued that reduced-form estimates implicitly assume that policy follows the "average" behavior in the sample. However, as there is no explicit description of this rule, it is hard to know what policy is being assumed, or to consider alternative choices.

[3] Shambaugh (2008) uses long-run restrictions and identifies shocks such as relative demand, relative supply, nominal, among others. In contrast, using DSGEs, a variety of shocks fall into each of these categories, each of them generating different CERPTs. In the case of Forbes et al. (2017, 2018), shocks are identified by sign restrictions, which does not take into account that shocks that imply very different dynamics can have the same sign responses. In fact, in the models we explore, the two main drivers of NER movements generate the same sign for impulse responses, but they imply significantly different ERPTs.

[4] Throughout the paper we assume rational expectations and perfect credibility. While clearly alternative setups may imply different quantitative results, we see our analysis as a starting point stressing the relevance of perceived policy paths in ERPT discussions.

The rest of the paper is organized as follows. Section 2 describes the empirical strategies used in the literature and their relationship with DSGE models. The baseline model is presented in Section 3. Section 4 shows the CERPTs and UERPTs, providing intuition behind the differences after each shock, and their magnitudes. The dependence and relevance on expected monetary policy are studied in Section 5. Section 6 discusses the robustness of the main results to several modifications in the baseline model. The quantitative DSGE model and its ERPT analysis are included in Section 7. Conclusions are discussed in Section 8.

2. The empirical approach to ERPT and DSGE models

We first describe two methodologies generally used in the reduced-form literature to estimate the ERPT: single-equation and VAR models. We then use a general linearized DSGE model to introduce the concept of CERPT. Finally, we discuss the relationship between CERPTs from DSGE models and the measure obtained using a VAR approach to understand the potential biases in using the latter.

2.1. The empirical approach

The empirical literature mostly features two alternative approaches to compute the ERPT: single-equation distributed-lag models and VARs. In the first the estimated model takes the form,

$$\pi_t^j = \alpha + \sum_{k=0}^{K} \beta_k \pi_{t-k}^S + \gamma c_t + v_t, \tag{1}$$

where π_t^j denotes the log-difference of the price of a good (or basket of goods) j, π_t^S is the log-diference of the NER, c_t is a vector of controls (external and/or domestic) and v_t is an error term. The parameters are generally estimated by OLS, and the ERPT h periods after the movement in the NER, is computed as $\sum_{k=0}^{h}\beta_k$, representing the percentage change in the price of good j generated by a 1% permanent change in the NER.

In the VAR approach a model for a vector of variables, x_t, including π_t^S and π_t^j, is specified. The reduced-form VAR(p) model is,

$$x_t = \Phi_1 x_{t-1} + \ldots + \Phi_p x_{t-p} + u_t, \tag{2}$$

where Φ_k for $k = 1, \ldots, p$ are matrices to be estimated, and u_t is a vector of *i. i. d.* reduced-form shocks, with mean zero and variance matrix Ω. Associated with u_t, the "structural" disturbances w_t are defined as,

$$u_t = P w_t, \tag{3}$$

where P satisfies $\Omega = PP'$, assuming the variance of w_t equals the identity matrix. It is generally assumed that P is lower triangular, obtained from the Cholesky decomposition of Ω, and the ERPT h periods ahead is defined as

$$ERPT_{\pi^j}^V(h) \equiv \frac{CIRF_{\pi^j,\pi^S}^V(h)}{CIRF_{\pi^S,\pi^S}^V(h)}, \tag{4}$$

where $CIRF_{y,\,z}^V(h)$ is the cumulative impulse-response of variable y, after a shock in the position of variable z, h periods after the shock. The ERPT is then the ratio of the cumulative percentage change in the price relative to that in the NER, originated by the shock associated with the NER. In general, it is assumed that π_t^S is ordered before π_t^j in the vector x_t. This assumption implies that the shock is unforecastable, conditional on the variables included, but it can be capturing disturbances of different structural origins.

While both approaches are used, here we take VARs as a benchmark for several reasons. First, most recent papers prefer that approach. Second, the ERPT obtained from (1) assumes a permanent change in the NER, while the measure (4) allows for richer dynamics. Third, the OLS estimates from (1) will likely be biased, as most of the explanatory variables generally included are endogenous. The VAR attempts to solve this problem by including lags and with its identification strategy. A potential advantage of single-equation models over VARs and DSGEs is the flexibility to capture non-linearities, which has been found important in empirical estimates of ERPTs (e.g. Jašová et al., 2019). While we focus on linear models, our concerns regarding the use of a reduced-form approach are general and should translate to non-linear dynamics as well.

2.2. DSGE models and conditional ERPT

The linearized solution of a DSGE model takes the form,

$$y_t = F y_{t-1} + Q e_t, \tag{5}$$

where y_t is a vector of variables (exogenous and endogenous, predetermined or not), e_t is a vector (of size $n_e \times 1$) of *i. i. d.* structural shocks, with mean zero and variance equal to the identity matrix, and the matrices F and Q are non-algebraic functions of the deep parameters.

Using the solution, the ERPT conditional on shock e^i for price j is,

$$CERPT^M_{\pi^j,e^i}(h) \equiv \frac{CIRF^M_{\pi^j,e^i}(h)}{CIRF^M_{\pi^S,e^i}(h)}, \tag{6}$$

which is analogous to the definition of $ERPT_{\pi^j}{}^V(h)$ in (4), with the difference that responses are conditional on shock e^i.

2.3. The relationship between VAR- and DSGE-based ERPT

We want to explore the link between $ERPT_{\pi^j}{}^V(h)$ and $CERPT_{\pi^j,\ e^i}{}^M(h)$ to identify potential biases, and to construct a measure of UERPT from the DSGE model that is comparable to $ERPT_{\pi^j}{}^V(h)$. This relationship cannot generally be obtained analytically because, as shown in Ravenna (2007), only in very specific cases we can represent the dynamics of a subset of variables in a DSGE model with a finite-order VAR model. In those specific cases, as shown in Appendix A.1, and if π_t^S is ordered first in the VAR, the following relationship holds,

$$ERPT^V_{\pi^j}(h) = \sum_{i=1}^{n_e} CERPT^M_{\pi^j,e^i}(h)\omega_i(h), \tag{7}$$

where $\omega_i(h)$ are weights associated with each shock e^i. In words, the ERPT from the VAR is a weighted sum of the CERPTs from the DSGE model. For $h = 0$ the weight $\omega_i(0)$ is the fraction of the forecast-error variance of the NER, at horizon $h = 0$, explained by the shock e^i. For $h > 0$ the weight $\omega_i(h)$ is an adjustment over $\omega_i(0)$ (see Appendix A.1 for the precise expression). In simpler terms, the weights depend on the importance of each shock in explaining NER fluctuations.

The relationship (7) implies that, to the extent that the CERPTs are different, predicting the effect on a price after movements in the NER using the unconditional measure will, almost surely, produce biased results. It will only give a correct assessment if the combination of shocks hitting the economy in a given moment is equal to the weights implicit in the VAR-based ERPT, which has zero probability for continuous-support shocks. As we will see in the next *sec*tions, the CERPTs are indeed very different, so this is an important limitation of UERPTs.

For the general case, we propose two alternatives to compute the UERPT. The first assumes that the relationship in (7) holds in general. We label this as $UERPT_{\pi^j}{}^M(h) \equiv \sum_{i=1}^{n_e} CERPT_{\pi^j,\ e^i}{}^M(h)\omega_i(h)$, where $CERPT_{\pi^j,\ e^i}{}^M(h)$ is computed as in (6), and $\omega_i(h)$ are analogous to the ones in (7).

The second UERPT measure is the one that would be estimated using the empirical VAR approach with an infinite sample generated by the DSGE. We call this alternative UERPT using a Population VAR, labeled as $UERPT_{\pi^j}{}^{PV}(h)$. This is analogous to (4) but with matrices Φ_k and Ω obtained from the unconditional moments computed from the solution of the DSGE model. Appendix A.2 shows the details.

In the following sections, we apply the CERPT and UERPTs measures to DSGE models to see the limitations of using empirical measures, and how they can be influenced by the expected monetary policy reaction.

3. The baseline model

This section presents a very simple DSGE model, based on Schmitt-Grohé and Uribe (2017, sec. 9.16), which has only the necessary ingredients to present our results. The model has four shocks to show the differences between CERPTs and UERPTs. It features two sectors (tradable, T, and non-tradable, N) to analyze the ERPT for different prices. Monetary policy sets the interest rate, using a Taylor rule in the baseline and then with other alternatives to evaluate the effects of different policy paths. It includes Calvo pricing with indexation, for its importance in the transmission of exchange-rate movements to internal prices. Section 6 presents variations in the baseline setup to show that our main conclusions hold for alternative specifications and parameter values. Appendix B presents the full description of the model.

3.1. Households

The representative household seeks to maximize,

$$E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{C_t^{1-\sigma}}{1-\sigma} - \xi \frac{h_t^{1+\varphi}}{1+\varphi} \right\}$$

where C_t is consumption and h_t are hours worked, β is the discount factor, σ is the risk aversion parameter, φ is the inverse of the Frish elasticity of labor supply and ξ is a scale parameter. Her budget constraint is,

$$P_t C_t + S_t B_t^* + B_t = W_t h_t + S_t R_{t-1}^* B_{t-1}^* + R_{t-1} B_{t-1} + \Pi_t.$$

Here P_t is the price of final consumption, S_t is the exchange rate, B_t^* and B_t are holdings of external and domestic bonds respectively (with gross interest rates R_t^* and R_t), W_t is the wage, and Π_t adds profits from all firms.

The consumption good is a composite of tradable consumption, C_t^T, and non-tradable consumption, C_t^N. Additionally, non-tradable consumption is an aggregate of non-tradable varieties, $C_t^N(i)$. These technologies are,

$$C_t = \left[\gamma^{1/\rho}\left(C_t^N\right)^{\frac{\rho-1}{\rho}} + (1-\gamma)^{1/\rho}\left(C_t^T\right)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}}$$

$$C_t^N = \left[\int_0^1 \left(C_t^N(i)\right)^{\frac{\varepsilon-1}{\varepsilon}} di\right]^{\frac{\varepsilon}{\varepsilon-1}}$$

where γ is the share of C_t^N in C_t, while ρ and ε are elasticities of substitution between, respectively, C_t^N and C_t^T and non-tradable varieties. The consumer price index, obtained from the expenditure-minimization problem is

$$P_t = \left[(1-\gamma)\left(P_t^T\right)^{1-\rho} + \gamma\left(P_t^N\right)^{1-\rho}\right]^{\frac{1}{1-\rho}}$$

where P_t^T and P_t^N are prices of C_t^T and C_t^N, respectively.

3.2. Firms

The tradable sector is assumed to have a stochastic endowment, Y_t^T, with a local price $P_t^T = S_t P_t^{T,*}$, where $P_t^{T,*}$ is the foreign price of the tradable good. In contrast, in the non-tradable sector, each firm of variety $i \in [0,1]$ produces using labor with the technology

$$Y_t^N(i) = [h_t(i)]^{\alpha},$$

where $Y_t(i)$ is the production of firm i, $h_t(i)$ are hours hired and $\alpha \in (0,1]$ is a parameter. The producer i faces a downward sloping demand given by:

$$Y_t^N(i) = \left(\frac{P_t^N(i)}{P_t^N}\right)^{-\varepsilon} Y_t^N$$

where $P_t^N(i)$ is the price of variety i and Y_t^N is the non-tradable composite. They choose prices *a la* Calvo, with a probability $1-\theta$ of setting prices optimally. If they cannot choose optimally, they update prices using a combination of past inflation, π_{t-1}, and the inflation target, $\overline{\pi}$:

$$\pi_{t-1}^{\zeta}\overline{\pi}^{1-\zeta}$$

where $\zeta \in [0,1]$. The dynamic indexation in the model is given by $\theta\zeta$, since θ can be interpreted as the fraction of prices not chosen optimally and ζ as the fraction indexed to past inflation. Note also that in the steady-state all prices grow at the rate $\overline{\pi}$, eliminating the welfare cost of price dispersion.

3.3. Monetary policy

We assume a simple Taylor rule for the domestic interest rate:

$$\left(\frac{R_t}{R}\right) = \left(\frac{\pi_t}{\overline{\pi}}\right)^{\alpha_\pi}\left(\frac{GDP_t}{GDP}\right)^{\alpha_y}\exp\left(e_t^m\right) \tag{8}$$

where variables without a time subscript are steady state values, GDP_t is gross domestic product (definition in appendix), e_t^m is the monetary shock, and α_π and α_y are non-negative parameters.

3.4. Foreign sector

The external price of tradables, $P_t^{T,*}$, and the external interest rate, R_t^*, are determined abroad. We assume that foreign inflation, $\pi_t^* \equiv P_t^{T,*}/P_{t-1}^{T,*}$, is exogenous. We also set,

$$R_t^* = R_t^W + \phi_B\left(\exp\left(\bar{b} - B_t^*/P_t^{T,*}\right) - 1\right) \tag{9}$$

where R_t^W is the exogenous world interest rate and $\phi_B, \bar{b} > 0$ are parameters. This equation is the closing device of the model.

3.5. Exogenous processes and parametrization

The model includes 4 shocks: foreign inflation, π_t^*, world interest rate, R_t^W, monetary policy shock, ε_t^m and tradable endowment, Y_t^T. Each of them follows a process

$$\log(x_t/x) = \rho_x \log(x_{t-1}/x) + u_t^x,$$

for $x_t = \{\pi_t^*, R_t^W, \varepsilon_t^m, Y_t^T\}$, where u_t^x is *i. i. d.* with standard deviation σ_x. The exact calibration of ρ_x and σ_x does not change the qualitative results. They do, however, affect the evolution of CERPTs and the computation of the UERPTs, as they affect the importance of each shock in explaining the nominal depreciation. To present a relatively informed computation, we calibrate these parameters based on the estimated model in Section 7. The rest of the calibration in Table 1 follows Schmitt-Grohé and Uribe (2017, sec. 9.16). In the baseline we assume *i. i. d.* monetary shocks and indexation only to the inflation target, but we relax these assumptions in Sections 5 and 6.

4. Conditional versus unconditional ERPTs

In this section, we show important differences between CERPTs, depending on the shock hitting the economy and on the price under consideration. To understand the propagation of these shocks we first discuss the impulse responses, normalized to produce a nominal depreciation.

A negative shock to external inflation, showed in Fig. 1, produces a negative wealth effect: ceteris paribus payments of previous-period external debt increase in domestic units, since foreign bonds are denominated in dollars. This contracts aggregate demand, reducing consumption of both goods and increasing labor supply. Since the non-tradable sector has to clear, its relative price falls. Both a nominal and a real depreciation materialize, inflation rises for both types of goods and the policy rate increases. This fall in foreign inflation also tends to decrease tradable prices domestically, dampening the consequences of the nominal depreciation. In other models (Sections 6 and 7), this shock may also generate an effect through export-related income, but not in this version as terms of trade do not change.

A rise in the world interest rate, showed in Fig. 2, causes two effects: a negative income effect (as this economy is assumed to be a net debtor), and an inter-temporal substitution effect (increasing the incentives to save today). These decrease current demand for all goods and increase labor supply. As a result, the relative price of non-tradable goods tends to decrease, leading to a real depreciation. Due to sticky prices, the nominal exchange rate also increases. The equilibrium effect in consumption (and output) of non-tradables depends on which of the two changes (drop in the demand, or increase in supply) dominates. Given the chosen parametrization, in the short run output contracts, and then it increases above its steady state level. Tradable consumption drops and converges from below.

Table 1
Baseline parametrization.

	Value	Description		Value	Description
β	1.0316^{-1}	Discount factor	$\overline{\pi}$	$1.03^{1/4}$	Inflation target
σ	2	Risk aversion	p^T	1	Relative price of T
φ	0.5	Inverse Frisch elast.	h	0.5	Hours
ρ	0.5	Sub. elast. C^T, C^N	s^{tb}	0.05	Trade bal./GDP
γ	0.74	Share of C^N in C	ρ_{π^*}	0.519	AR coef. π_t^*
α	0.75	Labor share in N	ρ_{R^W}	0.966	AR coef. R_t^W
ε	6	Sub. elast N varieties	ρ_{e^m}	0	AR coef. e_t^m
θ	0.7	Calvo prob. in N	ρ_{y^T}	0.878	AR coef. Y_t^T
ζ	0	Index. to π_{t-1} in N	σ_{π^*}	0.017	St. dev. π_t^*
α_π	1.5	Taylor coef. of π	σ_{R^W}	0.001	St. dev. R_t^W
α_y	0.5/4	Taylor coef. of GDP	σ_{e^m}	0.002	St. dev. e_t^m
ϕ_B	3.3510^{-5}	Ext. int. rate param.	σ_{y^T}	0.011	St. dev. Y_t^T

Notes: The source of all parameters is Schmitt-Grohé and Uribe (2017, sec. 9.16), except for the Taylor rule, external shocks and steady-state values. For those, respectively, we follow Taylor (1993), are based on the model in section 7, and are normalizations (s^{tb} was chosen so the country is a net debtor). See Appendix B for more details.

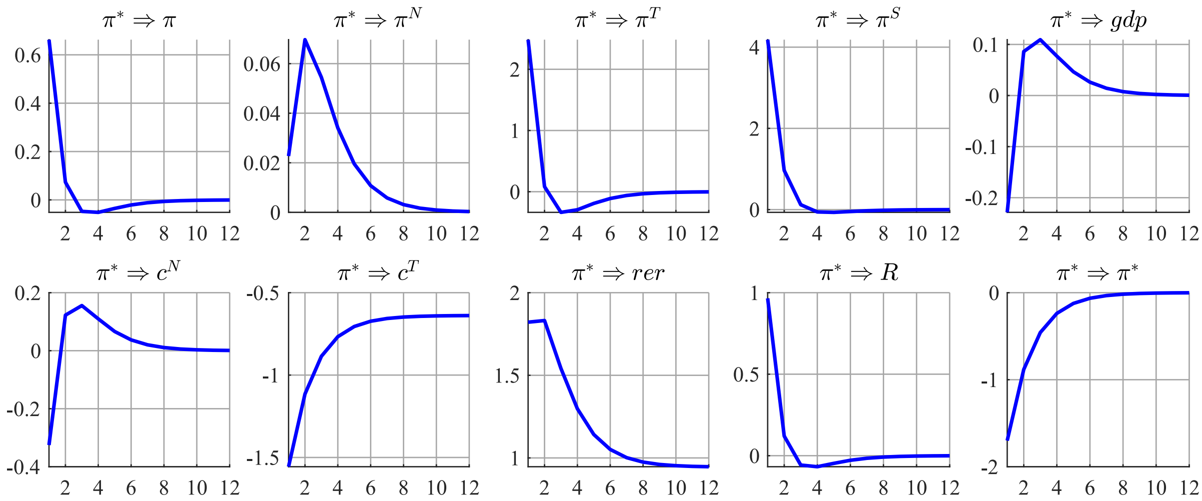

Fig. 1. IRF to external inflation. Note: Each graph displays the percentage change, relative to the steady state. The variables are: total, non-tradable and tradable inflation, nominal depreciation, output, non-tradable and tradable consumption, the real exchange rate, the policy rate and the variable shocked. The size of the shock is one standard deviation.

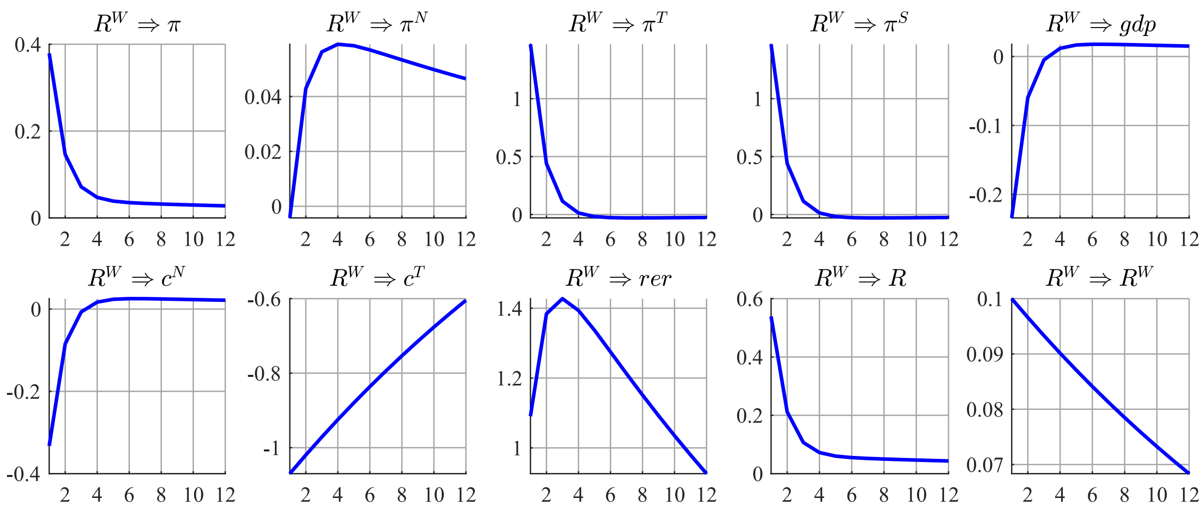

Fig. 2. IRF to the external interest rate. Note: See Fig. 1.

While qualitatively these effects are analogous to those originated by a drop in foreign inflation, there is an important difference relevant for ERPT discussions. After the shock π^*, the rise in domestic tradable prices induced by the depreciation is attenuated by the drop in foreign inflation. This will lead to a smaller CERPT.

A negative shock to the tradable endowment produces a negative wealth effect similar to the external interest rate. Because of this, and its minor importance in explaining the NER given our calibration (see Table 2 below), we present its IRF in the appendix.

Finally, a negative shock to the policy rule, shown in Fig. 3, decreases the nominal interest rate, triggering an intertemporal substitution effect towards current consumption. The higher demand for non-tradables causes an increase in its relative price and output. This leads to both real and nominal depreciations, increasing inflation. Under the chosen parametrization, tradable

Table 2
Variance decomposition of π^S in the baseline model.

π^*	R^W	y^T	ε^m
87.3	11.3	1.2	0.2

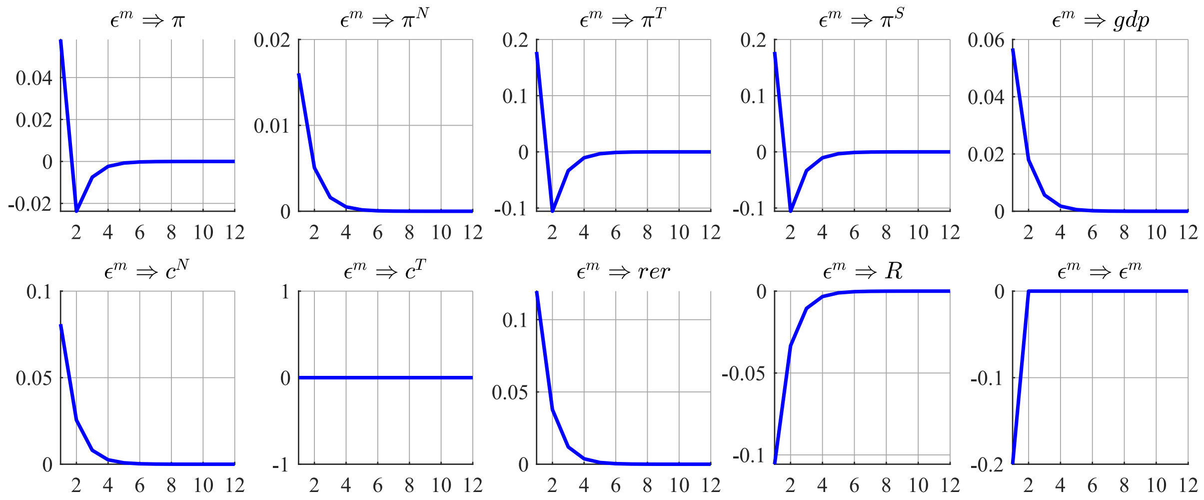

Fig. 3. IRF to a monetary policy shock. Note: See Fig. 1.

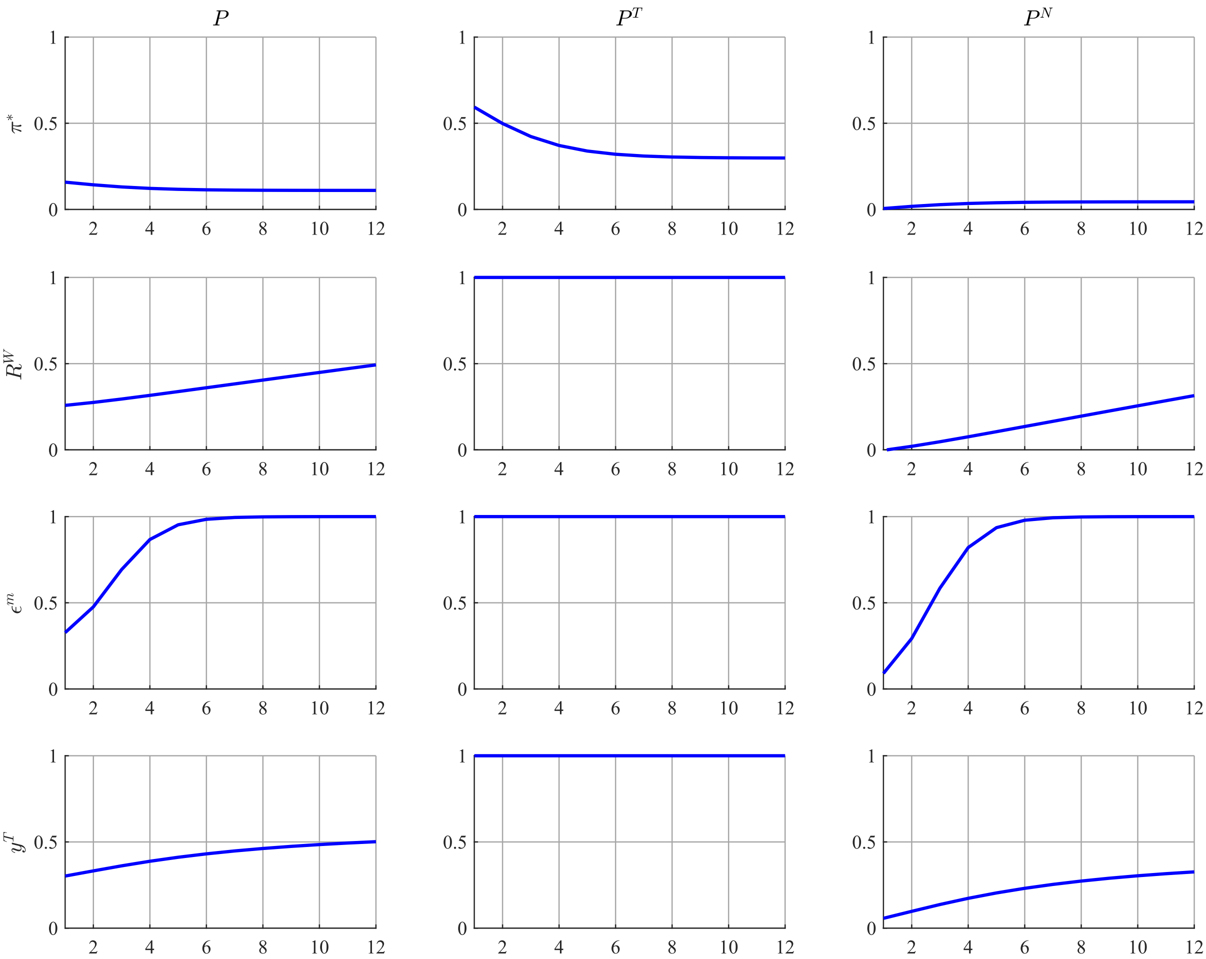

Fig. 4. Conditional ERPTs. Note: The graphs show the CERPT for the price in each column (CPI, tradables and non-tradables), conditional on the shock in each row (foreign inflation, world interest rate, monetary policy, and tradable output).

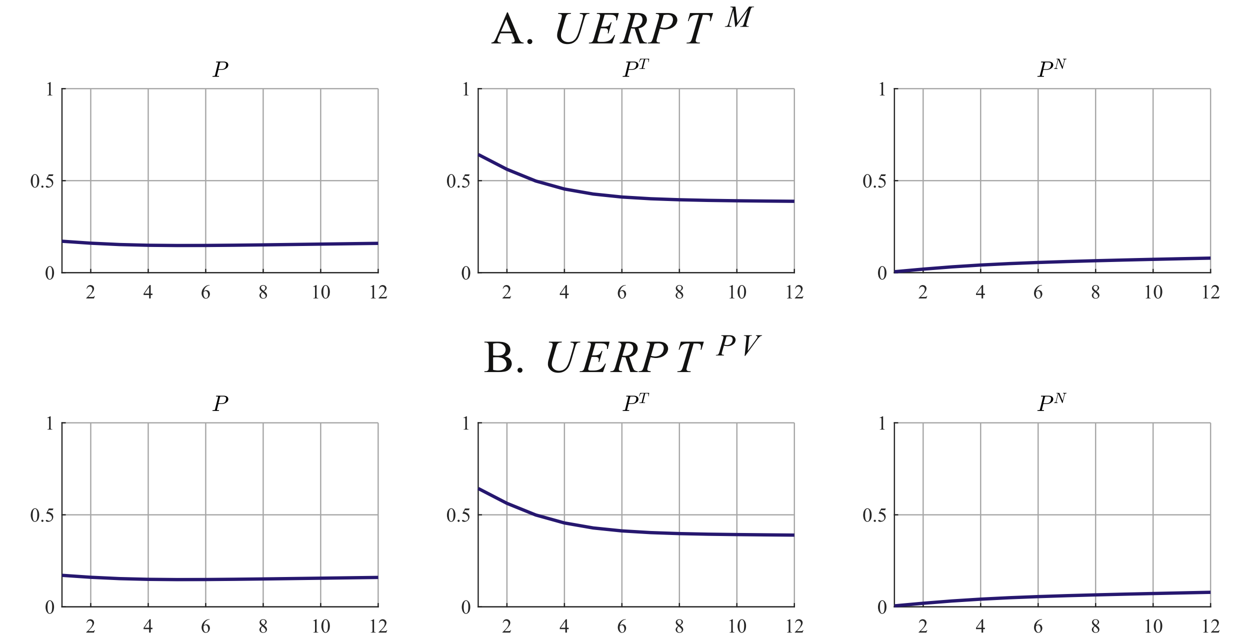

Fig. 5. Unconditional ERPTs. Note: The graphs show the unconditional UERPT for the price in each column (CPI, tradables and non-tradables), calculated using $UERPT^{M}$ above and $UERPT^{PV}$ below.

consumption is not affected by domestic shocks because the inter-temporal elasticity of substitution equals the intra-temporal elasticity between tradable and non-tradable goods.

It is relevant to notice that, after each shock, the rise in non-tradable inflation is linked to the way monetary policy is set. As the Taylor-type rule targets total inflation, whenever a nominal depreciation increases tradable prices, the rule smoothes the effect on total inflation, making non-tradable prices rise as well. This may change for other policy configurations, as shown in Section 5; already hinting a non-trivial role of policy for ERPT discussions.

Using these responses, we calculate the implied CERPTs, shown in Fig. 4. These are significantly different for the four shocks in the economy. Note first that the CERPTs for tradables is always higher than for non-tradables, since the former is not subject to price rigidities. Also, the CERPTs of tradable prices is equal to one for all shocks but external inflation, since the reaction of tradable prices and the NER depreciation is the same due to perfect tradables pass-through. In contrast, this is not the case for the shock to foreign-inflation, which does not require a complete ERPT to any domestic price, at any horizon. The CERPT for tradables after a π^* shock is around 0.6 in the first period and then decreases. This path is produced as external inflation falls by more than the nominal depreciation (recall Fig. 1), and tradable inflation is the product of these two.

The response of non-tradables is also higher for shocks to the world interest rate, the endowment of tradables and the policy rate, than after a foreign-inflation shock. While in the long run these CERPT should converge to one, in the short run the ERPT becomes close to unity only for the monetary shock. In response to the external interest rate and the tradable endowment, the ERPT increases steadily over time getting close to 0.3 after 12 quarters. In contrast, given a foreign inflation shock, the ERPT, while also increasing, is only 0.02 even after 12 quarters.

As expected, the CERPT for CPI lies between those for tradables and non-tradables. The highest CERPT is in response to the monetary shock, then to the endowment of tradables and foreign interest rate, while the smallest is produced by a foreign inflation shock. Besides the differences in size, the evolution over time is different as well. Before analyzing the UERPT, in line with Section 2, it is relevant to understand the relative importance of each shock in explaining NER variations. As shown in Table 2 fluctuations in foreign inflation and the external interest rate are the main drivers of the NER. Thus, we expect the UERPT to be determined mostly by CERPTs for these two shocks.

Fig. 5 shows that UERPTs are mostly determined by CERPTs after foreign inflation. It shows UERPTs calculated using the two measures explained in the previous section. For the computation of the population-VAR measure ($UERPT^{PV}$) the VAR uses the vector $\{\pi_t^S, \pi_t, \pi_t^T, \pi_t^N\}$ and lags are chosen to maximize the likelihood.

As discussed in the introduction, we can see that there is a lot of information lost when using the UERPT measures to predict the effect in prices after a given shock. Although this is a stylized and small model, the quantitative differences between CERPTs are similar to more realistic models (as the one in Section 7). For example, given a 10% depreciation, the unconditional measure would predict a 1.5% increase in CPI after one year, while if it is identified that the depreciation was caused by foreign inflation it would be 1.2%, by the external rate 3.2%, by the monetary shock 8.7% and by tradable output 3.9%. This illustrates how forecast accuracy can be greatly improved by using CERPTs, and how empirical ERPT measures can be misleading.

5. The relevance of expected monetary policy for ERPTs

This section explores the importance of accounting for expected monetary policy. We perform three exercises. The first is to keep the interest rate fixed for some periods after the shock, returning to the Taylor rule afterward. The second exercise studies the ERPT after a policy shock with different autocorrelation assumptions. The last one studies the optimal-policy case. Additional details are in Appendix C.

5.1. Fixing the interest rate

This exercise compares CERPTs following alternative policy paths. It contrasts the baseline –with the Taylor rule always setting the interest rate– with alternatives where, at the moment the shock hits, the policymaker decides to keep the interest rate fixed (at it steady-state value) for a number of periods, following the Taylor rule afterwards.[5] In particular, we evaluate fixing the rate for 2 and 4 periods. As we have argued, this simulates a relevant real-life case: when the central bank chooses not to react to the observed depreciation (perhaps because it believes the pass-through is low).

A priori, the consequences of alternative policy paths on ERPTs are not evident, since fixing the interest rate (a relatively more dovish policy than the baseline) will increase both inflation and the NER. Therefore, the effect on the ratio computed in the ERPT is unclear.

Fig. 6 shows that the effects of alternative policy paths vary depending on the shock. After a change in external inflation, if the interest rate is fixed for 2 periods, CERPTs are generally higher than when the interest rate follows the Taylor rule. In contrast, when the interest rate is fixed for 4 periods, CERPTs are lower than the other two cases. If instead we consider a world-interest-rate shock, the influence of alternative policy paths seems to be more important and monotone. As expected, the changes in UERPTs are averages of the conditional ones.

In sum, alternative policy paths can also alter the realized ERPT, with non-monotonic and shock-dependent effects. For example, focusing on the CPI, the consequence of a 10% depreciation caused by external inflation changes from 1.2% to 1.4% and 1.1% for fixing the rate 2 and 4 periods, respectively. And if it was caused by R^W shock the forecast would change from 3.2% to 3.6% and 3.8%. At the UERPT level, alternative policy paths also generate differences, but these are smaller given the averaging implicit in that measure. In the quantitative model in Section 7, and in many of the extensions in Section 6, these differences are even larger.

5.2. Autoregressive monetary shocks

As a complementary exercise, Fig. 7 presents the CERPTs to the monetary policy shock in the baseline calibration (assumed to be *i. i. d.*) and the case with autocorrelated shocks, with coefficients of 0.5 and 0.9. We show only the CERPTs after the monetary shock, as the others are not affected, and this shock has a quantitatively limited relevance for the unconditional measures. We can see that the ERPTs for both non-tradables and total CPI change significantly with more persistent shocks, while there is no change in the ERPT for tradables, since it equals one by construction.

As the autocorrelation coefficient increases, CERPTs are higher in the short-run and take more time to converge to one, which is explained by two effects. First, a higher autocorrelation implies a larger movement in the whole yield curve, making non-tradable consumption and inflation jump by more. It also implies a larger depreciation, but this difference is smaller than the additional effect on inflation, explaining an initially larger CERPT. Second, more policy persistence reduces the speed of convergence of the depreciation rate back to its steady-state, also contributing to a more persistent CERPT.

5.3. Optimal policy

As an alternative to the Taylor rule, here we analyze the effects of an optimal policy setup, defined as the one that maximizes the households' welfare conditional on the presence of monopolistic competition, sticky prices and incomplete markets. The optimal policy is an application of the characterization in Schmitt-Grohé and Uribe (2017, sec. 9.16), with the difference that our model features indexation. To eliminate price dispersion, prices optimally chosen and those indexed must increase at the same rate. Then, the optimal policy is to make non-tradable inflation equal to

$$\pi_t^N = (\pi_{t-1})^{\zeta}\overline{\pi}^{1-\zeta}$$

For the baseline, this means indexing to the target, since $\zeta = 0$.

Fig. 8 shows the CERPTs and UERPT of the baseline compared to those under optimal policy. For non-tradables, all ERPTs are zero with this alternative, as non-tradable inflation always equals the target and therefore does not react to shocks. The CERPT for tradables, as in previous examples, is different from one only after shocks to external inflation. Under optimal policy, this CERPT is initially higher and then lower than in the baseline. Given the negative wealth effect after this shock, an initially higher tradable price avoids a contraction in non-tradable demand that would otherwise generate price dispersion. But this happens only in the initial period, leading to a relatively smaller CERPT. Unconditional measures change accordingly.

[5] Computationally, assuming full credibility in the announcement, this is implemented by a backward-looking solution as in Kulish and Pagan (2017) or the appendix in Garcia-Cicco (2011).

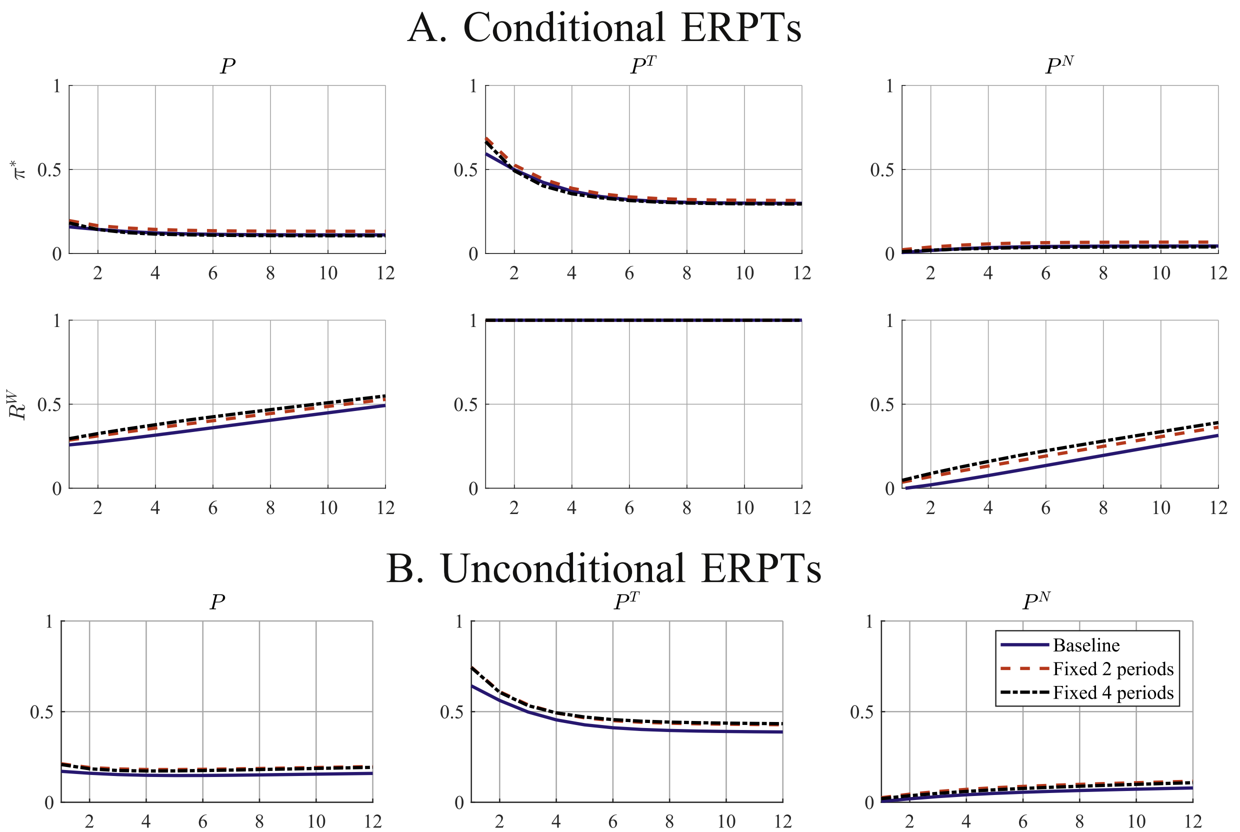

Fig. 6. Conditional and unconditional ERPTs fixing the policy rate for T periods. Notes: the graphs show CERPTs to foreign inflation and the foreign interest rate and $UERPT^M$ (this sets the policy-shock weight to zero, as it trivially has no role in this exercise). The solid blue line is the baseline, the dashed red line fixes the rate for 2 periods and the dash-dotted black line for 4 periods.

Overall, we have shown that alternative policy paths can greatly influence ERPTs, both conditional and unconditionally. Therefore, it would be more informative to show policymakers alternative ERPT measures, one for each future policy path under consideration. Results from the empirical literature cannot be used to this end. In contrast, DSGE models provide a way to compute these alternatives; although the previous literature has no explored this advantage.

6. Sensitivity analysis for the baseline model

In this section, we study the robustness of our main results to alternative assumptions in the baseline model. We explore the role of indexation, different pricing and currency-of-invoicing assumptions for tradables, and financial frictions. We also compare alternative parameter values. The goal is to see if the distinctions between CERPTs and UERPTs, as well as the expected-monetary-

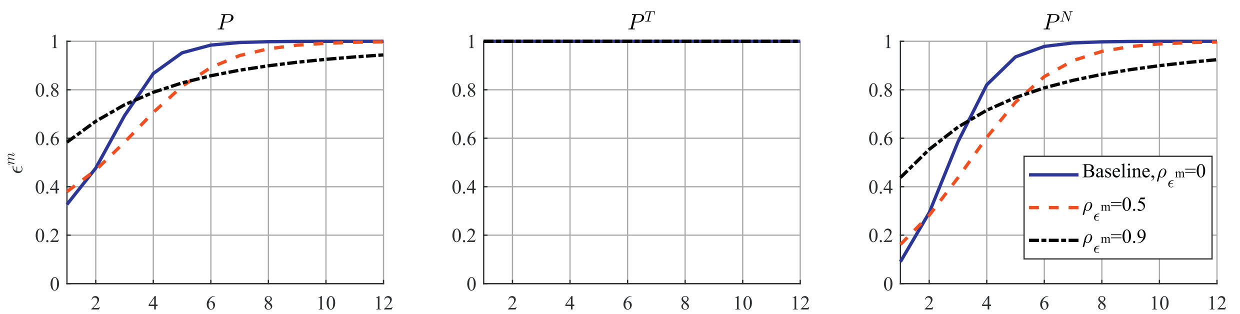

Fig. 7. Conditional ERPTs under more persistent policy shocks. Notes: The graphs show the CERPTs to the monetary shock. The blue solid line is the baseline with *i. i. d.* shocks, the dashed red line is for a coefficient of 0.5 and the dash-dotted black line of 0.9.

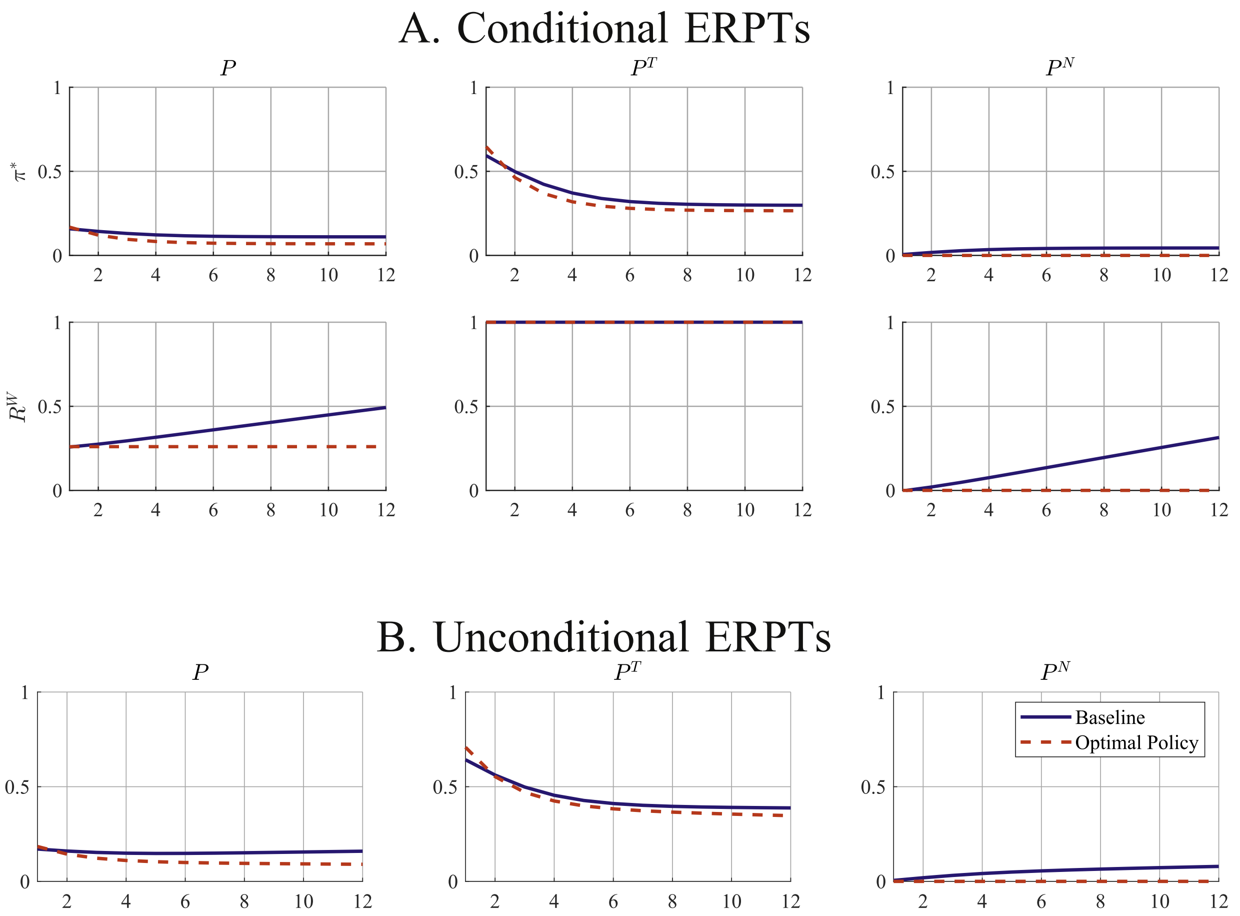

Fig. 8. Conditional and unconditional ERPTs of the optimal monetary policy. Notes: the graphs show CERPTs to foreign inflation and world interest rate, and $UERPT^M$. The solid blue line is the baseline and the dashed red line the optimal policy.

policy role, change in these alternative setups. We present a short description of each case and discuss the main findings. Appendix D contains additional details.

6.1. Alternative indexation schemes

Many price and wage contracts, particularly in emerging economies, include indexation clauses. The baseline assumes that non-tradable firms index prices to the inflation target whenever prices are not chosen optimally. Instead, here we consider two alternatives: indexation to same-sector inflation, π_{t-1}^N, or to total inflation, π_{t-1}.

Results are presented in Fig. 9. When indexation is only to the target, the connection between non-tradable prices and the NER is only through a general equilibrium channel. For a given shock, the N market has to clear, and so its price moves. If we add indexation to own-sector inflation, there is an amplification mechanism for the same general equilibrium effect. Initially, non-tradable inflation increases less than the baseline, but then it takes longer to go back to its steady state for all shocks (responses can be seen in Appendix D), while changes in the NER are comparable. This implies a longer convergence of CERPTs to their long-run value. These differences are less important after a foreign-inflation shock. Still, the UERPTs significantly differ from the CERPTs.

When non-tradables are indexed to total inflation, price dynamics change significantly: now NER changes produce an additional, although delayed, impact through indexation. Compared to previous cases, on impact non-tradable inflation increases by less, but then rises by more following the jump in the NER in the first period. This implies lower CERPTs initially but larger afterward. The differences between CERPTs and UERPTs persist.

We also study the sensitivity of ERPT measures to different expected policy paths. Fig. 10 compares the baseline policy with the case that fixes the interest rate for 2 periods, for the alternative indexation schemes. As can be seen, both CERPTs and UERPTs still change significantly under alternative policy paths, with differences even larger than in the baseline.

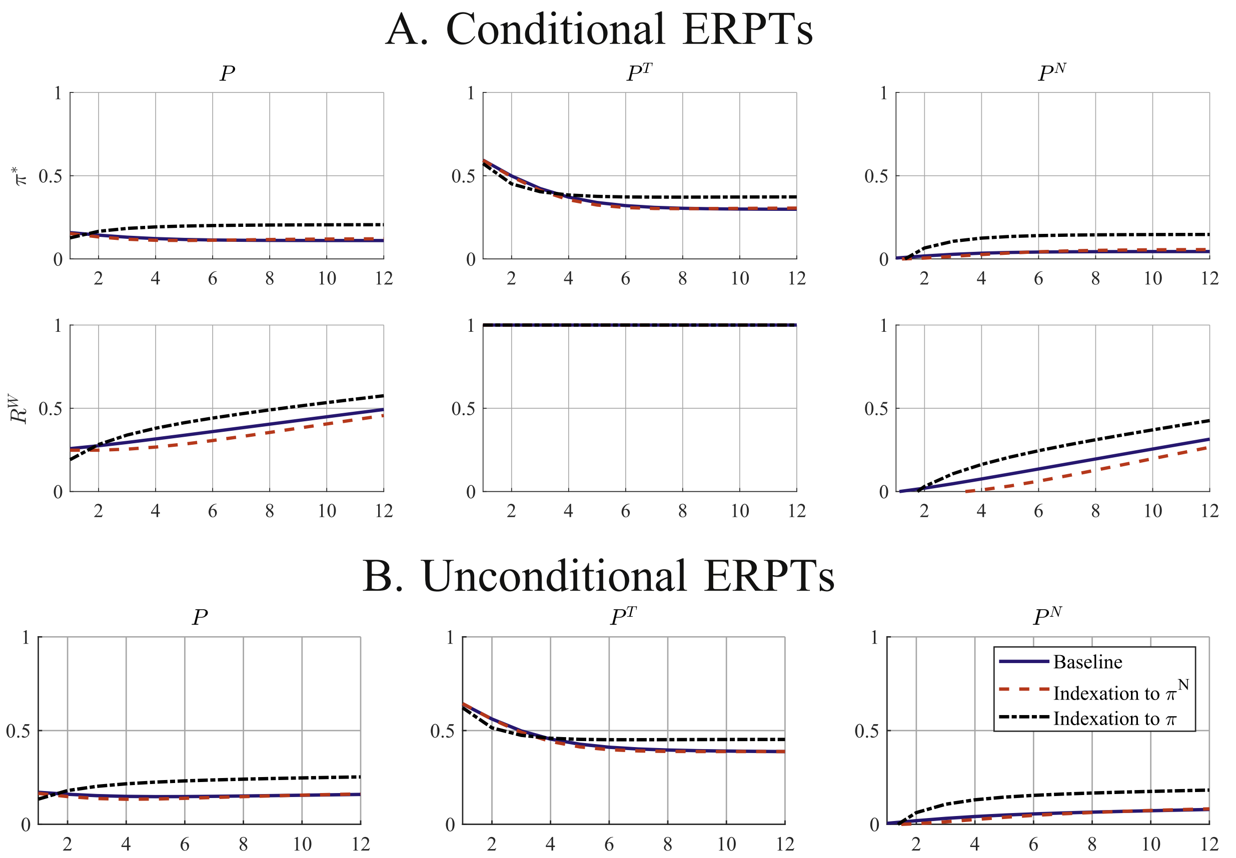

Fig. 9. Conditional and unconditional ERPTs for alternative indexation. Notes: the graphs show CERPTs and $UERPT^M$. The blue solid line is the baseline, with indexation to the inflation target, the dashed red line is indexation to sectoral N inflation, and the dash-dotted black line is indexation to CPI inflation. $\zeta = 1$ in both alternatives.

6.2. Currency of invoicing and the pricing of tradables

In open economies, the propagation of shocks depends on the currency in which tradable prices are set. An early literature contrasts local vs. producer currency pricing (LCP vs PCP); see the survey in Corsetti et al. (2010). More recently, following the evidence that most tradable goods are invoiced in a few major currencies (prominently, the US dollar), many papers explore a dominant currency pricing (DCP) setup; e.g. Gopinath et al. (2010), Gopinath et al. (2020). In the baseline model, there is no choice of prices in the tradable sector, as we assumed perfect competition and the law of one price (if anything, all tradable prices are set in dollars). But this literature specifically analyzes the role of monopoly power and price rigidities, so we modify the model to study alternative setups along these lines.

We add two monopolistic-competitive markets within the tradable sector: one selling domestically and the other abroad. In both, a continuum of monopolists buy a homogeneous tradable good, supplied either by the tradable endowment or by imports. Both groups of monopolists produce varieties and face Calvo-style frictions when setting prices. These varieties are then purchased by competitive aggregators that build bundles, sold either domestically or abroad.

There are different alternatives depending on the currency in which monopolists price their goods. We introduce the following notation for tradables prices: $P_t^{T,\,l,\,c}$ denotes the price of the tradable bundle, sold in location l, in the currency of country c (both l and c can either be domestic, d, or foreign, f). The pricing options are:

- LCP: $P_t^{T,\,f,\,f}$ and $P_t^{T,\,d,\,d}$ are chosen and sticky, while $P_t^{T,\,f,\,d} = P_t^{T,\,f,\,f} S_t$ and $P_t^{T,\,d,\,f} = P_t^{T,\,d,\,d}/S_t$.
- PCP: $P_t^{T,\,f,\,d}$ and $P_t^{T,\,d,\,d}$ are chosen and sticky, while $P_t^{T,\,f,\,f} = P_t^{T,\,f,\,d}/S_t$ and $P_t^{T,\,d,\,f} = P_t^{T,\,d,\,d}/S_t$.
- DCP: $P_t^{T,\,f,\,f}$ and $P_t^{T,\,d,\,f}$ are chosen and sticky, while $P_t^{T,\,f,\,d} = P_t^{T,\,f,\,f} S_t$ and $P_t^{T,\,d,\,d} = P_t^{T,\,d,\,f} S_t$.

We additionally assume a demand for the exportable bundle that is elastic to the relative price between these goods and the international price $P^{T,\,*}$, with an elasticity that we calibrate to -0.3. The Calvo parameter of these new monopolists is calibrated to the same value used for non-tradables. For more details see Appendix D.

The dynamics in these cases depend on the evolution of the domestic terms of trade, i.e. $P_t^{T,\,f,\,d}/P_t^{T,\,d,\,d}$. In the baseline and DCP, this ratio is not affected by changes in the NER. Under LCP, a nominal depreciation increases this terms of trade, as the denominator is relatively sticky but the numerator is fully affected. With PCP, the opposite happens.

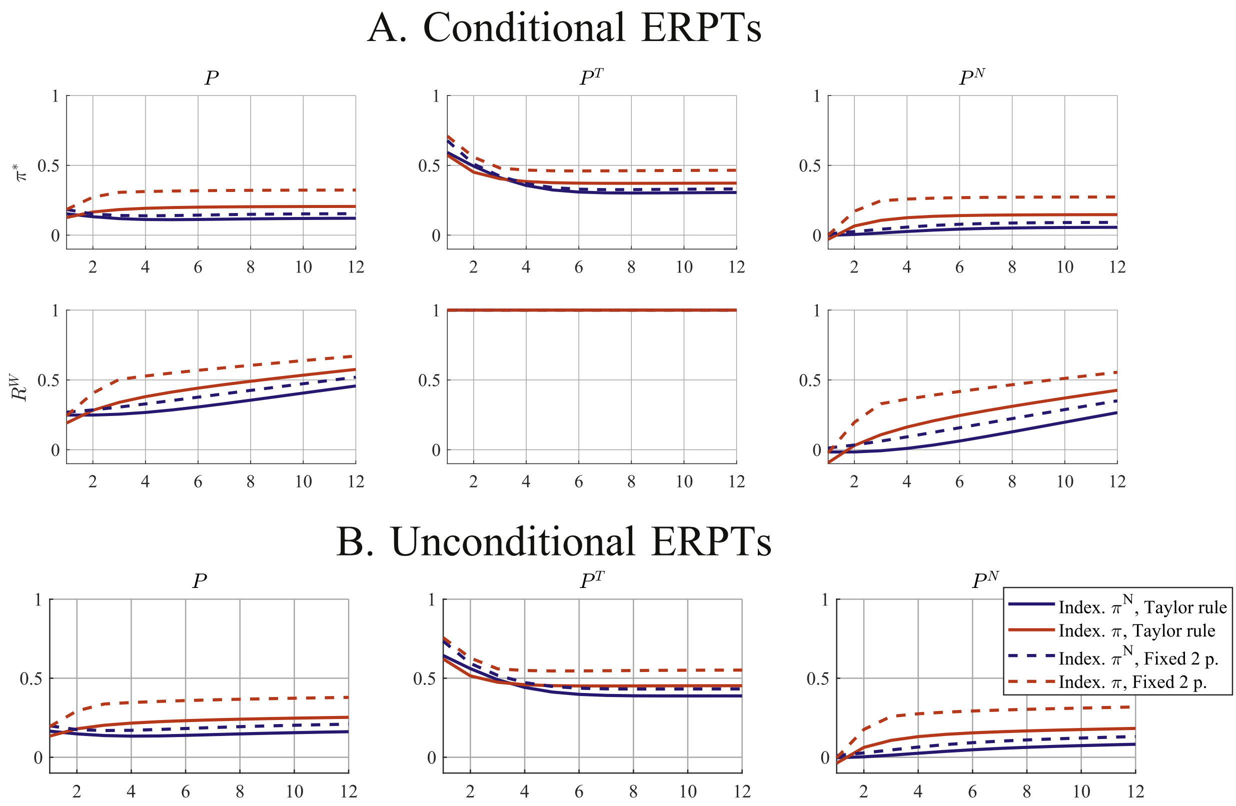

Fig. 10. Conditional and unconditional ERPTs for alternative indexation. The role of expected monetary policy. Notes: The blue lines correspond to the case of indexation to N inflation, while the red lines to CPI-inflation indexation. The solid lines assumes the policy rate follows the Taylor rule, while in the dashed lines the rate remains fixed for 2 periods.

Fig. 11 shows the CERPTs and UERPTs for the four alternative models. As can be seen, the baseline and DCP feature almost identical CERPTs for the external interest rate shock. Differences after the shock to π^* arise because in the DCP model exports are elastic to changes in $P^{T,*}$.

The LCP alternative displays smaller CERPTs for tradables, since their domestic prices are sticky in local currency. For non-tradables, as the nominal depreciation improves the domestic terms of trade, the contraction in demand and the effect on P^N are smaller.

Under PCP, the CERPTs for tradables are also smaller relative to the baseline but, as the depreciation induces a fall in the domestic terms of trade, non-tradable consumption and inflation fall, leading to lower CERPTs.

Still, regardless of the pricing assumption for tradables, CERPTs and UERPTs are quite different. Under some of these alternatives, differences are even exacerbated.

Finally, when conditioning on alternative monetary-policy paths (shown in Appendix D), it is still true that changes in expected monetary policy affect ERPTs. The differences under alternative paths seem to be less important for tradables and more relevant for non-tradables in these cases.

6.3. Financial frictions

A large literature highlights the role of financial frictions in propagating shocks in emerging countries, particularly those exposed to liability dollarization. We explore how our results change if these concerns are present. To keep the model as simple as possible, we follow Garcia-Cicco et al. (2010) and make the external premium elastic to the ratio of foreign debt to GDP. In particular, we change the premium in eq. (9) to:

$$R_t^* = R_t^W + \phi_B\left[\exp\left(\bar{b} - \frac{S_t B_t^*}{S_t P_t^{T,*} y_t^T + P_t^N y_t^N}\right) - 1\right]. \qquad (10)$$

Furthermore, we increase the value for ϕ_B, which was 0.0000335, since otherwise using (9) or (10) produces virtually the same results.

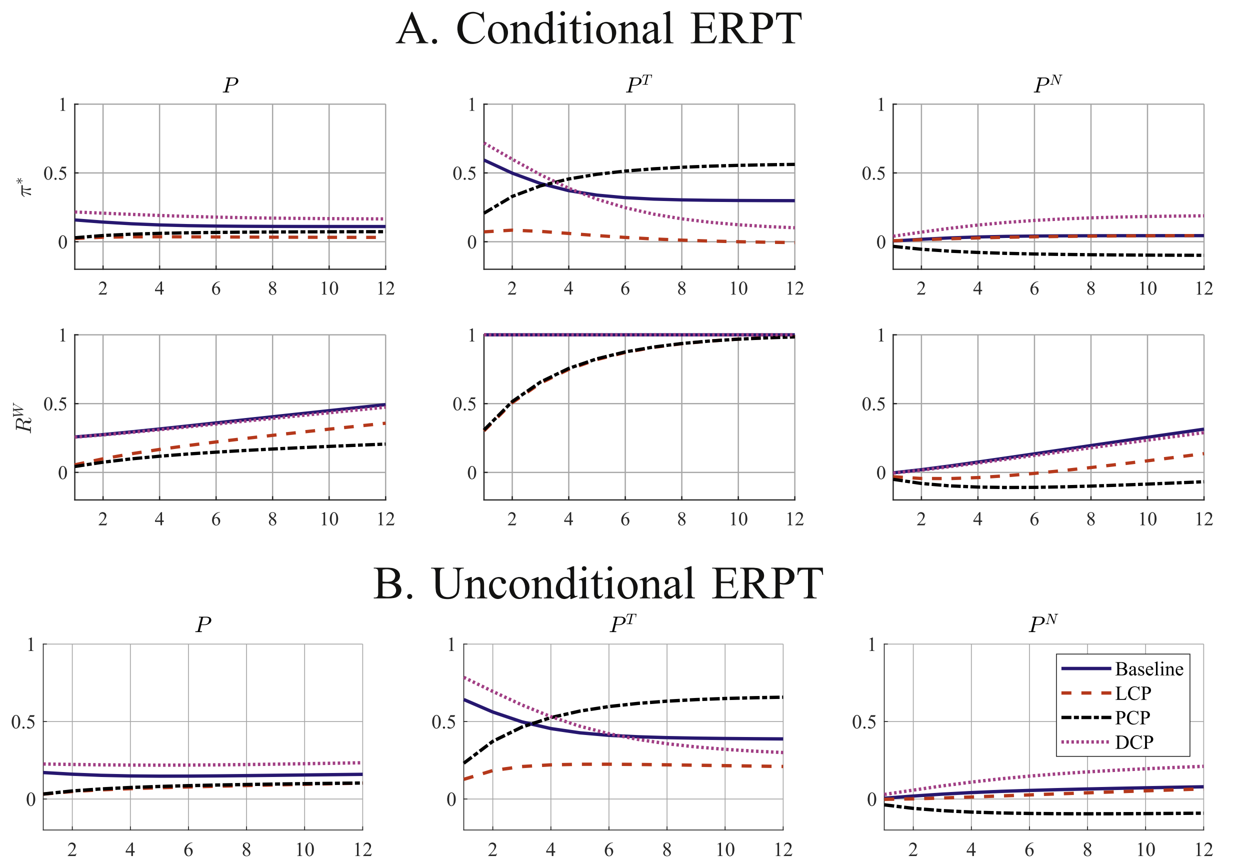

Fig. 11. Conditional and unconditional ERPTs for alternative currency of invoicing assumptions. Notes: the graphs show CERPTs and $UERPT^M$. The solid-blue line is the baseline, the dashed-red line is LCP, the dash-dotted black line is PCP and the dotted-pink line is DCP.

To understand the role of financial frictions, notice that in the baseline model all shocks inducing a depreciation increase the debt ratio in (10); either because of the RER depreciates, debt rises, activity falls, or a combination of them. As a consequence, under financial frictions, all shocks are relatively more contractionary and require a larger real depreciation. As ϕ_B increases, a larger nominal depreciation is induced, while non-tradable inflation rises by more and more persistently (the Taylor rule is key to this result). Thus, it is not ex-ante obvious if ERPT will be larger (if the price effect dominates) or smaller (if NER movements are more important).

Fig. 12 compares the ERPTs in the baseline with the financial-friction alternative under two values for ϕ_B: 0.03 and 0.07. To give an idea of the severity of these frictions, the contraction of real GDP after a world-interest-rate shock (shown in the appendix) is 1.4 times larger if $\phi_B = 0.03$ and 4.5 times larger with $\phi_B = 0.07$, both relative to the baseline. We can see that the price responses dominate under financial frictions, increasing CERPTs for all prices, particularly after a shock to π^*, reducing the difference between CERPTs and UERPTs.

Finally, as in previous cases, it can be shown that alternative policy paths under financial frictions produce differences comparable to those obtained with the baseline (see Appendix D for details).

6.4. Robustness to alternative parameter values

Here we briefly discuss the main takeaways of many comparisons we performed to assess the robustness to alternative parameter values. In general, our main conclusions are not altered: it is always important to identify the shocks and also to control for the expected policy response. These general results are only changed in very extreme cases (e.g. if the setup is such that prices do not respond).

The parameters that seem to have a relatively larger impact on CERPTs are the fraction of non-tradables in total consumption, γ, and the elasticity of substitution between tradable and non-tradable consumption, ρ. A higher value for γ leads to a higher tradable CERPTs after the shock to external inflation and a lower non-tradable CERPTs after all shocks. Since CPI is more dependent on non-tradables, its CERPTs changes accordingly.

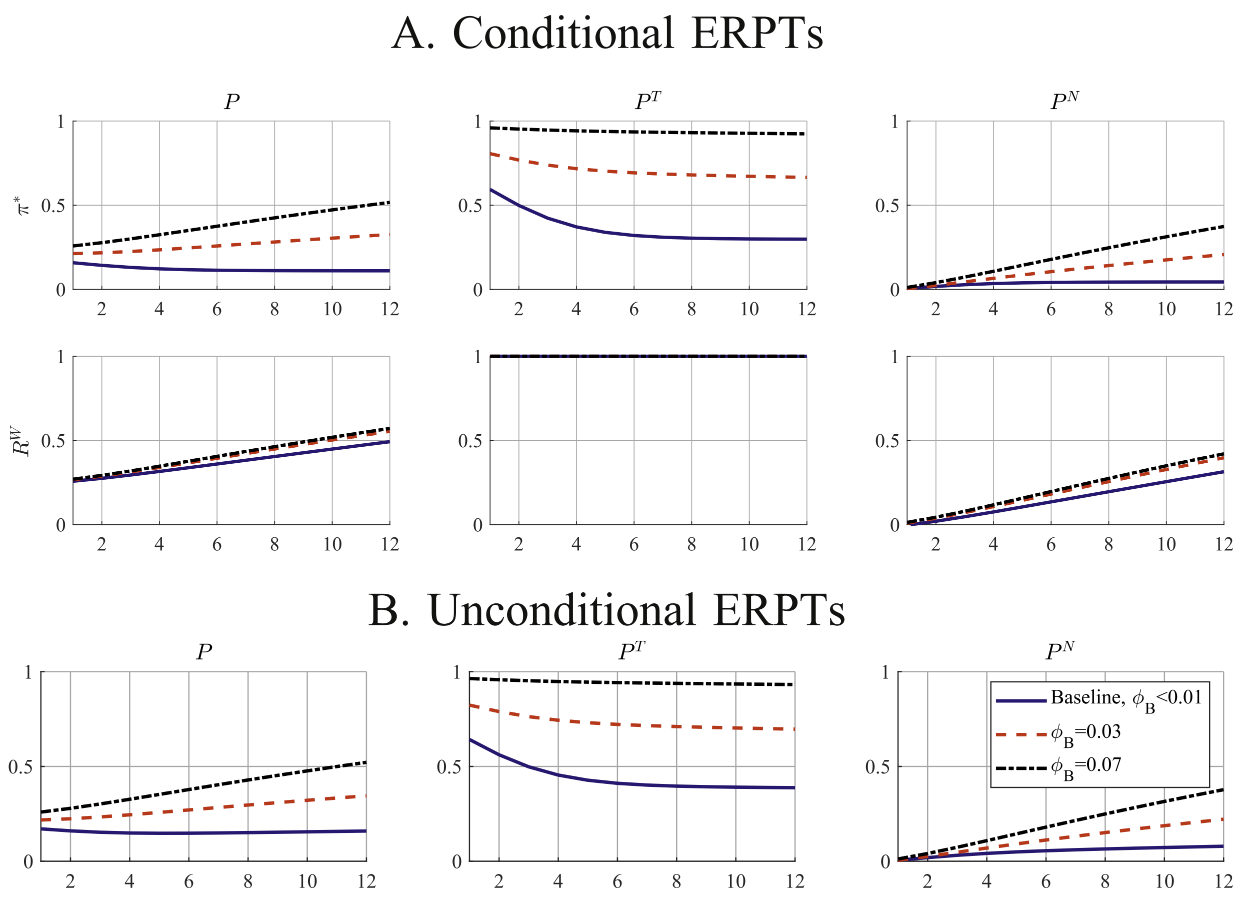

Fig. 12. Conditional and unconditional ERPTs with financial frictions. Notes: the graphs show CERPTs and $UERPT^M$. The blue solid lines are the baseline ($\phi_B = 0.0000335$), the dashed red lines and dash-dotted lines are cases with financial frictions, with $\phi_B = 0.03$ and $\phi_B = 0.07$ respectively.

In contrast, a higher value of ρ is associated with a lower CERPT for tradables and non-tradables after a shock to external inflation, and higher CERPTs for non-tradables after world interest rate disturbances. Still, in all cases, the differences between CERPTs and UERPTs remain significant.

7. Results based on a quantitative DSGE model

The points we stress in this paper are of quantitative nature, and therefore it is relevant to evaluate them with a model that matches real-data dynamics. To that end, in this section, we perform the main exercises using a DSGE model estimated for Chile. We present an overview of the model and the main results, leaving additional details to Appendix E.

7.1. Model overview

Our setup is one of a small open economy with both nominal and real rigidities, and incomplete financial markets. There are three goods produced domestically: commodities (*Co*), non-tradables (*N*), and exportables (*X*). The first is assumed to be an exogenous endowment that is fully exported, while the other two are produced by combining labor, capital, imported goods (*M*, which are sold domestically through import agents) and energy (*E*). On the demand side, consumption is a combination of a tradable composite (*T*, combining *X* and *M*), *N*, *E* and food (*F*). Goods *E* and *F* are combinations of *X* and *M*, and they are treated differently to distinguish between headline and core inflation; a key distinction to explain inflation in Chile. Investment is a combination of *N*, *X* and *M* goods, and government consumption is fully spent on *N*. Long run-growth is exogenous under a balanced-growth path, although we allow for sector-specific trends in the short-run.

Households derive utility from consumption (with habits) and leisure. They invest (with adjustment costs) and borrow in both domestic and foreign bonds. They also have monopoly power in supplying labor.

Prices for goods *X*, *N* and *M*, as well as wages, are subject to Calvo-style frictions. They feature indexation to a combination of the inflation target and past CPI inflation, and also to own-sector inflation in the case of prices.

Table 3
Variance decomposition.

Var.	*M. P.*	R^W	*C. P.*	*UIP*	ΔF^*	Sum.
π^S	3	8	2	14	67	94
π	3	12	3	5	8	31
π^T	4	19	5	9	14	50
π^N	2	13	3	2	6	27

Note: Each entry shows the % of the unconditional variance of the variable in each row, explained by the shock in each column. The shocks in order are monetary policy, world interest rate, country premium, deviations from *UIP* and the trend in international prices. The variables are: nominal depreciation, total, tradable and non-tradable inflation.

Monetary policy follows a Taylor rule. Fiscal policy finances an exogenous stream of consumption using lump-sum taxes and proceedings from the ownership of part of the commodity production. Finally, the rest of the world sets international prices and interest rates, which are exogenous for the local economy. A variety of domestic and foreign shocks are included, such as disturbances to preferences, productivities, international prices and interest rates.

The parameter values are chosen by a combination of calibration and Bayesian estimation. We use data for Chile, at a quarterly frequency from 2001.Q3 to 2016.Q3. The data includes local and international variables and, among the local, both aggregate and sectoral series. We show in the appendix that the estimated model can satisfactorily match second moments for the relevant observables. All the results presented in the following subsections fix parameter values at the posterior mode.

7.2. Main drivers of the NER and implied dynamics

As in the baseline, we first need to identify the shocks driving NER movements. Table 3 shows the contribution of the 5 most important shocks, that explain almost 95% of the variance of the nominal depreciation. The first is a common trend in international prices (ΔF^*), explaining almost 70% of the volatility. This shock affects at the same time the foreign price of commodities, imported goods and CPI of trade partners. The other four shocks are related with the uncovered interest rate parity condition: the monetary policy shock (*M. P.*), world interest rate (R^W), a shock to the country premium (*C. P.*), and a risk shock representing deviations from the parity (*UIP*).

Note that these five shocks also play a non-trivial role in accounting for inflation variability, explaining around 50% of tradable inflation, almost 30% of non-tradable and 30% of total CPI. Thus, the determinants of the NER are also important for inflation dynamics.

We present results using the two most important shocks, ΔF^* and *UIP*. Despite the higher complexity of this model, the intuition behind these shocks is qualitatively similar to the intuition after a shock to external inflation and the world interest rate in the baseline model. In particular, recall that changes in international prices have a dampening effect, implying smaller CERPTs.

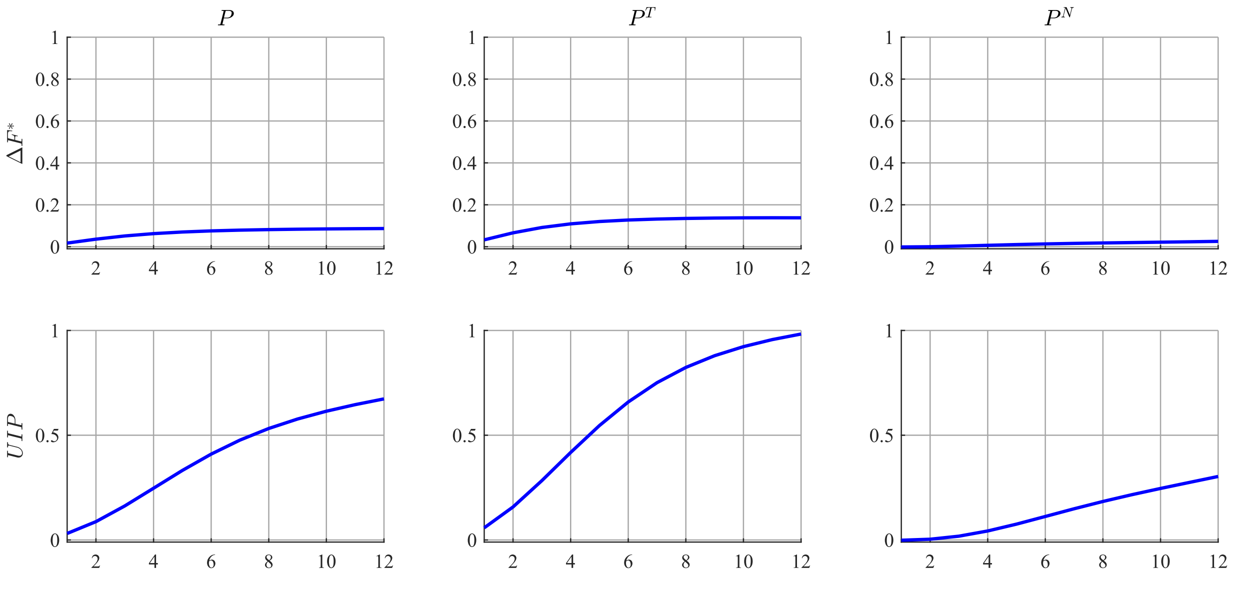

Fig. 13. Conditional ERPTs. Note: The graphs show the CERPT for the price in each column (CPI, tradables and non-tradables), conditional on the shock in each row (external prices and *UIP*).

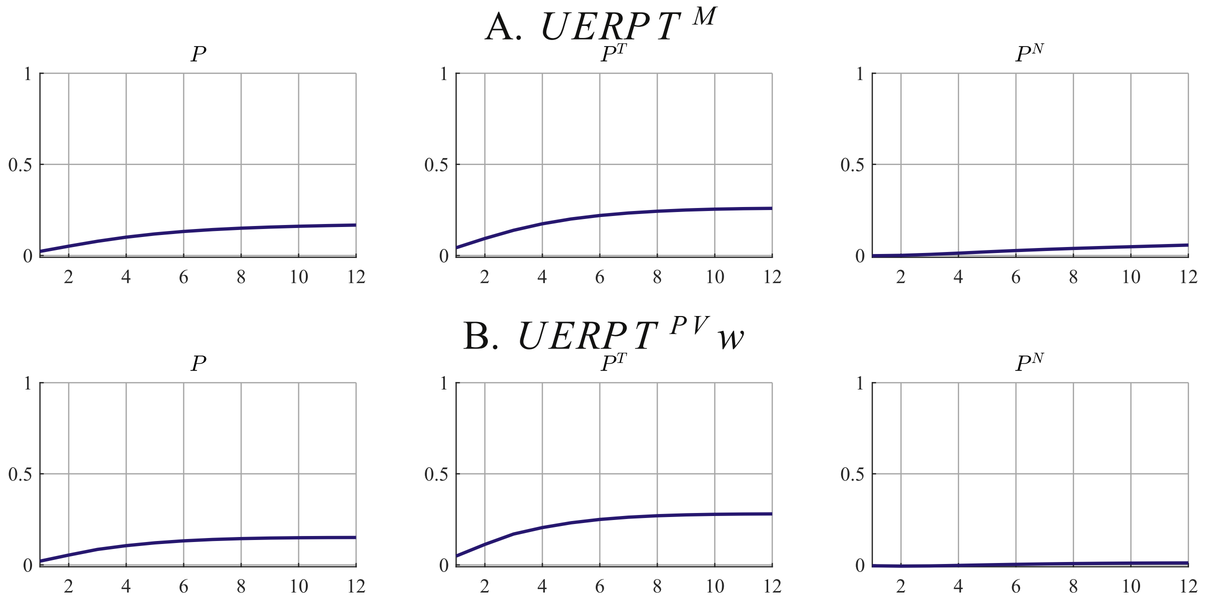

Fig. 14. Unconditional ERPTs. Note: The graphs show $UERPT^M$ and $UERPT^{PV}$ for the price in each column (CPI, tradables and non-tradables).

7.3. Conditional versus unconditional ERPTs

As can be seen in Fig. 13, the CERPTs generated by international prices, ΔF^*, are significantly different from those implied by the *UIP* shock. We present results for aggregate CPI (P), tradables (P^T) and non-tradables (P^N). For a two-year horizon the CERPT after a shock to international prices is less than 0.1 for total CPI, close to 0.15 for tradables, and smaller than 0.05 for non-tradables. In sharp contrast, for the same horizon, after a *UIP* shock the CERPTs are much higher for all prices: close to 0.5 for CPI, larger than 0.8 for tradables, and near 0.2 for non-tradables.

Fig. 14 displays both UERPTs measures introduced in Section 2: the weighted average of CERPTs and the one based on the Population VAR.[6] In line with our previous analysis, these lie between the conditional measures reported before. Moreover these estimates are close to the empirical Chilean estimates, which are around 0.2 for total CPI and tradables and around 0.05 for non-tradables after two years (e.g. Justel and Sansone, 2016; Contreras and Pinto, 2016; Albagli et al., 2015).

Overall, the evidence presented in this section confirms the intuition developed with the simple model: CERPTs are quite different from those obtained from aggregate ERPT measures comparable to those in the literature. Thus, using the results from the empirical literature will lead to important biases in the inferred dynamics of inflation after movements in the NER. In turn, the analysis can be greatly improved by an assessment of which shocks are behind the particular NER change, and by the use of CERPT measures. An interesting extension would be to describe how the historical inferred path of these shocks can explain time variations observed in UERPT measures; which we leave for future research.

7.4. ERPT and expected monetary policy

As in the baseline model, we compare the policy that follows a Taylor rule with two relatively more dovish alternatives that fix the interest rate for 2 and 4 periods, following the rule afterward. As shown in panel A of Fig. 15, CERPTs after the shock to international prices vary significantly depending on the reaction of monetary policy. For instance, after two years, the CERPT to total CPI almost doubles if the policy rate remains fixed for a year; and the difference is even larger for non-tradables. In contrast, and particularly in the first two years, CERPTs do not vary much after a shock to the *UIP*, with some differences in non-tradables.

Notes: the graphs show CERPTs and $UERPT^M$. The solid blue line is the baseline, the dashed red and dash-dotted black lines are the cases when the interest rate is held fixed for 2 and 4 periods respectively.

In panel B of Fig. 15 we see that, influenced mainly by the behavior of the ERPT after the shock to international prices, the UERPT also increases with more dovish policies.

Overall, this section highlights the quantitative relevance of the information missing when using UERPTs, instead of using CERPTs and taking into account expected monetary policy. When predicting inflation, the one-year forecast can be either half

[6] The VAR contains the variables used in the empirical literature: foreign inflation, world interest rate, growth of external GDP, world inflation of imports and commodities, the local interest rate, output growth, nominal depreciation rate, and inflations for CPI, tradables, importables and non-tradables. The ERPT is computed using the shock for π^S in the Cholesky decomposition. We ran a VAR(2) based on the BIC criterion.

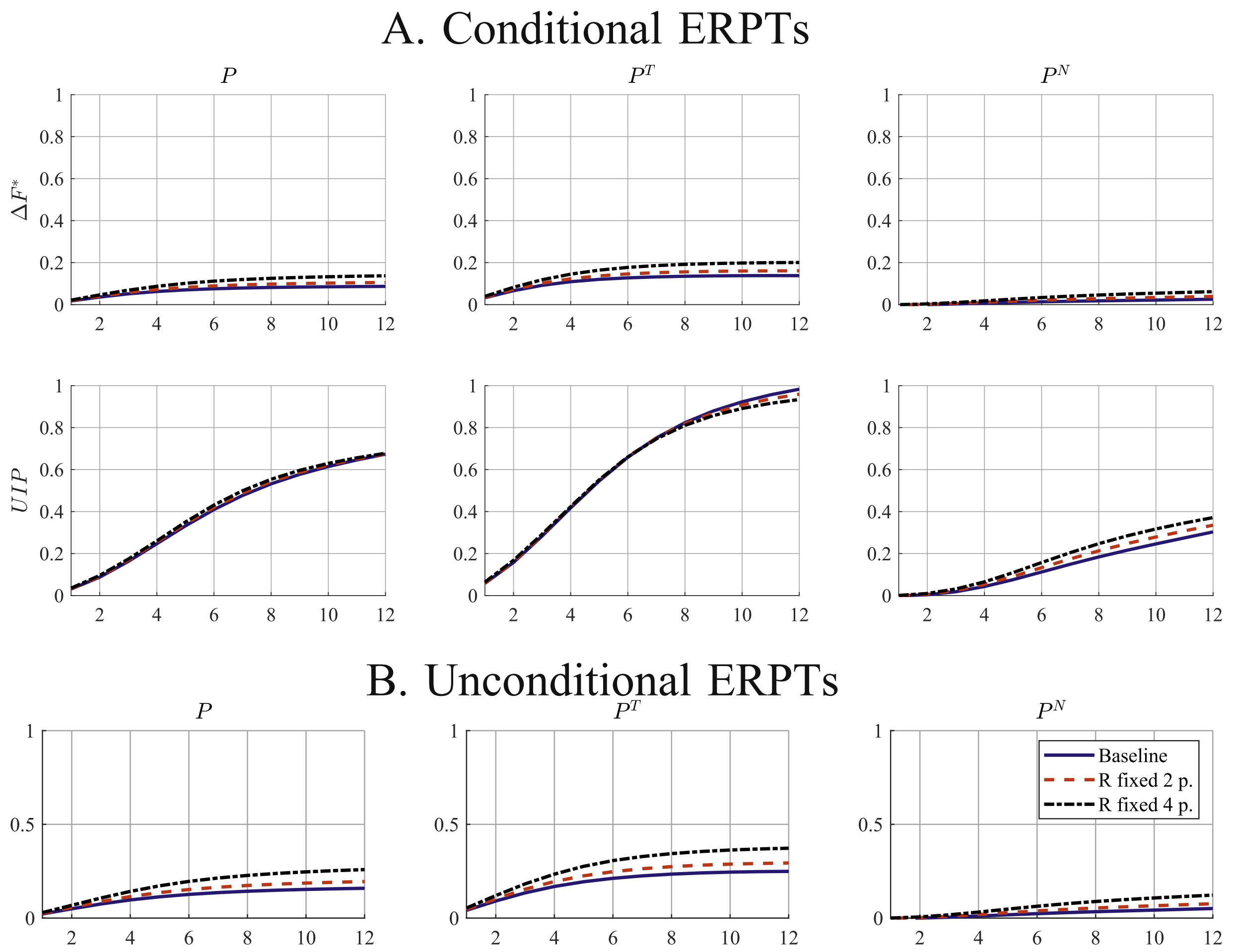

Fig. 15. Conditional and unconditional ERPTs under alternative policy paths.

or double depending on the shock hitting the economy and the policy in place. These differences are non-trivial, particularly from the point of view of policymakers.

8. Conclusions

This paper highlighted two important shortcomings of using ERPT measures obtained with empirical/reduced-form methodologies for monetary-policy analysis: the dependence of ERPTs on the shock hitting the economy and the influence of expected policy paths. We first established the relationship between ERPT measures in the empirical literature and comparable objects obtained in DSGE models. A simple model was used to understand the two shortcomings and to provide a qualitative assessment. We also presented results under different model specifications and monetary policies, making clear that our critiques are generally independent of specific characteristics of the baseline version. Finally, we showed the quantitative importance of these distinctions using a large DSGE model estimated with Chilean data.

The ERPT is just a conditional correlation, not a structural characteristic of the economy. As such, all the relevant aspects for monetary policy design could be described without using the concept of ERPT at all. It is however appealing to use a simple metric to summarize results, which probably explains its widespread use. We stress that empirical estimates may hide relevant information and, importantly, should not be taken as policy invariant. As shown, DSGE models can be used to improve on these fronts.

The influence of monetary policy on the realized ERPT should have a more prominent role in policy-related discussions. When choosing among alternative policy paths, the monetary authorities would benefit from knowing the expected ERPT for each of these options. An interesting line of future research would be to study particular episodes of large depreciations, trying to disentangle the influence that the perceived expected policy path had on the dynamics of inflation that followed.

An important caveat is that throughout we have assumed rational expectations and perfect information. Alternative expectation-formation setups or imperfect credibility might change quantitatively our results, by changing the inflationary consequences of a given NER depreciation. Indeed, for instance, Carriere-Swallow et al. (2016) document that the heterogeneity across countries in (unconditional) ERPTs can be in part explained by measures of policy credibility. While future work is needed to quantify these effects, conceptually one should expect that differentiating between CERPTs, and especially controlling for *perceived* policy paths, to remain relevant under these alternative setups as well.

Finally, the influence of monetary policy on the exchange rate is also related to direct interventions in the FX market. It is frequent to find arguments in policy discussions separating exchange rate management (i.e. FX interventions) from monetary policy (i.e. interest rates). Our analysis highlights that such a distinction is not always clear and that even "regular" monetary policy can be extremely relevant for ERPTs. In fact, studies on the effect of sterilized interventions (e.g, Sarno and Taylor, 2001) emphasize a signaling channel: FX interventions may work not by itself but by conveying information about future monetary policy, which is well-aligned with our discussion. It would be interesting for future work to evaluate the impact of foreign-reserves management on ERPTs.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jinteco.2020.103389.

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