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Real exchange rate dynamics in New-Keynesian models - The Balassa-Samuelson effect revisited

Maren Brede*

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Abstract

This paper explores the Balassa-Samuelson effect in a New-Keynesian DSGE model of a monetary union with traded and non-traded goods. Credible sets for theoretical impulse response functions show that a model with perfect intersectoral labour mobility is unable to reproduce an appreciation of the real exchange rate caused by higher productivity in the traded sector. Allowing for imperfect intersectoral labour mobility resolves this obstacle and delivers testable restrictions for model parameters governing the labour market specification in a Bayesian estimation context.

Keywords: Real exchange rate, Balassa-Samuelson, prior predictive analysis

JEL classification: F41, F45, F47, C51

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1 Introduction

The textbook Balassa-Samuelson effect (see Balassa (1964) and Samuelson (1964)) prescribes that productivity growth differentials drive changes in the real exchange rate.¹ Traditionally, it has been used to explain higher inflation rates and hence rising prices in catching-up economies due to rising non-traded goods prices. With higher productivity due to e.g. intensified competition in the traded sector, wages paid in that sector increase. Given intersectoral labour mobility, wages in the non-traded goods producing sector will simultaneously increase leading to higher prices for non-traded goods driving the appreciation of the real exchange rate. This is in line with the empirical observation that price levels in advanced economies exceed price levels in less developed economies.²

The traditional mechanism works through non-traded goods that differ in price across countries as traded goods were believed to obey the law of one price. Corsetti et al. (2007), Berka et al. (2014) and Bordo et al. (2017) deal with an augmented version of the Balassa-Samuelson effect coming from the terms of trade. When traded goods are imperfect substitutes or when trade barriers hamper price equalisation, productivity growth differentials in the traded sector will lead to changes in the terms of trade and hence the real exchange rate.³ The impact of the terms of trade channel could hamper or even reverse the standard effect of productivity shocks on the real exchange rate.⁴

A prominent tool that has been extensively used in the past decades to identify and disentangle drivers of macro aggregates is Bayesian estimation of DSGE models.⁵ Naturally, this approach can be applied to a two-country, two-sector New-Keynesian model of a monetary union to dissect the driving forces behind real exchange rate dynamics. The agenda of this paper is to clarify whether this model is in fact capable of identifying a Balassa-Samuelson effect. To abstract from nominal exchange rate

¹ Several works acknowledge the contribution of Harrod (1933) and call it the Harrod-Balassa-Samuelson effect.

² The observation of higher price levels in advanced economies can also be explained via demand instead of supply side factors as prescribed by the Balassa-Samuelson theory. See for instance Bergstrand (1991) who proposes homothetic preferences where non-traded goods are luxuries and traded goods necessities to explain higher price levels in rich countries.

³ Zhang (2017) provides some very recent evidence that the law of one price or purchasing power parity does not hold. He explains persistent differences in traded goods prices via differences in product quality.

⁴ See Corsetti et al. (2008) and Choudhri and Schembri (2010).

⁵ See An and Schorfheide (2007) for an extensive overview of models that have been estimated with Bayesian methods.

effects, I focus on a model of a monetary union and ask whether the model is able to deliver rich enough dynamics in the real exchange rate to realistically accept or reject the Balassa-Samuelson hypothesis in a Bayesian estimation. Given model nesting, Bayesian techniques can assess the likelihood of distinct model versions. Additionally, I analyse the prescribed relevance and sign of the terms of trade effect given the model's structure in explaining real exchange rate movements.

This paper makes use of a prior predictive analysis or model validation exercise in the spirit of Geweke (2007) and Faust and Gupta (2012) that have become increasingly popular in recent years. The analysis finds that a standard Balassa-Samuelson effect or even an appreciation of the real exchange rate following an increase in traded sector productivity cannot be replicated if the model features perfect intersectoral labour mobility. If the model nests both perfect and imperfect intersectoral labour mobility, the response of the real exchange rate is not predetermined by the model structure but allows both an appreciation or depreciation of the real exchange rate. The nesting parameters that specify the set-up of the labour market deliver testable restrictions for a Bayesian estimation of the model.

Irrespective of the specification of the labour market, the terms of trade effect on the real exchange rate cushions if not reverses the traditional mechanism of Balassa-Samuelson. This is because, given higher productivity, firms in the traded sector lower their prices as marginal costs have declined. The terms of trade necessarily increase, i.e. the domestic economy becomes internationally more competitive. As a result, the terms of trade channel always favours a depreciation of the real exchange rate in a New-Keynesian set-up. Both findings provide further support for the necessity of model validation exercises that have been rarely found but are recently on the rise in the existing literature.

The paper proceeds as follows: Section 2 presents the model set-up of the monetary union consisting of two economies featuring two sectors of production. Section 3 analyses the model's ability to deliver testable restrictions for the Balassa-Samuelson effect through the conventional and terms of trade channel. A sensitivity analysis in section 4 discusses the relevance of the size of the economy within the monetary union for the results. Section 5 concludes.

2 A two-sector, two-country model of a monetary union

The monetary union consists of two economies and is populated by a measure one of households which have access to an internationally traded bond. A share $1 - n$ lives in the home economy (H) and the remainder in the foreign economy (F). Each economy produces traded (T) and non-traded goods (N) of which the latter can only be consumed by domestic households. Both economies feature nominal price rigidities in both sectors and a centralised monetary authority sets a union-wide nominal interest rate. There is no labour mobility across countries, i.e. no migration.

The set-up of the home economy is presented in the following paragraphs. If not stated otherwise, the set-up of the foreign economy is equivalent. Foreign variables are denoted by an asterisk.

2.1 Households

Households maximise their expected lifetime utility

$$\mathbb{E}_t \sum_{k=0}^{\infty} \beta^k [U(C_{t+k}) - V(L_{t+k})]$$

derived from consumption C_t less disutility derived from supplying labour L_t to domestic firms. The discount factor is denoted by $\beta \in (0, 1)$. Consumption C_t is composed of tradeable, C_T , and non-tradeable, C_N , consumption goods via

$$C_t = \left[(1 - \delta)^{\frac{1}{\iota}} C_{T,t}^{\frac{\iota-1}{\iota}} + \delta^{\frac{1}{\iota}} C_{N,t}^{\frac{\iota-1}{\iota}} \right]^{\frac{\iota}{\iota-1}}$$

where ι measures the substitutability between T and N goods and δ the steady state share of N goods in the consumption basket. The domestic consumer price level is given by

$$P_t = \left[(1 - \delta) P_{T,t}^{1-\iota} + \delta P_{N,t}^{1-\iota} \right]^{\frac{1}{1-\iota}}$$

where P_T and P_N denotes the prices of T and N goods. The optimal allocation of consumption expenditures implies that $C_{T,t} = (1 - \delta) \left(\frac{P_{T,t}}{P_t} \right)^{-\iota} C_t$ and $C_{N,t} = \delta \left(\frac{P_{N,t}}{P_t} \right)^{-\iota} C_t$. The representative household supplies labour to both sectors earning the real wages w_N and w_T . I follow the specification of Horvath (2000) so that hours supplied to the two sectors are aggregated via the CES function

$$L_t = \left[\alpha^{1-\gamma} L_{T,t}^{\gamma} + (1 - \alpha)^{1-\gamma} L_{N,t}^{\gamma} \right]^{\frac{1}{\gamma}}$$

where $0 < \alpha < 1$ is the weight of hours supplied to the traded sector and γ measures the substitutability or mobility of hours worked across sectors.⁶ Barriers to labour mobility could be costs related to sector-specific human capital, relocation or psychological costs due to shifting sectors. The household maximises his lifetime utility given his periodic budget constraint

$$C_t + \frac{B_t}{P_t} = R_{t-1} \frac{B_{t-1}}{P_t} + w_{T,t} L_{T,t} + w_{N,t} L_{N,t} + \Pi_t$$

where B_t denotes the internationally traded bond that yields the nominal interest rate R_t in $t + 1$ and Π_t profit transfers from domestic firms. The functional forms of utility read

$$\begin{aligned} U(C_t) &= \log(C_t - bC_{t-1}) \\ V(L_t) &= \frac{1}{1 + \kappa} L_t^{1+\kappa} \end{aligned}$$

with the degree of internal habit captured by b and the inverse Frisch elasticity by κ . The optimal paths of consumption and hours supplied to the two sectors are described by the set of optimality conditions of the utility maximisation problem. Besides the standard intertemporal Euler equation, one can combine the sector labour supply conditions to obtain

$$\frac{w_{T,t}}{w_{N,t}} = \left(\frac{\alpha}{1 - \alpha} \right)^{1-\gamma} \left(\frac{L_{T,t}}{L_{N,t}} \right)^{\gamma-1}$$

that summarises the versatility of the Horvath (2000) specification. The model nests the case of perfect labour mobility and equal wages across sectors under $\gamma = 1$ and $\alpha = 0.5$. While calibrations with $\alpha \neq 0.5$ capture constant differences in real wages, the case of imperfect labour mobility $\gamma > 1$ is able to generate dynamic differences across sector wages. The prior predictive analysis will show that the specification of the labour market is at the core of determining the model's ability to replicate a Balassa-Samuelson effect.

2.2 Firms

2.2.1 Intermediate goods producing firms

In each sector there is a continuum of monopolistically competitive firms indexed by i , $i \in [0, 1]$, which set their prices in a Calvo fashion with indexation, i.e. a fraction μ of

⁶ An important assumption in the original Balassa-Samuelson theory is that of perfect labour mobility across sectors implying that relative wages should remain unchanged in response to productivity differentials. Cardi and Restout (2015) show for a panel of fourteen OECD countries that this prediction of the Balassa-Samuelson hypothesis does not hold in the data and suggest to employ the specification of Horvath (2000).

firms, unable to reoptimise prices, indexes their price to last period's inflation. The firms produce intermediate goods varieties using a linear production technology and sector- and country-specific technology Z_S , $S \in [T, N]$.

In the non-tradeable goods sector an intermediate goods producing firm i produces with

$$Y_{N,t}(i) = \exp(Z_{N,t})L_{N,t}(i)$$

and seeks to maximise its expected profit given that with probability θ the firm is not able to adjust its price, $P_{N,t}(i)$, in a given period. Formally, it sets its price to solve the problem

$$\max \mathbb{E}_t \sum_{k=0}^{\infty} \theta_N^k Q_{t,t+k} \left[Y_{N,t+k|t}(i) P_{N,t}(i) - W_{t+k}^N L_{N,t+k}(i) \right]$$

where $Q_{t,t+k} = \beta^k \frac{U'(C_{t+k})}{U'(C_t)} \frac{P_t}{P_{t+k}}$ is the stochastic discount factor, $Y_{N,t+k|t}(i)$ output of firm i in $t+k$ given the price set in t , i.e. $Y_{N,t+k|t}(i) = \left(\frac{P_{N,t}(i)}{P_{N,t+k}} \left(\frac{P_{N,t+k-1}}{P_{N,t-1}} \right)^{\mu_N} \right)^{-\epsilon} Y_{N,t+k}$ and W_t^N the nominal wage paid in that sector. μ_N denotes the share of indexing firms.

The set-up and maximisation problem of an intermediate goods producing firm in the traded sector is analogous. Intermediate goods in the traded sector in the home economy are produced by firm i via the production function

$$Y_{H,t}(i) = \exp(Z_{T,t})L_{T,t}(i).$$

Firm i in the tradeable sector sets its price, $P_{H,t}(i)$, to maximise

$$\max \mathbb{E}_t \sum_{k=0}^{\infty} \theta_H^k Q_{t,t+k} \left[Y_{H,t+k|t}(i) P_{H,t}(i) - W_{t+k}^T L_{T,t+k}(i) \right].$$

given that with probability θ_H the firm in the traded sector cannot readjust its price and given demand $Y_{H,t+k|t}(i) = \left(\frac{P_{H,t}(i)}{P_{H,t+k}} \left(\frac{P_{H,t+k-1}}{P_{H,t-1}} \right)^{\mu_H} \right)^{-\epsilon} Y_{H,t+k}$. The share of indexing firms is denoted by μ_H .

The sector-technologies are assumed to follow AR(1) processes of the form

$$Z_{N,t} = \rho_{Z_N} Z_{N,t-1} + \epsilon_{Z_N,t}$$

$$Z_{T,t} = \rho_{Z_T} Z_{T,t-1} + \epsilon_{Z_T,t}.$$

Innovations $\epsilon_{Z_S,t}$ are uncorrelated across sectors and countries.

2.2.2 Retailers

Retailers in both sectors are perfectly competitive and combine intermediate goods to produce the final goods to be sold to the household. The final non-traded good,

Y_N , is produced with technology $Y_{N,t} = \left(\int_0^1 Y_{N,t}(i)^{\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}}$ where ϵ is the elasticity of substitution across different varieties $Y_N(i)$ of the non-tradeable intermediate good. Given the technology, retailers in the non-traded sector maximise their profit

$$\max P_{N,t} Y_{N,t} - \int_0^1 P_{N,t}(i) Y_{N,t}(i) di$$

which yields the demand function

$$Y_{N,t}(i) = \left(\frac{P_{N,t}(i)}{P_{N,t}} \right)^{-\epsilon} Y_{N,t}$$

where $P_{N,t}(i)$ is the price for variety i of the non-traded good and $P_{N,t} = \left(\int_0^1 P_{N,t}(i)^{1-\epsilon} di \right)^{\frac{1}{1-\epsilon}}$.

In the traded sector, retailers combine intermediate home and foreign produced traded goods, $Y_{H,t}(i)$ and $Y_{F,t}(i)$, to produce the final traded good, Y_T , consumed by domestic households. They choose their inputs to maximise

$$\max P_{T,t} Y_{T,t} - \int_0^1 P_{H,t}(i) Y_{H,t}(i) di - \int_0^1 P_{F,t}(i) Y_{F,t}(i) di$$

subject to technologies

$$\begin{aligned} Y_{T,t} &= \left[(1-\omega)^{\frac{1}{\varphi}} Y_{H,t}^{\frac{\varphi-1}{\varphi}} + \omega^{\frac{1}{\varphi}} Y_{F,t}^{\frac{\varphi-1}{\varphi}} \right]^{\frac{\varphi}{\varphi-1}}, \\ Y_{H,t} &= \left(\int_0^1 Y_{H,t}(i)^{\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}} \quad \text{and} \\ Y_{F,t} &= \left(\int_0^1 Y_{F,t}(i)^{\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}} \end{aligned}$$

where φ is the elasticity of substitution between final home and foreign traded goods in the production of Y_T and ω stands for the steady state share of imported goods in the final traded good. Home bias for home produced traded goods is present when $\omega < 0.5$.⁷

The profit maximisation yields the demand functions

$$\begin{aligned} Y_{H,t}^d(i) &= (1-\omega) \left(\frac{P_{H,t}(i)}{P_{H,t}} \right)^{-\epsilon} \left(\frac{P_{H,t}}{P_{T,t}} \right)^{-\varphi} Y_{T,t} \\ Y_{F,t}^d(i) &= \omega \left(\frac{P_{F,t}(i)}{P_{F,t}} \right)^{-\epsilon} \left(\frac{P_{F,t}}{P_{T,t}} \right)^{-\varphi} Y_{T,t} \end{aligned}$$

where $P_{H,t}(i)$ and $P_{F,t}(i)$ are the prices of the home and foreign traded variety i and where the price indices are defined as $P_{H,t} = \left(\int_0^1 P_{H,t}(i)^{1-\epsilon} di \right)^{\frac{1}{1-\epsilon}}$, $P_{F,t} = \left(\int_0^1 P_{F,t}(i)^{1-\epsilon} di \right)^{\frac{1}{1-\epsilon}}$ and $P_{T,t} = \left[(1-\omega) P_{H,t}^{1-\varphi} + \omega P_{F,t}^{1-\varphi} \right]^{\frac{1}{1-\varphi}}$.

⁷ Analogously, foreign bias is implied by setting $\omega > 0.5$.

2.2.3 Terms of trade and the real exchange rate

Due to the presence of the non-traded goods sector, the model includes external and internal terms of trade. The (external) terms of trade, T_t , are defined as the price of foreign produced traded goods relative to home produced traded goods, i.e.

$$T_t = \frac{P_{F,t}}{P_{H,t}}.$$

A rise in the terms of trade ameliorates the trade position of the home economy as the foreign produced traded goods become relatively more expensive. The internal terms of trade, $T_{N,t}$, are defined as

$$\begin{aligned} T_{N,t} &= \frac{P_{N,t}}{P_{T,t}} \quad \text{and} \\ T_{N,t}^* &= \frac{P_{N,t}^*}{P_{T,t}^*} \end{aligned}$$

and measure the internal competitiveness across sectors within a country. They capture the price of the non-traded good relative to the final traded good within a member country of the monetary union. The real exchange rate is defined as

$$rer = \frac{P_t^*}{P_t} = \frac{P_{T,t}^*}{P_{T,t}} \left(\frac{1 - \delta + \delta T_{N,t}^{*1-t}}{1 - \delta + \delta T_{N,t}^{1-t}} \right)^{\frac{1}{1-t}} = \left(\frac{(1 - \omega) T_t^{1-\varphi} + \omega}{1 - \omega + \omega T_t^{1-\varphi}} \right)^{\frac{1}{1-\varphi}} \left(\frac{1 - \delta + \delta T_{N,t}^{*1-t}}{1 - \delta + \delta T_{N,t}^{1-t}} \right)^{\frac{1}{1-t}}$$

which is a function of external and domestic and foreign internal terms of trade.

In the textbook Balassa-Samuelson effect, traded goods prices would be identical ($\omega = 0.5$) so that changes in the real exchange rate are entirely driven by differences in non-traded goods prices. A rise in non-traded goods prices leads to an appreciation (or fall) of the real exchange rate via the rise in T_N , i.e. the domestic price level, P , rises relative to the foreign, P^* . Allowing for differing traded goods prices ($\omega \neq 0.5$), the model is able to capture changes in the real exchange rate through the terms of trade. In the absence of non-traded goods ($\delta = 0$) changes in the real exchange rate would be entirely driven by the terms of trade.

2.3 Monetary policy

Monetary policy is conducted at the union level and responds to average union-wide consumer price inflation $\pi_t^U = (1 - n)\pi_t + n\pi_t^*$. The Taylor-type interest rate rule reads

$$R_t = \left(\frac{1}{\beta} \right)^{1-\rho_R} (R_{t-1})^{\rho_R} (\pi_t^U)^{(1-\rho_R)\phi} + \epsilon_{R,t}$$

where ρ_R denotes the interest rate persistence and ϕ the aggressiveness with which the central bank reacts to union-wide consumer price inflation.

2.4 Market clearing

The market clearing conditions for traded and non-traded goods, the labour market and the international bond market are

$$\begin{aligned} Y_{T,t} &= C_{T,t} + G_{T,t} \\ Y_{N,t} &= C_{N,t} + G_{N,t} \\ (1-n)\frac{B_t}{P_t} &= n\frac{B_t^*}{P_t^*} \end{aligned}$$

where G_T and G_N are sector-specific demand disturbances following an AR(1)

$$\begin{aligned} G_{T,t} &= \rho_{G_T} G_{T,t-1} + \epsilon_{G_T,t} \\ G_{N,t} &= \rho_{G_N} G_{N,t-1} + \epsilon_{G_N,t} \end{aligned}$$

A debt-elastic interest rate à la Schmitt-Grohé and Uribe (2003) induces debt-stationarity. The model is approximated around a zero-inflation steady state.

3 Model validation

In this section I perform a model validation exercise or prior predictive analysis in order to determine whether the model can reproduce a Balassa-Samuelson effect given certain model structures. I do this by simulating the model and computing *prior* impulse response functions given relatively agnostic priors for parameters that would usually be estimated. This allows to evaluate whether the model is suited to test for the presence of a Balassa-Samuelson effect in the data via Bayesian techniques.⁸

3.1 Approach

I compute the range of prior impulse response functions, i.e. impulse response functions that the model can produce given calibration and prior range of parameters of interest.

⁸This approach is inspired by Leeper et al. (2017) who show how the size of estimated fiscal multipliers is heavily model-dependant. They find that by including government consumption in the household's utility function and by varying the parameter governing the degree of substitutability or complementarity of public to private consumption the model is able to produce a wide range of fiscal multipliers.

I compare two model structures: a restricted model version that calibrates α and γ to the values corresponding to equal sector-wages and perfect labour mobility (M_1) and an unrestricted version that nests M_1 where α and γ can differ to allow for imperfect labour mobility (M_2). I proceed in three steps:

1. Given the model structure, $M \in [M_1, M_2]$, I specify prior density functions $p(\theta_M)$ for the model parameters θ_M . Parameters that are known to be less well identified or have clear cut empirical counterparts are assigned point priors, i.e. they are calibrated.
2. Together with the parameter priors, the linearly approximated model delivers ex ante distributions for the model's observables, y_t , from $p(y_t) = \int p(\theta_M)p(y_t|\theta_M)d\theta_M$.
3. The prior predictive analysis draws from $\theta_M \sim p(\theta_M)$ and $y_t \sim p(y_t|\theta_M)$ and computes impulse response functions for y_t given prior draws.

Testing the model structures' ability to reproduce a Balassa-Samuelson effect *before* taking the model to the data is essential to judge the model's appropriateness to be estimated in that context. If the model is not able to produce a considerable range of real exchange rate dynamics, it is not fit to robustly reject or accept the Balassa-Samuelson hypothesis irrespective of the information contained in the data.

3.2 Calibration and priors

The baseline calibration is for two symmetric countries of equal size. The calibration is summarised in table 1 and mainly follows Duarte and Wolman (2008). As the steady state share of non-traded goods as well as the steady state import share would be calibrated in an explicit application to a certain country, they are fixed in the prior predictive analysis. Depending on goods classification schemes, the share of non-tradable goods ranges from around 40-60% across European economies. Calibrating δ to 0.4 hence represents the lower bound for changes in the real exchange rate caused by changes in the internal terms of trade. A steady state import share of 0.4 implies a small degree of home bias, allowing for price differentials due to differences in traded goods prices. Again, this calibration should be seen as a lower bound to allow changes in the real exchange rate to be driven by the (external) terms of trade. Importantly, the baseline calibration fixes the parameters α and γ to the values corresponding to equal sector-wages and perfect labour mobility in the restricted model version.

Description	Parameter	Value
Size of the home economy	$1 - n$	0.5
Discount factor	β	0.99
Inverse Frisch elasticity	κ	1
Steady state share of N goods	δ	0.4
Steady state import share in T good	ω	0.4
Elasticity of substitution between T and N goods	ι	0.74
Elasticity of substitution between H and F goods	φ	1.5
Elasticity of substitution across good varieties	ϵ	10
Weight on L_T in CES	α	0.5
Elasticity of substitution between T and N hours	γ	1

Table 1: Calibrated parameters (α and γ are not calibrated in the unrestricted model)

The priors follow standard ranges and distributions from the existing literature and are displayed in table 2. As changes in the real exchange rate for two countries in a monetary union are reflected by price changes and hence differing inflation rates, parameters linked to the price setting of firms are of major interest, i.e. Calvo parameters and the shares of indexing firms. As consumption patterns are heavily driven by the

Description	Parameter	Distribution	Mean	Std. Dev.
Calvo parameter	$\theta_N, \theta_{N^*}, \theta_H, \theta_F$	Beta	0.75	0.15
Indexation	$\mu_N, \mu_{N^*}, \mu_H, \mu_F$	Beta	0.6	0.2
Habit persistence	b	Normal	0.5	0.1
Monetary policy strength	ϕ	Normal	1.5	0.1
Interest rate rule persistence	ρ_R	Beta	0.7	0.1
Technology shock persistence	$\rho_{Z_T}, \rho_{Z_N}, \rho_{Z_T^*}, \rho_{Z_N^*}$	Beta	0.7	0.1
Demand shock persistence	$\rho_{G_T}, \rho_{G_N}, \rho_{G_T^*}, \rho_{G_N^*}$	Beta	0.7	0.1
Elasticity of subst. between T and N hours	γ	uniform	5.5	$9/\sqrt{12}$
Weight on L_T in CES	α	Normal	0.5	0.1

Table 2: Priors (α and γ are calibrated in the restricted model)

degree of habit persistence, I include b in the prior predictive analysis. Additionally, the responsiveness and persistence of the nominal interest rate exert significant influence on inflation dynamics and are thus given some range. In the unrestricted model version, I allow for imperfect intersectoral labour mobility by setting a uniform prior for the elasticity of substitution between hours supplied to the two sectors, γ , ranging from 1 (perfect labour mobility) to 10 (considerable degree of intersectoral immobility). The

prior for the weight of L_T in the CES aggregator, α , is set to a normal distribution with mean 0.5 and standard deviation 0.1.

3.3 Results

For the analysis, I generate 100000 draws from the prior distributions and compute impulse response functions at each draw. The following graphs display the mean response and 95% credible set for the computed prior impulse response functions given the priors reported in table 2. The analysis focuses on the response of the real exchange rate, the internal and external terms of trade, and price levels to a one standard deviation increase in traded sector technology. Note that for this exercise, I calibrate the traded sector technology shock persistence, ρ_{Z_T} , to 0.7.

To begin with, figure 1 displays the mean impulse response function and 95% credible sets for the restricted model (left) and unrestricted model (right) of the real exchange rate. In the restricted model, the change in the real exchange rate is undoubtedly positive, i.e.

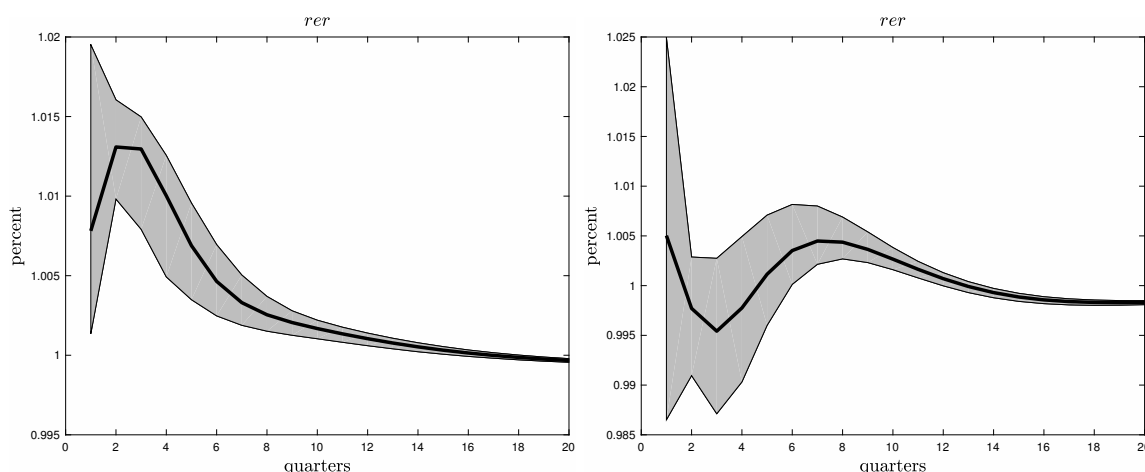


Figure 1: Prior mean impulse response functions and 95% credible sets for the real exchange rate in the restricted (left) and unrestricted model (right).

the domestic economy's price level decreases relative to the foreign economy's price level. The restricted model is not able to generate an appreciation, i.e. a fall in the real exchange rate at any time horizon following the productivity shock. The unrestricted model on the other hand delivers a more agnostic view. While the mean impulse response function shows an increase in the real exchange rate on impact the credible sets reveal the greater flexibility of the unrestricted model. Most importantly, the level of the real exchange rate can *fall* as well as increase in response to the traded sector technology shock at various

time horizons.

Figure 2 supports this finding by revealing that only the unrestricted model is able to produce an increase in the domestic aggregate price level. The finding that the restricted

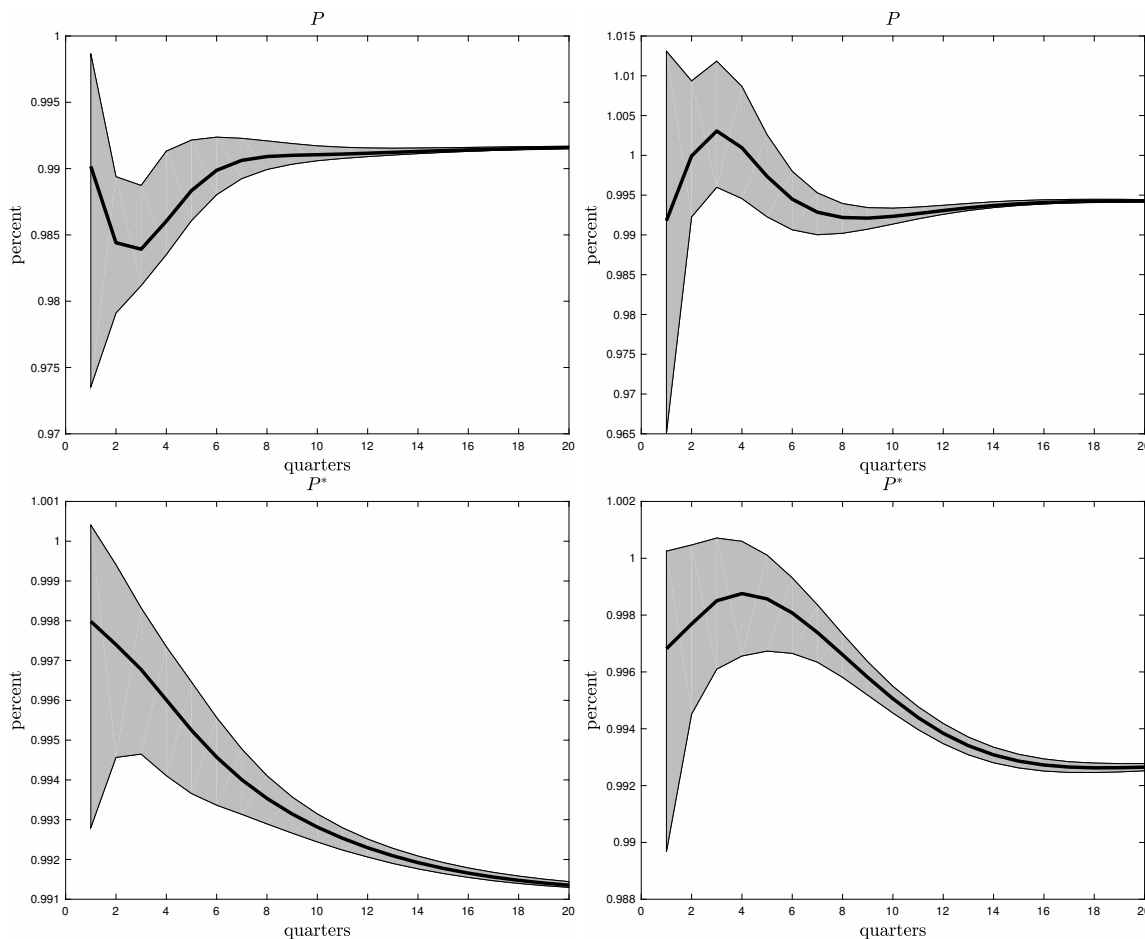


Figure 2: Prior mean impulse response functions and 95% credible sets for domestic and foreign final goods price levels in the restricted (left) and unrestricted model (right).

model assuming equal wages across sectors *forces* a depreciation of the real exchange rate via a fall in the domestic aggregate price level is at the core of this paper. When taken to the data, traded sector technology shocks could not explain an appreciation given the model's structure. Instead, the unrestricted model takes an unprejudiced stance on the effects of traded sector technology shocks on the real exchange rate. It remains to show whether the (potential) increase in the domestic price level in the unrestricted model can be caused by a mechanism à la Balassa-Samuelson, i.e. via a rise in the internal terms of trade due to higher prices for non-traded goods.

Figure 3 displays the responses of the external and domestic and foreign internal

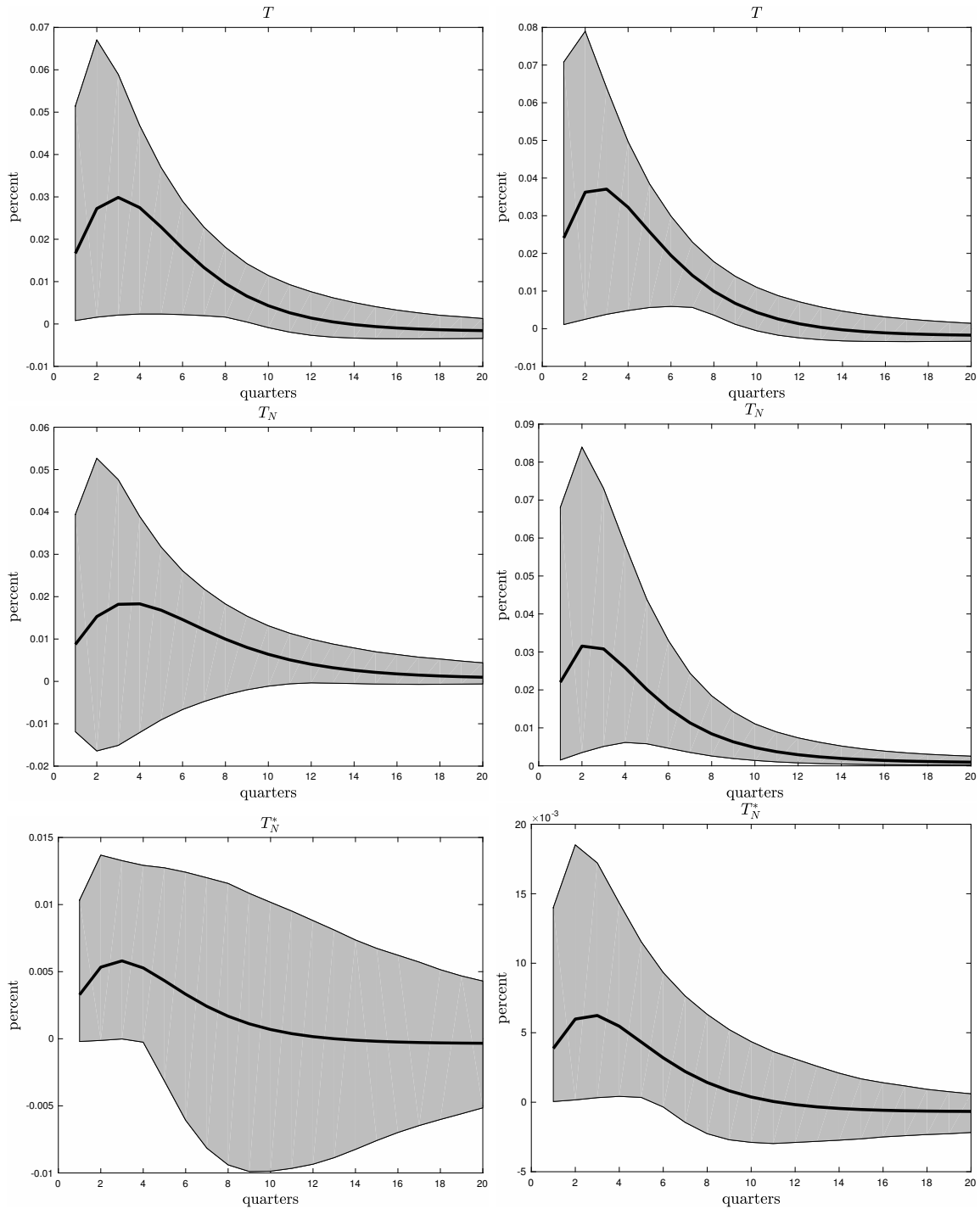


Figure 3: Prior mean impulse response functions and 95% credible sets for external T and domestic T_N and foreign T_N^* internal terms of trade in the restricted (left) and unrestricted model (right).

terms of trade to the traded sector technology shock.⁹ Both models posit an increase in

⁹ See figure 9 and 10 in the Appendix for *changes* in the external, domestic and foreign internal terms of trade and inflation rate responses.

external competitiveness, T , following the traded sector technology shock which supports a depreciation of the real exchange rate. In New-Keynesian models, firms set prices as a markup over marginal costs. As marginal costs in the traded sector decrease, firms seek to lower their prices. Irrespective of the specification of the labour market, domestic firms producing traded goods will lower their prices, P_H , so that the external terms of trade will unambiguously increase.

Similarly, the behaviour of foreign and domestic internal terms of trade, T_N and T_N^* , does not differ greatly across the restricted and unrestricted model. Domestic and foreign internal terms of trade increase though to a larger extent in the home economy supporting an appreciation of the real exchange rate. In the restricted model, the terms of trade effect largely outweighs the effect coming from the internal terms of trade explaining the definite depreciation of the real exchange rate. In the unrestricted model, the effect from the internal terms of trade is able to outweigh the rise in competitiveness permitting a depreciation of the real exchange rate.

Nevertheless, one has to notice that the rise in the internal terms of trade in both models is subject to distinct mechanisms. Inspecting price level responses of final traded and non-traded goods, P_T and P_N , displayed in figure 4 shows an unambiguous *fall* of non-traded goods prices in the restricted model. This is because of the common wage structure under perfect intersectoral labour mobility. In a New-Keynesian model an increase in technology leads undoubtedly to a fall in the labour demand of firms.¹⁰ In the specific example of a traded sector technology shock, firms in the traded sector reduce their labour demand which leads to a fall in the nominal wage paid in that sector. Under perfect labour mobility and equal sector wages, firms in the non-traded sector also pay lower wages, reducing their marginal costs and allowing them to lower their prices.

When labour is not perfectly mobile, sector wages differ and the effect works through demand. The fall in prices in the traded sector triggers a fall in the nominal interest rate that raises demand for goods, in particular non-traded goods. Accordingly, firms in the non-traded sector increase their labour demand which is accompanied by a rise in the wage paid in the non-traded sector. As marginal costs increase, firms in the non-traded sector will raise their prices. As a result, the unrestricted model that nests both labour market specifications delivers real exchange rate dynamics rich enough to enable the

¹⁰This also holds true when capital is explicitly modelled, hence the results in this paper are robust to the inclusion of capital.

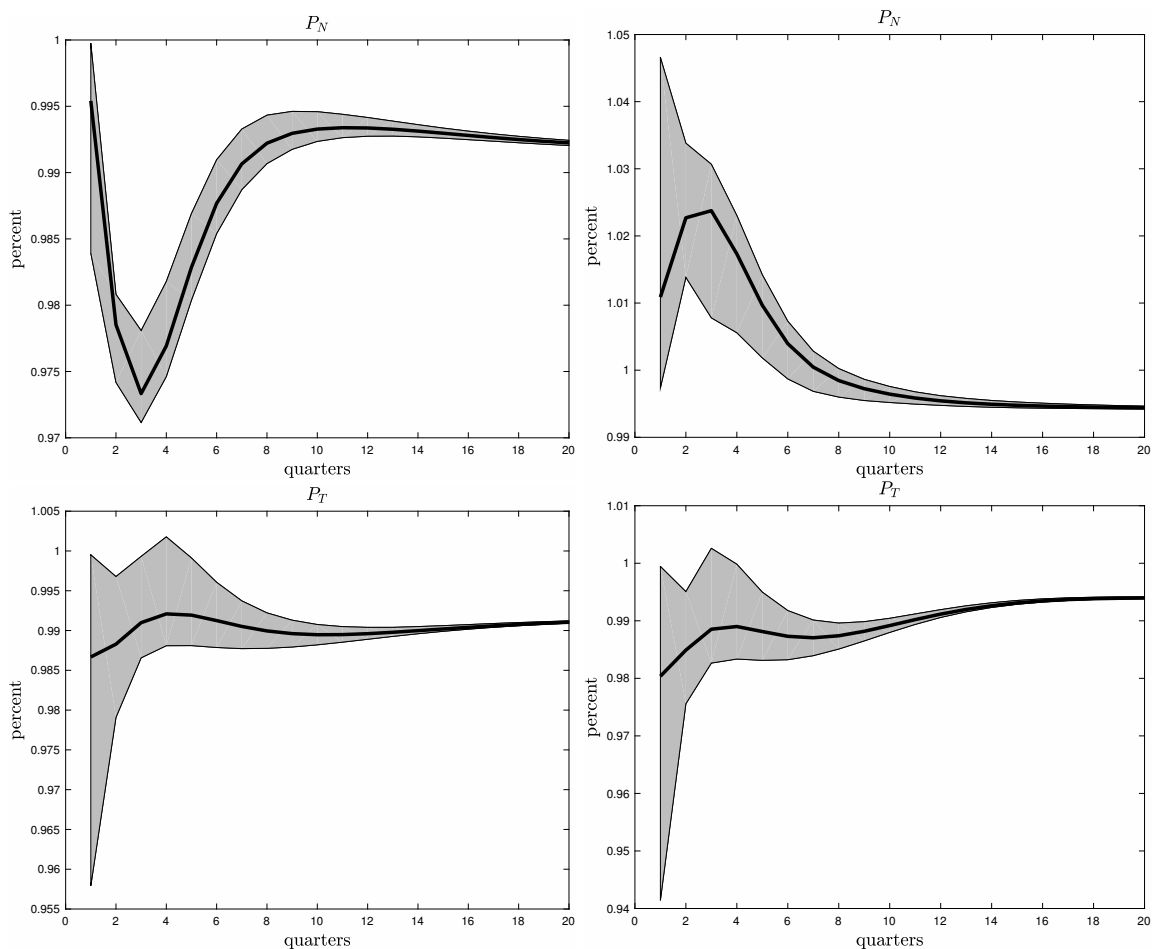


Figure 4: Prior mean impulse response functions and 95% credible sets for final traded and non-traded domestic and foreign goods price levels in the restricted (left) and unrestricted model (right).

model to reject or accept the Balassa-Samuelson hypothesis given the data.

I have shown that if one seeks to explain and dissect dynamics in the real exchange rate, specifically to identify a Balassa-Samuelson effect, one has to take an agnostic stance on the specification of the labour market when employing a New-Keynesian model. In particular, the assumption of perfect intersectoral labour mobility prevents a two-sector model of a two-country monetary union to replicate and thus identify a Balassa-Samuelson effect of higher prices in the non-traded sector due to higher productivity in the traded sector irrespective of the information contained in the data. The specification of $V(L_{T,t}, L_{N,t})$ and the estimation of the nesting parameters α and γ determining the degree of labour mobility across sectors facilitates testable restrictions in the context of a Bayesian estimation.

4 Robustness of the results

The results from the previous section have been computed for a home economy that is of equal relative size to the foreign economy ($n = 0.5$). With decreasing size falls the responsiveness of the Taylor rule of the common central bank to domestic inflation and vice versa. Given that the potential rise in non-traded goods prices under imperfect labour mobility is partly dependant on the response of the nominal interest rate it is necessary to assess the robustness of the results with respect to the size of the home economy.

4.1 Small economy in a monetary union

The country weights within the Euro area ranged from 0.1% (Malta) to 28.0% (Germany) in 2017.¹¹ I focus on the size of the smallest economy within the EMU to analyse the lower bound of the potential responses of the real exchange rate via non-traded goods prices posited by the model. The figures below repeat the prior predictive analysis given previous priors from table 2 but calibrating the size of the home economy to $1 - n = 0.001$.

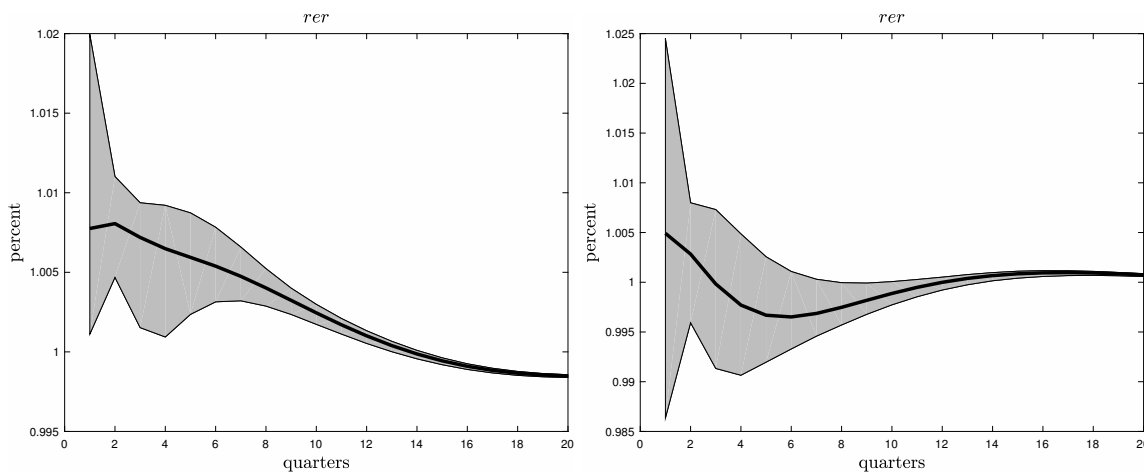


Figure 5: Prior mean impulse response functions and 95% credible sets for the real exchange rate in the restricted (left) and unrestricted model (right).

Figure 5 supports the previous finding that the restricted model is unfit to display an appreciation of the real exchange rate after a rise in traded sector productivity. The credible set of responses of the real exchange rate contains exclusively positive values. The

¹¹See figure 8 in the Appendix.

unrestricted model on the other hand continues to produce potential a- and depreciation dynamics as displayed by the relatively wide credible set containing positive and negative responses.

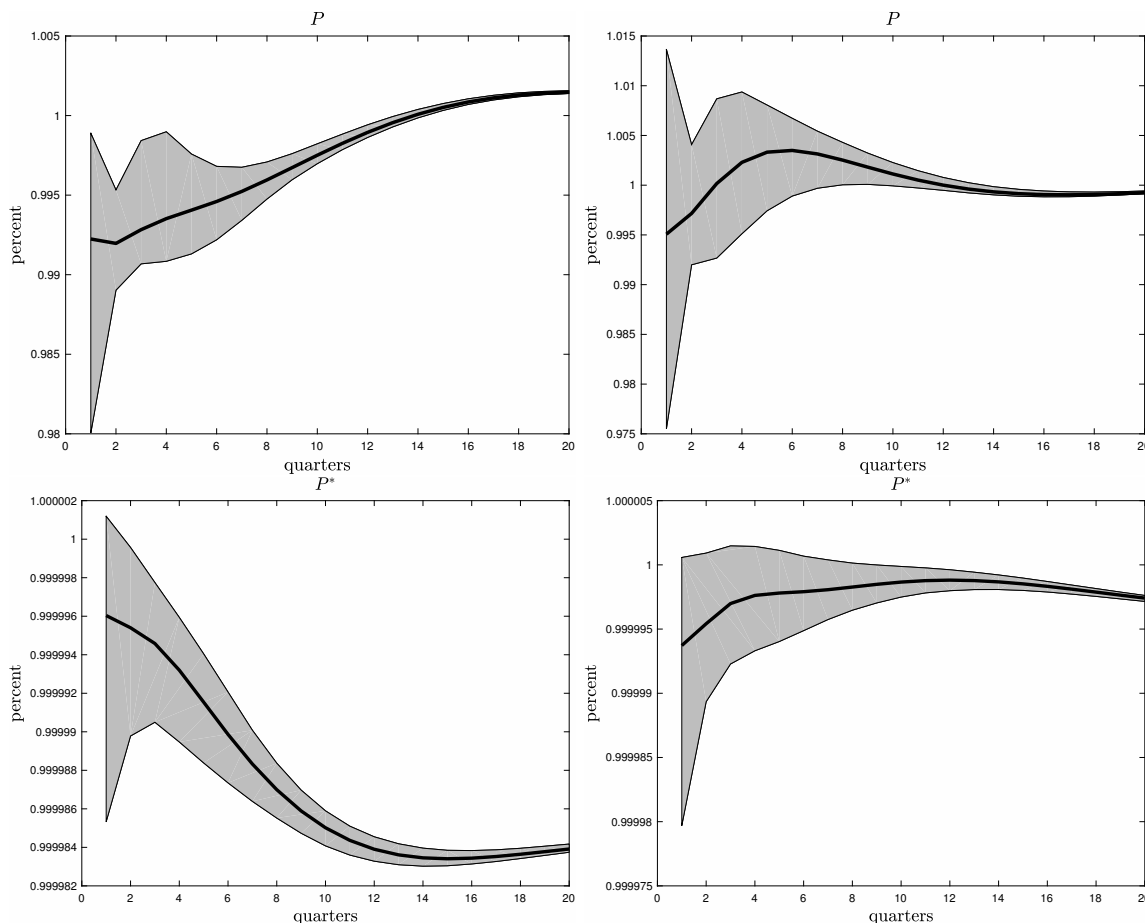


Figure 6: Prior mean impulse response functions and 95% credible sets for domestic and foreign final goods price levels in the restricted (left) and unrestricted model (right).

The responses of aggregate price levels, P and P^* , follow previously seen patterns as depicted in figure 6. The price level in the home economy will necessarily fall in the restricted model, explaining the categorical depreciation of the real exchange rate under perfect intersectoral labour mobility. As before, the possibility of imperfect intersectoral labour mobility endows the model to produce a rise in the domestic aggregate price level driving the potential appreciation of the real exchange rate.

Even when the home economy is small, the Balassa-Samuelson effect can still be replicated when allowing for imperfect intersectoral labour mobility. Importantly, figure 7 shows the potential rise in non-traded goods prices, P_N , in the unrestricted model, causing the rise in P and thus the appreciation of the real exchange rate. The dynamics

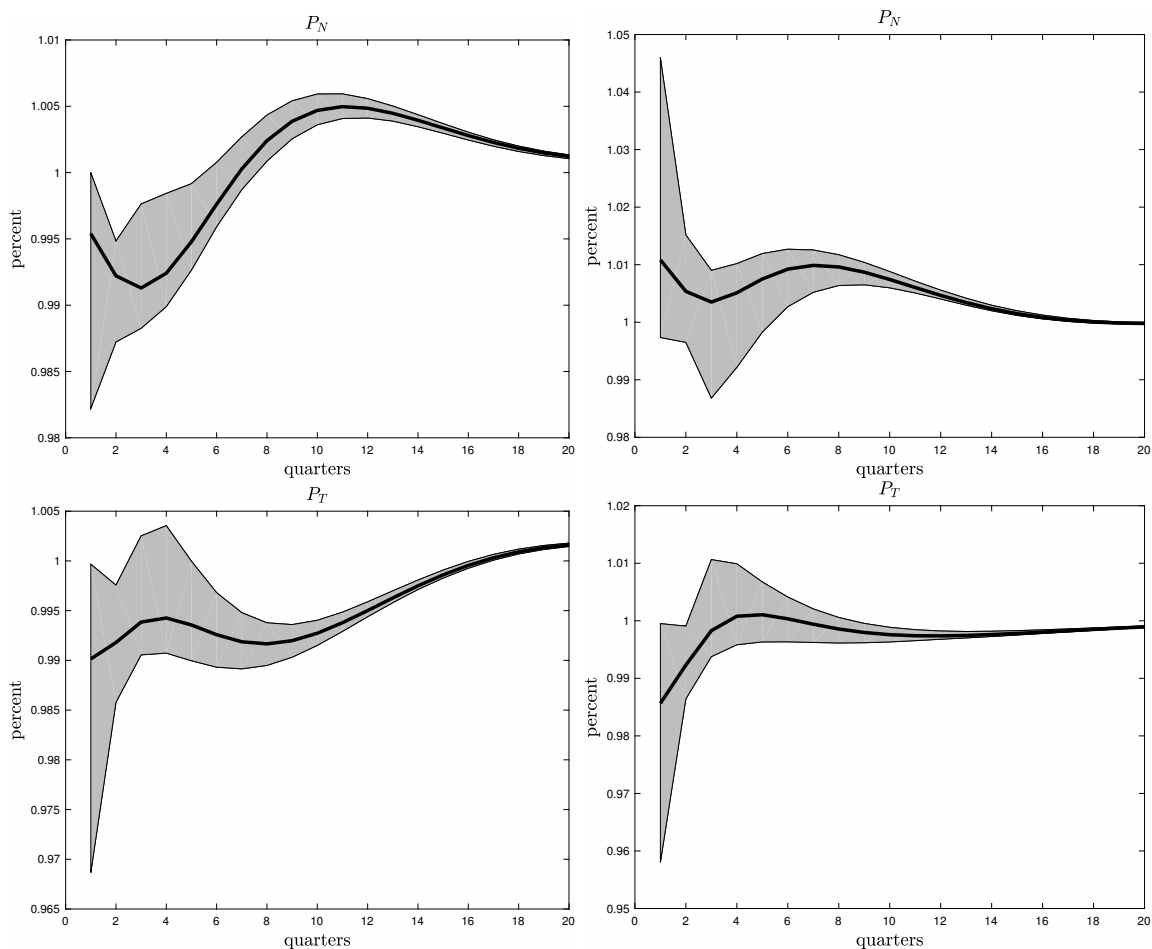


Figure 7: Prior mean impulse response functions and 95% credible sets for final traded and non-traded domestic and foreign goods price levels in the restricted (left) and unrestricted model (right).

of non-traded goods prices are a little richer in the restricted model when the economy is small. While in the short run, P_N will still undoubtedly fall, the model prescribes a rise in P_N after around 6-8 quarters. In the context of identifying a Balassa-Samuelson effect in a Bayesian estimation, those dynamics remain to be too restrictive though since the aggregate price level, P , in the restricted model remains unable to fall.

The results discussed in the model validation exercise in section 3 are robust to the size of the home economy, i.e. even when the home economy is small. The model can accept or reject the Balassa-Samuelson hypothesis given parameter estimates on α and γ determining the specification of the labour market.

5 Conclusion

I show that a New-Keynesian model of a monetary union might not be suited to test for the presence of a Balassa-Samuelson effect when decomposing real exchange rate dynamics. In particular the specification of the labour market plays the deciding role in determining the model's ability to robustly accept or reject the Balassa-Samuelson hypothesis. A model with perfect intersectoral labour mobility and thus equal sector wages will always reject the Balassa-Samuelson hypothesis. This is because in New-Keynesian models labour demand falls in response to productivity shocks. When traded sector productivity increases, firms in that sector lower their labour demand leading to a fall in the economy-wide wage. This causes marginal costs and hence prices to fall in the non-traded sector which contradicts the prescribed Balassa-Samuelson effect. Allowing for imperfect intersectoral labour mobility by employing the Horvath (2000) specification of the labour market delivers testable parameter restrictions for a Bayesian estimation of the model.

The results are robust to the size of the economy. That is, the established framework can be applied to various European economies. Countries of interest range from Spain, that experienced large and persistent inflation rates exceeding the EMU average especially after the introduction of the Euro to the new accession countries in Eastern Europe. Beside the Balassa-Samuelson effect, the presented model nests additional drivers of real exchange rates such as demand disturbances or varying inflationary processes via differences in price-setting across sectors and countries. Bayesian techniques allow a clear-cut decomposition of the contribution of each of those drivers to real exchange rate dynamics.

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Appendix

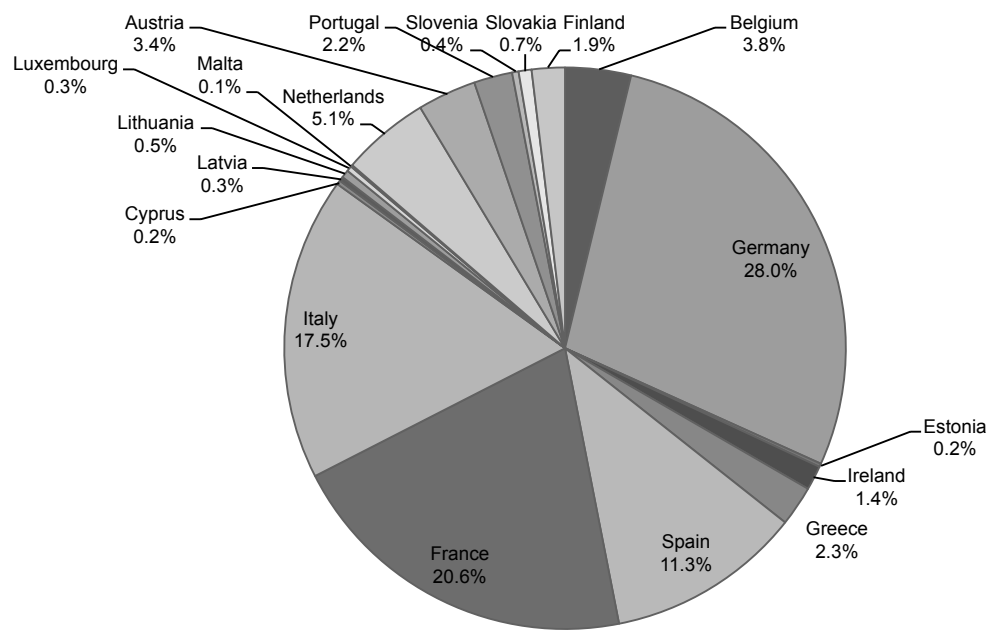


Figure 8: Country weights within the Euro Area in 2017.

Source: Eurostat.

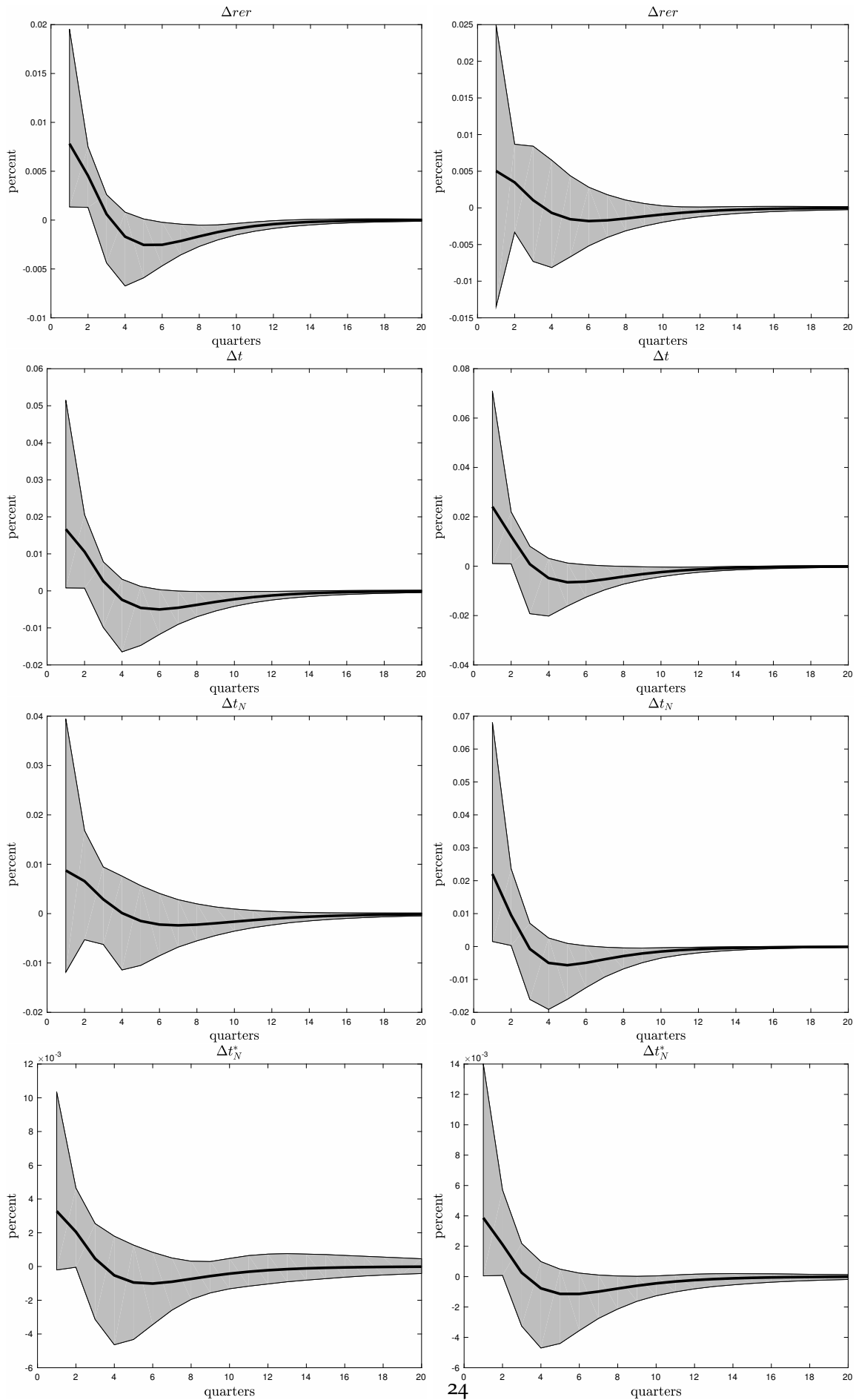


Figure 9: Prior mean impulse response functions and 95% credible sets for changes in the real exchange rate and terms of trade in the restricted (left) and unrestricted model

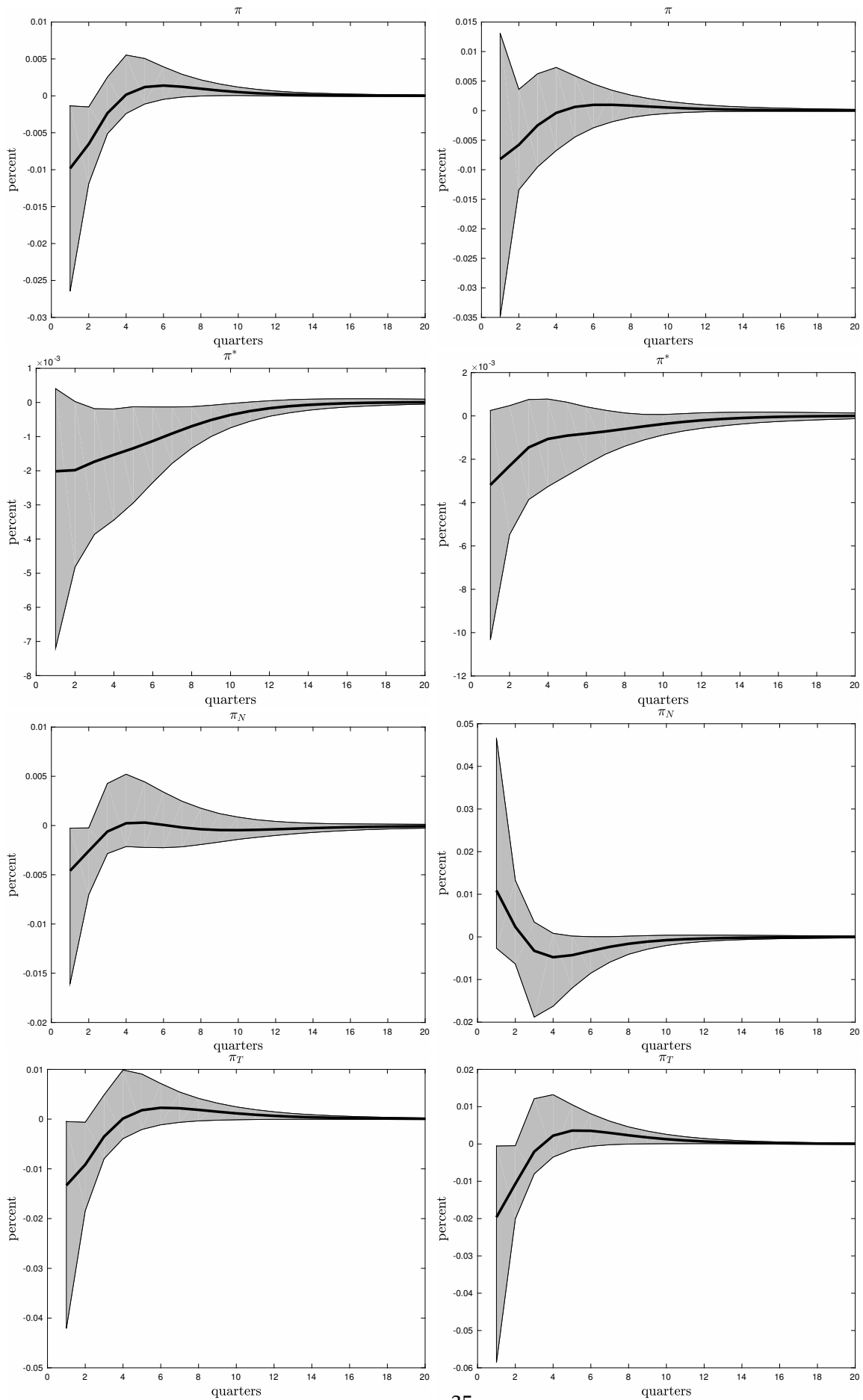


Figure 10: Prior mean impulse response functions and 95% credible sets for domestic and foreign goods price inflation rates in the restricted (left) and unrestricted model (right).