

INFLATION – THE HARROD-BALASSA-SAMUELSON EFFECT IN A DSGE MODEL SETTING

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ABSTRACT: *This paper sets up a two-country two-sector dynamic stochastic general equilibrium model that introduces sector specific productivity shocks with quality improvement mechanism of goods. It provides a model-based theoretical background for the Harrod-Balassa-Samuelson phenomenon that describes the relationship between productivity and price inflation within different sectors in a particular economy. Both, the calibrated and the estimated model are able to show that the Harrod-Balassa-Samuelson effect is confirmed by inducing tradable sector productivity shocks as they drive the non-tradable sector price inflation higher than the tradable sector price inflation. By doing this, we overcome the problem that the tradable productivity increase in a typical open economy specification reduces the relative price of domestic tradable goods relative to the foreign ones.*

Key words: *Harrod-Balassa-Samuelson effect, DSGE model, inflation, productivity, quality improvement*

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1 INTRODUCTION

The relationship between productivity and price inflation is described by the theory of the Harrod-Balassa-Samuelson phenomenon (henceforth HBS). Harrod (1933), Balassa (1964) and Samuelson (1964) independently developed and formulated the HBS productivity approach in order to explain the purchasing power parity². The HBS effect represents a tendency for countries that experience higher tradable-sector productivity growth compared to non-tradable sector productivity growth to have higher overall price levels (Obstfeld and Rogoff, 1996). In more detail, the basic idea behind it is that the growth in the productivity of a tradable sector influences the growth of wages in the tradable and later on in the non-tradable sector. Wage growth in the tradable sector consequently affects the growth of prices in the non-tradable sector. Depending on the nominal exchange rate regime of a particular economy, it affects the real exchange rate as well. However, Betts and Kehoe (2008) studied the relationship between the real exchange rate and the relative price of non-tradable to tradable goods. Their conclusion is that the relation between the

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² Baumol and Bowen (1967) developed a similar model that only describes the relationship between productivity and wages, and presents an important part of the HBS hypothesis, as discussed by Wagner and Hlouskova (2004).

two variables is stronger in an intense trade environment. Therefore, the basic assumption is that the relationship between the relative growth in the productivities of the tradable to non-tradable sector and the relative price of non-tradable to tradable goods is relatively straightforward if we include sectoral data for European countries, for example. In addition to the close trade environment, the sole Euro area integration process suppresses the ability of economies to adjust through the nominal exchange rate channel, which could consequently put more pressure on non-tradable price inflation.

The HBS hypothesis can be tested on different entities, which in general represent countries, regions, or in many cases, sectors. In our case, we divide these entities into a tradable sector and a non-tradable sector; we use a similar principle as the De Gregorio, Giovannini, and Wolf's (1994) methodology by using the ratio of exports to total production to define both sectors. In order to do that we include and combine the NACE Revision 2 10-sector breakdown statistical classification time series data of economic activities, which provides data on labour productivity and price levels across the two sectors, and the ratio of exports to total production data calculated from the input-output tables, which are available at the World Input-Output Database (WIOD)³. By obtaining the relevant tradable and non-tradable data for further analysis and adding other observable macroeconomic data, we estimate the constructed DSGE model.

The problem of permanent tradable productivity increase in a typical dynamic open economy specification is reducing the relative price of domestic tradable goods relative to the foreign ones. This implies worsening the terms of trade for the domestic economy and consequently, its real exchange does not increase. These dynamics are not consistent with empirical evidence found for the new European Union member states. The main contribution of the paper is to overcome the typical dynamic open economy setting by constructing and estimating a two-country two-sector DSGE model with the quality improvement extension, proposed by Masten (2008), in a smaller calibrated version of a dynamic model. The basic assumption is therefore the separation of the economy into a tradable and a non-tradable sector. The tradable sector is open and allows domestic goods to be exported and foreign goods to be imported, whereas the non-tradable sector is closed to foreign markets (a similar structure was used by Masten, 2008; Rabanal, 2009; Micaleff and Cyrus, 2013). The assumption is that the tradable and non-tradable sectors are exposed to different productivity shocks; this means that non-stationary real variables can grow at a different pace, thus providing a case for the HBS effect. In specifying technology, we allow a quality improvement mechanism, which is needed to replicate the appreciation of prices, without resorting to the unrealistic assumption of perfect competition in the tradable sector (Masten, 2008).

We find evidence for the HBS effect, based on an augmented technology process that considers a quality improvement mechanism, which affects marginal costs by requiring

³ In defining the tradable and the non-tradable sector we differ from the standard approach used in the literature by excluding the not distinctively tradable or non-tradable sectors from the analysis.

the use of more advanced inputs in the production process. The quality improvement of goods overcomes the typical open economy theoretical specification that reduces the relative prices of domestic tradable goods relative to foreign prices, and consequently worsens the terms of trade for the domestic economy. By introducing a sector-specific domestic tradable technology shock, the modelled economy responds by increasing price differential of non-tradable relative to tradable prices and the overall domestic inflation. Doing this we are able to theoretically explain why the economies with higher economic and productivity growth during the catching-up phase experienced higher inflation.

In Section 2, a review of the HBS related literature is presented and discussed. Section 3 provides a theoretical framework for the DSGE model. In section 4, the classification and definition of economic activities into a tradable and a non-tradable sector is presented, obtaining sectoral price indices and time series of sectoral labour productivity growths. The calibrated model is presented in Section 5, while the estimation results of the DSGE model are given and discussed in Section 6. Section 7 presents the conclusions.

2 LITERATURE REVIEW

Despite treating the HBS theory as an old idea, in which the sectoral productivity differential is seen as the driver for price inflation in the non-tradable sector (Harrod, 1933; Balassa, 1964; and Samuelson, 1964), the empirical testing of the HBS effect only became more popular in recent years as econometric methods advanced and new (or additional) time series data became available. This availability was largely due to the establishment of the EU and later on its enlargement process, together with advances and convergence of methodologies in collecting data by the national statistical offices. At the same time, addressing the HBS issue became relevant from the economic policy perspective trying to identify the different sources of (structural) inflation. Betts and Kehoe (2008) show that a close trade environment lowers the significance of the nominal exchange rate adjustment. This was (and can still be) especially important for the future EU and euro area countries, which are obliged to satisfy the Maastricht criterion of low and stable inflation, as well as for other emerging economies in trying to stabilise their overall inflation.

In their comprehensive survey, Tica and Družić (2006) gather empirical evidence regarding the HBS effect. They point out that most of the empirical work supports the HBS effect. Especially strong evidence comes from the work based on cross-section empirical studies, similar to Balassa's (1964) work. A large number of papers focus on studying the magnitude of the HBS effect in accession countries in the EU. Čihák and Holub (2001) for instance study the presence of the HBS effect in the Czech Republic *vis-à-vis* EU countries, while allowing for differences in structures of relative prices. Jazbec (2002) considers Slovenia as the HBS case of an accession country, while Dedu and Dumitrescu (2010) test the HBS effect using Romanian data. Papers by Cipriani (2000), Coricelli, and Jazbec (2004), Halpern and Wyplosz (2001), Arratibel, Rodríguez-Palenzuela, and Thimann (2002), Breuss (2003), Wagner and Hlouskova (2004), Mihaljek and Klau (2008) consider

a larger accession country panel. Some of the work focuses also on emerging economies. Jabeen, Malik, and Haider (2011) test the HBS hypothesis on Pakistani data, while Guo and Hall (2010) test the HBS effect on Chinese regional data.

These empirical strands of the HBS effect related literature opened up new questions regarding data issues and were related mostly to availability in reliability of sectoral data. As databases, especially in Europe, became more complete, new available data enabled studying the HBS effect between individual tradable and non-tradable sectors of a particular economy. Since it is difficult to clearly divide tradable and non-tradable commodities in the real world, some of the early papers tried to identify the tradability/non-tradability of commodities. Officer (1976) proposed that manufacturing and/or industry combine a tradable sector, while the services represent the non-tradable sector. De Gregorio, Giovannini, and Wolf (1994) used a ratio of exports to total production of each sector to define both sectors.

In empirical studies, mostly total factor productivity (TFP) or average productivity of labour are used. Marston (1987), De Gregorio, Giovannini, and Wolf (1994), De Gregorio and Wolf (1994), Chinn and Johnston, (1997), Halikias, Swagel, and Allan (1999), Kakkar (2002), and Lojshová (2003) use total factor productivity as a productivity proxy, while due to the lack of data on TFP, many others, i.e., Coricelli and Jazbec (2004) and Žumer (2002), use average productivity of labour. Comparing total factor productivity and average productivity of labour, the argument against the use of average productivity of labour is that it is not completely clear if average labour productivity should be regarded as a reliable indicator for representing a sustainable productivity growth, which has a long-term effect on the economy (De Gregorio and Wolf, 1994). However, according to Canzoneri, Cumby, and Diba (1999), the argument against TFP is that TFP is a result of a possibly unreliable data collection of sectoral capital stocks comparing to data collection of sectoral employment and sectoral gross value added, especially in the case of the shorter-term series. Sargent and Rodriguez (2000) also conclude that if the intent of the research is to examine trends in the economy over a period of less than a decade or so, labour productivity would be a better measure than total factor productivity. According to Kovács (2002), another setback of using TFP is that during the catching-up phase the capital accumulation intensifies faster in the transition/accession countries than in the developed countries, due to the lower starting point in fundamentals of transition/accession countries. Therefore, the HBS effect might be overestimated. Listing some of the arguments against using TFP, we rather include the average labour productivity as a productivity proxy in the model.

Comparing to the vast HBS literature in the 2000s in the accession process of the countries to the EU and the monetary union, less theoretical work was done with regards to the HBS effect in more structural and more complex models. Rogoff (1992) was the first to implement a general equilibrium framework, introducing the demand side of the economy within the HBS theory. This opened the possibility to further investigate the effects of relative productivities of production factors and the effects of the demand side of the economy on price levels. For instance, Mihaljek and Klau (2002) conclude that the

HBS effect could have important policy implications for the EU accession countries in order to satisfy the Maastricht inflation criterion. To further investigate Mihaljek's point, Masten (2008) constructs a two-sector DSGE model to see whether the HBS effect could represent an issue in satisfying the Maastricht inflation criterion. Further on, Natalucci and Ravenna (2002) compare the magnitude of the HBS effect within different exchange rate regimes in the general equilibrium model, while Restout (2009) allows for varying mark-ups in its general equilibrium framework. However, Asea and Mendoza (1994) conclude that the proof of the HBS theory within the framework of general equilibrium cannot reliably assess the relationship between output per capita and domestic relative prices. In other words, conclusions regarding the HBS theory from cross-country analyses can only be conditionally accepted since it is difficult to account for cross-country trend deviations from purchasing power parity (PPP). Even more, Bergin, Glick, and Taylor (2004) show that the relationship between output per capita and domestic relative prices had historically oscillated too much for the HBS theory to be proved by cross-section empirical studies. In order to test the HBS theory their suggestion is that it should be tested with a sector-specific analysis.

Following the general equilibrium strand of the HBS related literature, Rabanal (2009) offers three explanations for studying sectoral inflation dynamics in Spain in a DSGE model structure. The first explanation relates to the role of productivity growth differentials, which directly brings the possibility to study the HBS effect. Altissimo et al. (2005) introduced a seminal paper on productivity growth differentials in a DSGE model setting. The second explanation adds the role of the demand-side effects in shaping the inflation dynamics (López-Salido et al., 2005). The third explanation suggests that, due to different product and labor market structures, there is heterogeneity of inflation dynamics processes in each country of the union (Angeloni and Ehrmann, 2007; Andrés et al., 2003). Rabanal (2009) concludes that even when economies are hit by symmetric external shocks, such as for example oil prices, world demand, or nominal exchange rate, the response of sectoral inflation will be different across countries. The Rabanal's model was adopted by Micaleff and Cyrus (2013) as well. They analyse the relative importance of the three main determinants of inflation differentials in Malta. Based on these considerations, a structured theoretical framework is presented in the following section.

3 MODEL

In this section, we present the theoretical framework for the two-country two-sector DGSE model. The DSGE framework follows the Rabanal (2009) model, but the main contribution of the theoretical model is its extension for sectoral wage rigidities, thus making the model more realistic. Additionally, we introduce an augmented technology process with quality improvement (Masten, 2008). In order to investigate the HBS effect phenomenon, different sectoral productivity shocks have to be introduced providing asymmetry between sectors. The monetary union is made of two economies; a domestic and a foreign country with the common monetary policy rule. They are indexed on intervals $[0, s]$ and $[s, 1]$, respectively, where s denotes the size of the domestic country with

respect to the two-country universe. In our case, we relate to Slovenia and the rest of the euro area. The following section only gives a structural domestic economy description since the foreign economy block is analogous to the domestic economy, which is in our case Slovenia.

3.1 Households

The assumption is that the representative household maximizes its utility function, given by

$$E_0 \sum_{t=0}^{\infty} \beta^t = \left[\ln(C_t(i) - hC_{t-1}(i)) - \frac{L_t(i)^{1+\varpi}}{1+\varpi} \right] \quad , \quad (1)$$

where $C_t(i)$ and $L_t(i)$ present consumption and quantity of work effort of a particular household. The parameter $0 < \beta < 1$ is the discount factor of household. We assume that households value the current consumption more than the future one. The parameter $0 < \varpi < \infty$ is the inverse of the elasticity of work effort with respect to the real wage (Frisch elasticity parameter). We assume consumption habits as well, which is represented by the parameter $0 < h < 1$.

The consumption index $C_t(i)$ is defined by the constant elasticity of substitution (CES) function between tradable and non-tradable goods and holds for all households, so that $C_t(i) = C_t^A$

$$C_t = \left[(\omega_{TN})^{\frac{1}{v_{TN}}} (C_t^T)^{\frac{v_{TN}-1}{v_{TN}}} + (1 - \omega_{TN})^{\frac{1}{v_{TN}}} (C_t^N)^{\frac{v_{TN}-1}{v_{TN}}} \right]^{\frac{v_{TN}}{v_{TN}-1}} \quad , \quad (2)$$

where the parameter ω_{TN} presents the share of the tradable goods in the aggregate consumption basket. The parameter $v_{TN} > 1$ presents the elasticity of substitution between tradable and non-tradable goods.

Since the demand for tradable goods is not dependent only on domestic goods but foreign as well, the index of the tradable consumption good is written analogously to the equation (3) with which the aggregate consumption index is defined

$$C_t^T = \left[(\omega_{HF})^{\frac{1}{v_{HF}}} (C_t^H)^{\frac{v_{HF}-1}{v_{HF}}} + (1 - \omega_{HF})^{\frac{1}{v_{HF}}} (C_t^F)^{\frac{v_{HF}-1}{v_{HF}}} \right]^{\frac{v_{HF}}{v_{HF}-1}} \quad , \quad (3)$$

4 We scale the variables in the model with $Z_t^C = (Z_t^T)^{\omega_{TN}} (Z_t^N)^{(1-\omega_{TN})}$ so that the variables enter the model detrended, for example, $c_t = \tilde{c}_t / Z_t^C$. The scaling variable Z_t^C ensures a constant steady-state level of utility and is determined by productivity dynamics (Masten, 2008).

where ω_{HF} represents the share of domestic tradable goods in the tradable consumption basket. The parameter $\nu_{HF} > 1$ is therefore the elasticity of substitution between domestic tradable goods and tradable goods produced abroad.

The indexes of individual goods are defined by the following equations and represent a continuum of differenced goods of the same type

$$C_t^H \equiv \left[\int_0^S c_t^H(h)^{\frac{\nu-1}{\nu}} dh \right]^{\frac{\nu}{\nu-1}} \quad (4)$$

$$C_t^F \equiv \left[\int_S^1 c_t^F(f)^{\frac{\nu-1}{\nu}} df \right]^{\frac{\nu}{\nu-1}} \quad (5)$$

and

$$C_t^N \equiv \left[\int_0^S c_t^N(n)^{\frac{\nu-1}{\nu}} dn \right]^{\frac{\nu}{\nu-1}}. \quad (6)$$

The parameter $\nu > 1$ denotes the elasticity of substitution within one type of differentiated goods: c_t^H , c_t^F and c_t^N . The same principle can be applied to price indexes. The aggregate price index P_t is then given by

$$P_t = [\omega_{TN}(P_t^T)^{1-\nu_{TN}} + (1 - \omega_{TN})(P_t^N)^{1-\nu_{TN}}]^{\frac{1}{1-\nu_{TN}}}. \quad (7)$$

As above, the price index for tradable goods is given by

$$P_t^T = [\omega_{HF}(P_t^H)^{1-\nu_{HF}} + (1 - \omega_{HF})(P_t^F)^{1-\nu_{HF}}]^{\frac{1}{1-\nu_{HF}}} \quad (8)$$

Households have a set of contingent riskless euro area bonds B_t^{EA} at their disposal that pay one unit of currency in every possible state of nature in $t+1$. The assumption is that households can trade these bonds that pay a gross interest rate of R_t^{EA} . Since households are *ex ante* identical, they face the same budget constraint in each period:

$$\frac{B_t^{EA}}{P_t Z_t R_t^{EA}} \leq \frac{B_{t-1}^{EA}}{Z_t P_t} + W_t L_t - C_t + \zeta_t \quad (9)$$

where W_t represents the real wage, while ζ_t represents other income sources of households. As shown in Chari, Kehoe, and McGrattan (2002), the real exchange rate is given by

$$RER_t = \frac{P_t^*}{P_t} = \frac{\mu_t^*}{\mu_t}, \quad (10)$$

where the variables μ_t and μ_t^* represent the marginal utilities of domestic and foreign consumption, respectively.

Labour market is, in comparison to the Rabanal (2009) model, differentiated, thus provides a more realistic model assumption. Further on, the aggregation of work effort of both sectors (i.e., tradable and non-tradable) holds

$$L_t = L_t^T + L_t^N \quad . \quad (11)$$

Against this backdrop, each household working in the tradable or the non-tradable sector sets its own wage (Erceg et al., 2000; Christiano et al., 2005). Firms aggregate the differentiated supply of labour by transforming it into a homogenous input of labour L_t^j , where $j=N, T$, in accordance with the Dixit-Stiglitz (1977) aggregator

$$L_t^j = \left[\int_0^1 L_t^j(i) \frac{v_{L,j}^{-1}}{v_{L,j}} di \right]^{\frac{v_{L,j}}{v_{L,j}-1}} \quad . \quad (12)$$

The parameter $v_{L,j}$ is defined as the wage elasticity within different varieties of labour services in a particular sector, where $j=N, T$. Based on that the labour demand function for a particular is given by

$$L_t^j(i) = \left[\frac{W_t^j(i)}{W_t^j} \right]^{-v_{L,j}} L_t^j \quad . \quad (13)$$

Combining equations (12) and (13) we get the aggregate wage, which is obtained from differentiated labour

$$W_t^j = \left[\int_0^1 W_t^j(i)^{1-v_{L,j}} di \right]^{\frac{1}{1-v_{L,j}}} \quad . \quad (14)$$

In order to introduce wage frictions in the model, we apply the Calvo (1983) principle. Each household has monopolistic power over the setting of its wage $W_t^j(i)$, where $j=N, T$. Yet not all the households can set their optimal wage at any point of time, but only a fraction of households $(1-\alpha_{L,j})$, where the Calvo parameter is defined on the interval $0 < \alpha_{L,j} < 1$. The other part of households $(\alpha_{L,j})$ indexate their wage according to inflation target and current inflation. The wage inflation of a non-optimizing household is then given by

$$W_{t+k}^j(i) = \prod_{n=1}^k \left(\frac{P_{t+n-1}}{P_{t-1}} \right)^{\varphi_{L,j}} \Pi^{1-\varphi_{L,j}} W_t^j(i) \quad , \quad (15)$$

where the parameter $0 < \varphi_{L,j} < 1$ stands for the degree of wage indexation with respect to inflation target and current inflation, where $j=N, T$.

When reoptimizing their wage in period t , workers of a particular sector choose an optimal wage $W_t^{j,opt}$ in order to maximize household utility as opposed to their individual utility, where $j=N, T$. The utility is subject to a sequence of iso-elastic demand schedules for their labour type, and the usual sequence of household flow budget constraints. The first order condition associated with that problem can be written as

$$E_t \sum_{k=0}^{\infty} (\alpha_{L,j})^k \Lambda_{t,t+k} \times \left[\left(\frac{W_t^{j,opt} \left(\frac{P_{t+k-1}}{P_{t-1}} \right)^{\varphi_{L,j}} \Pi^{k(1-\varphi_{L,j})} - (C_{t+k} - hC_{t+k-1}) (L_{t+k}^j(i))^{\omega}}{P_{t+k}} \right) L_{t+k}^j(i) \right], \quad (16)$$

where the expression $\Lambda_{t,t+k} = \beta^k \lambda_{t+k} / \lambda^t$ represents the stochastic discount factor. The wage dynamics should therefore be

$$W_t^j \equiv [\alpha_{L,j} (W_{t-1}^j (\Pi_{t-1})^{\varphi_{L,j}} (\Pi_T)^{1-\varphi_{L,j}})^{1-\nu_{L,j}} + (1 - \alpha_{L,j}) (W_t^{j,opt})^{1-\nu_{L,j}}]^{\frac{1}{1-\nu_{L,j}}}, \quad (17)$$

where $j=N, T$. The average wage on an economy scale is then given by $W_t = (W_t^T)^{\omega_{TN}} (W_t^N)^{1-\omega_{TN}}$.

3.2 Firms

On the supply side, there are three types of firms, producing two types of tradable goods (indexed by H, H^*) and domestic non-tradable goods (indexed by N). Each type of firm is facing price rigidities (Calvo, 1983). That means that only a fraction of firms $(1-\alpha_i)$, where $i=N, H, H^*$, can set their optimal price. Other firms (α_i) , where $i=N, H, H^*$, index their prices according to the inflation target and current inflation based on the parameter $0 < \varphi_i < 1$, where $i=N, H, H^*$, which stands for the degree of price indexation with respect to inflation target and current inflation.

Domestic and foreign economies are facing the same deterministic technology process, providing a case for output growth. This means that all the real variables entering the model are non-stationary in levels, but stationary in first differences.

3.2.1 Tradable sector

In the tradable sector there are two types of firms. One type of firm produces tradable goods for the domestic market and tries to satisfy domestic consumption of tradable

goods, C_t^H . The other type of firm produces tradable goods meant for export and tries to satisfy the foreign consumption of domestic goods, $C_t^{H,*}$. Each firm in the tradable sector follows the Cobb-Douglas production function, where work effort is the only production factor

$$y_t^H(h) = A_t^T L_t^{T,H}(h) \quad (18)$$

and

$$y_t^{H,*}(f) = A_t^T L_t^{T,H,*}(f) \quad (19)$$

The variable A_t^T is a sector-specific productivity process that is characterised by quality improvement of higher-quality goods in the tradable sector index $\chi_t = (Z_t^T)^{\theta_Z}$ with quality improvement parameter $\theta_Z > 0$ (Masten, 2008), so that

$$\ln A_t^T = \ln Z_t^T - \ln \chi_t \quad (20)$$

The variable χ_t represents a quality improvement of goods index that influences wages and marginal costs via positive productivity shocks. Masten (2008) finds that the problem of permanent tradable productivity improvement in a typical open economy specification reduces the relative price of domestic tradable goods relative to the foreign ones, thus worsens the terms of trade. Consequently, the real exchange does not increase and is not consistent with empirical evidence based on the new European Union member states. On the other hand, introducing quality improvement of higher-quality goods may require the use of more advanced inputs in the production process and will consequently increase the marginal costs and product prices. Sallekaris and Vijselaar (2004) introduce a similar mechanism, as they adjust capital with a simple quality correction.⁵

The variable Z_t^T represents a tradable sector productivity shock, which is country-specific

$$Z_t^T = \rho_{Z,T} \ln Z_{t-1}^T + \varepsilon_t^Z + \varepsilon_t^{Z,T} \quad (21)$$

We assume that productivity shocks of both sectors can be different and that their growth rates could be different. We let the tradable productivity process Z_t^T to be affected by two different productivity innovations $\varepsilon_t^{Z,T}$, which are country and sector specific, and ε_t^Z , which represents a euro-area wide innovation. For the labour supply it holds $L_t^T = L_t^{T,H} + L_t^{T,H,*}$.

⁵ The idea of adjusting prices with quality improvements goes back into the 90s, as the study of Gordon (1990) tried to empirically document these biases. Later research focused on constructing quality-adjusted price indexes (Hulten, 1992; Greenwood et al., 1997; Cummins and Violante, 2002), production based estimates (Bahk and Gort, 1993), and capital model (Hobijn, 2000).

Tradable sector firms producing domestic goods for the domestic market maximize their profits according to

$$E_t \sum_{k=0}^{\infty} \alpha_H^k \Lambda_{t,t+k} \left[\frac{P_t^{H,opt}(h) \left(\frac{P_{t+k}^H}{P_{t-1}^H} \right)^{\varphi_H} (\Pi_H)^{k(1-\varphi_H)} - MC_{t+k}^T}{P_{t+k}} y_{t+k}^{H,d}(h) \right] \quad (22)$$

subject to

$$y_{t+k}^{H,d}(h) = \left[\frac{P_t^{H,opt}(h) \left(\frac{P_{t+k}^H}{P_{t-1}^H} \right)^{\varphi_H} (\Pi_H)^{k(1-\varphi_H)}}{P_{t+k}} \right]^{-\nu} Y_{t+k}^H, \quad (23)$$

where the expression $\Lambda_{t,t+k} = \beta^k \lambda_{t+k} / \lambda_t$ represents the stochastic discount factor, and $y_{t+k}^{H,d}(h)$ is the tradable goods demand of a firm in time $t+k$. Y_t^H is the aggregate domestic-made tradable goods demand.

Similarly, we can write the maximization profit function for tradable sector firms producing domestic goods for the foreign market

$$E_t \sum_{k=0}^{\infty} \alpha_{H,*}^k \Lambda_{t,t+k} \left[\frac{P_t^{H*,opt}(h) \left(\frac{P_{t+k}^{H,*}}{P_{t-1}^{H,*}} \right)^{\varphi_{H,*}} (\Pi_{H,*})^{k(1-\varphi_{H,*})} - MC_{t+k}^T}{P_{t+k}} y_{t+k}^{H*,d}(f) \right] \quad (24)$$

subject to

$$y_{t+k}^{H*,d}(f) = \left[\frac{P_t^{H*,opt}(h) \left(\frac{P_{t+k}^{H,*}}{P_{t-1}^{H,*}} \right)^{\varphi_{H,*}} (\Pi_{H,*})^{k(1-\varphi_{H,*})}}{P_{t+k}} \right]^{-\nu} Y_{t+k}^{H,*}, \quad (25)$$

where the expression $\Lambda_{t,t+k} = \beta^k \lambda_{t+k} / \lambda_t$ represents the stochastic discount factor, and $y_{t+k}^{H*,d}(h)$ is the tradable goods demand of a firm in time $t+k$. $Y_t^{H,*}$ is the aggregate domestic tradable goods demand from abroad.

Real marginal costs in the tradable sector for both types of firms are defined as MC_t^T . Marginal costs are defined as the real wage normalized for augmented productivity

$$MC_t^T = \frac{w_t^T}{A_t^T}. \quad (26)$$

Both types of tradable sector firms maximize their profit with respect to prices p_t^H (h) and $p_t^{H,*}$ (f) and demands $y_{t+k}^{H,d}(h)$ and $y_{t+k}^{H,*d}(f)$, respectively. The tradable price dynamics of domestic produced goods for the domestic market is

$$P_t^H \equiv \left[\alpha_H (P_{t-1}^H (\Pi_{t-1}^H)^{\varphi_H} (\Pi_H)^{1-\varphi_H})^{1-\nu} + (1 - \alpha_H) (P_t^{H,opt})^{1-\nu} \right]^{\frac{1}{1-\nu}}, \quad (27)$$

where $P_t^{H,opt}$ is the optimal price and $\Pi_{t-1}^H = P_{t-1}^H / P_{t-2}^H$. The tradable price dynamics of domestic goods for the foreign market is

$$P_t^{H,*} \equiv \left[\alpha_{H,*} \left(P_{t-1}^{H,*} (\Pi_{t-1}^{H,*})^{\varphi_{H,*}} (\Pi_{H,*})^{1-\varphi_{H,*}} \right)^{1-\nu} + (1 - \alpha_{H,*}) (P_t^{H*,opt})^{1-\nu} \right]^{\frac{1}{1-\nu}}, \quad (28)$$

where $P_t^{H*,opt}$ is the optimal price and $\Pi_{t-1}^{H,*} = P_{t-1}^{H,*} / P_{t-2}^{H,*}$.

3.2.2 Non-tradable sector

Analogously to the tradable sector, each non-tradable sector firm follows the Cobb-Douglas production function, where work effort is the only production factor

$$y_t^N(n) = A_t^N L_t^N(n) \quad . \quad (29)$$

The variable A_t^N is a sector-specific productivity process that is characterised by quality improvement index $\chi_t = (Z_t^N)^{\theta_Z}$ so that

$$\ln A_t^N = \ln Z_t^N - \ln \chi_t \quad . \quad (30)$$

In this respect, we assume that the sector-specific productivity process A_t^N is affected by quality improvement of goods χ^t in the tradable sector, while the variable Z_t^N represents a non-tradable sector productivity shock, which is again country-specific

$$\ln Z_t^N = \rho_{Z,N} \ln Z_{t-1}^N + \varepsilon_t^{Z,N} \quad , \quad (31)$$

where we let the non-tradable productivity process Z_t^N to be affected by a sector-specific innovation, $\varepsilon_t^{Z,N}$.

Non-tradable sector firms maximize their profits

$$E_t \sum_{k=0}^{\infty} \alpha_N^k \Lambda_{t,t+k} \left[\frac{P_t^{N,opt} (n) \left(\frac{P_{t+k-1}^N}{P_{t-1}^N} \right)^{\varphi_N} (\Pi_N)^{k(1-\varphi_N)} - MC_{t+k}^N}{P_{t+k}} y_{t+k}^{N,d}(n) \right] \quad (32)$$

subject to

$$y_{t+k}^{N,d}(n) = \left[\frac{P_t^{N,opt}(n)}{P_{t+k}^N} \left(\frac{P_{t+k-1}^N}{P_{t-1}^N} \right)^{\varphi_N} (\Pi_N)^{k(1-\varphi_N)} \right]^{-\nu} Y_{t+k}^N, \quad (33)$$

where the expression $\Lambda_{t,t+k} = \beta^k \lambda_{t+k} / \lambda^t$ represents the stochastic discount factor, and $y_{t+k}^{N,d}(n)$ is the non-tradable goods demand of a firm in time $t+k$. Y_t^N is the aggregate non-tradable goods demand. Real marginal costs in the non-tradable sector are defined as MC_t^N . From the cost-optimization perspective, the marginal costs are defined as the real wage normalized for productivity

$$MC_t^N = \frac{w_t^N}{A_t^N}. \quad (34)$$

A non-tradable sector firm maximizes its profit with respect to price $p_t^N(n)$ and demand $y_{t+k}^{N,d}(n)$. The non-tradable price dynamics should therefore be

$$P_t^N \equiv \left[\alpha_N (P_{t-1}^N (\Pi_{t-1}^N)^{\varphi_N} (\Pi_N)^{1-\varphi_N})^{1-\nu} + (1 - \alpha_N) (P_t^{N,opt})^{1-\nu} \right]^{\frac{1}{1-\nu}}, \quad (35)$$

where $P_t^{N,opt}$ is the optimal price and $\Pi_{t-1}^N = P_{t-1}^N / P_{t-2}^N$.

3.3 Monetary policy

Monetary policy is modelled as a Taylor rule (Taylor, 1993) and is the same for both economies

$$R_t^{EA} = \bar{R}^{1-\varrho_r} (R_{t-1}^{EA})^{\varrho_r} \left(\frac{\Pi_t^{EA}}{\bar{\Pi}} \right)^{(1-\varrho_r)\gamma_\pi} \left(\frac{Y_t^{EA}}{\bar{Y}} \right)^{(1-\varrho_r)\gamma_y} e^{\varepsilon_t^{MP}}, \quad (36)$$

where ε_t^{MP} represents the monetary policy shock, while the interest rate R_t^{EA} responds to inflation and output gaps. The total output of the euro area is defined by $Y_t^{EA} = (Y_t^*)^s (Y_t^*)^{1-s}$, while the overall inflation in the euro area is defined by $\Pi_t^{EA} = (\Pi_t^*)^s (\Pi_t^*)^{1-s}$, where s is the size of the domestic country. The parameter ϱ_r is the weight parameter for the responsiveness of the past interest rate, while γ_π and γ_y are Taylor type parameters for the response of the interest rate accordingly to both gaps.

3.4 Market clearing

The clearing conditions are

$$Y_t^T = C_t^H + C_t^{H,*} + G_t^T \quad (37)$$

and

$$Y_t^N = C_t^N + G_t^N, \quad (38)$$

where variables G_t^T and G_t^N represent exogenous government spending shocks. Combining equations (37) and (38), the real GDP is

$$Y_t = \frac{P_t^T}{P_t} Y_t^T + \frac{P_t^N}{P_t} Y_t^N \quad . \quad (39)$$

What is left to do is to define the government sectoral spending process

$$\ln G_t^i = \rho_{G,i} \ln G_{t-1}^i + \varepsilon_t^{G,i}, \quad (40)$$

where $i=N,T$.

4 TRADABILITY OF SECTORS AND DATA

As the theoretical model is divided into tradable and non-tradable sectors, some attention is needed for the specification and the sectoral definition of the data. The dataset consists of quarterly Slovene and euro area sectoral data, which is available from the Eurostat⁶ website. The time series data spans from 1998Q4 to 2018Q1 and includes sectoral gross value added data and sectoral price indexes data.

4.1 Tradability of sectors

To begin with, the tradability of the sectors has to be defined. Officer (1976) proposes the following sector division. Manufacturing and other industry activities represent the tradable sector, while the services represent the non-tradable sector. De Gregorio et al. (1994) use a ratio of exports to total production to define both sectors. Their division threshold is set to 10 percent, stating that the sector is defined as tradable if the ratio of exports exceeds the 10 percent threshold, and the sector is defined as non-tradable if the ratio of exports does not exceed the 10 percent threshold. Following the De Gregorio et al. (1994) sector division, we take a step further by strictly distinguishing between the tradable and the non-tradable sector. This means that we exclude those activities from the analysis that oscillate around the 10 percent threshold too much. We provide a more detailed specification below.

⁶ Available at the European Commission's statistical database site <http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/>.

First, data on the share of exports in total value added have to be extracted from the input-output tables available at the World Input-Output Database (WIOD). We use a standard ISIC/NACE Revision 2 aggregation category, which is used for reporting data from the System of National Accounts (SNA) for a wide range of countries. We present a 10-sector breakdown in Table 1.

Table 1: *NACE Revision 2 10-sector classification of economic activities*

NACE Revision 2	Sector description	Ratio of exports (in %)	Tradability
A	Agriculture, forestry and fishing	18.32*	
B, C, D, E	Manufacturing, mining and quarrying and other industry	45.99	T
F	Construction	2.20	N
G, H, I	Wholesale and retail trade, transportation and storage, accommodation and food services	17.25	T
J	Information and communication	10.42	
K	Financial and insurance activities	12.63	
L	Real estate activities	0.56	N
M, N	Professional, scientific, technical, administrative and support services	16.39**	
O, P, Q	Public administration, defence, education, human health and social work services	0.95	N
R, S, T, U	Other services	6.27	N

Source: European Commission, author's calculations.

*Note: Countries, such as Belgium, the Netherlands and Luxembourg, stand out with their ratio-of-export figures, thus driving up the average of ratio of exports in the agriculture sector.

**Note: Countries, such as Ireland, the Netherlands and Luxembourg, stand out with their ratio-of-export figures, thus driving up the average of ratio of exports in the professional services sector.

As mentioned above, to divide the 10 sectors into tradable and non-tradable sectors, we use a similar approach as De Gregorio et al. (1994). However, in the present paper we put emphasis only on strictly tradable and non-tradable sectors, meaning that the sectors which are not distinctively tradable or non-tradable are excluded from the analysis. A sector is then treated as tradable if its ratio of exports exceeds the 10 percent threshold for at least 75 percent of time using the WIOD data in the 2000-2011 period. The same principle is applied for the definition of a non-tradable sector. A sector is treated as non-tradable if its ratio of exports is under the 10 percent threshold for at least 75 percent of time using the WIOD data in the 2000-2011 period. Applying stricter conditions regarding the division of sector means that NACE Rev. 2 sectors, such as agriculture, forestry and fishing (A), information and communication (J), financial and insurance activities (K), professional, scientific, technical, administration and support services (M and N), are excluded from the analysis. These excluded sectors account for around 20 percent in total value added. Based on this threshold the manufacturing, mining, quarrying and other industries (B, C,

D and E), wholesale, retail, transportation, storage, accommodation and food services (G, H and I) are treated as tradable sectors, while construction (F), real estate activities (L), public administration, defence, education, human health, social work services (O, P and Q), and other services (R, S, T and U) are treated as non-tradable sectors.

4.2 Sectoral inflation and productivity

Based on quarterly data available from the Eurostat website and consideration of the classification of economic activities into a tradable and a non-tradable sector (as defined in Table 1), supported by time-varying sectoral gross value added weights expressed in millions of euros in 2015, growth rate in prices for the tradable and the non-tradable sector are obtained. We use the same principle that was applied to divide economic activities into the tradable and non-tradable sectors to divide sectoral growth rate of value added for both sectors, based on the aggregation done for sectoral inflation. This way we get growth rates for the output on a quarterly frequency basis for a separate sector, i.e. tradable and non-tradable.

4.3 Data entering the model

After defining and obtaining the sectoral data, we can provide a full description of the dataset entering the model in Table 2. There are 9 observable variables at a quarterly frequency in the period of 1998Q4-2018Q1, thus providing 78 observations. Tradable sector figures stand out the most and have the highest variability. Intuitively, this means that the tradable sector is more responsive to changes in different phases of business cycles. Additionally, Slovene data in comparison to the euro area data varies more, thus providing a case that small open economies are more vulnerable to macroeconomic imbalances.

Table 2: *Descriptive statistics (in p.p. deviations from the steady state)*

Variable description	Data transformation	Country	Minimum	Maximum	Standard deviation
Weighted tradable sector inflation	demeaned log-differences	SI	-2.59	2.21	0.92
Weighted tradable sector inflation	demeaned log-differences	EA	-1.08	1.31	0.39
Weighted tradable sector gross value added	demeaned log-differences	SI	-10.17	3.02	1.64
Weighted tradable sector gross value added	demeaned log-differences	EA	-6.36	1.23	1.07
Weighted non-tradable sector inflation	demeaned log-differences	SI	-1.22	1.84	0.69
Weighted non-tradable sector inflation	demeaned log-differences	EA	-0.76	0.80	0.30

Variable description	Data transformation	Country	Minimum	Maximum	Standard deviation
Weighted non-tradable sector gross value added	demeaned log-differences	SI	-3.20	5.13	1.51
Weighted non-tradable sector gross value added	demeaned log-differences	EA	-0.73	1.02	0.41
3-month Euribor	Interest rate given by $\log(1+r/400)$, demeaned log-differences	EA	-0.55	0.78	0.42

Source: Eurostat, author's calculations.

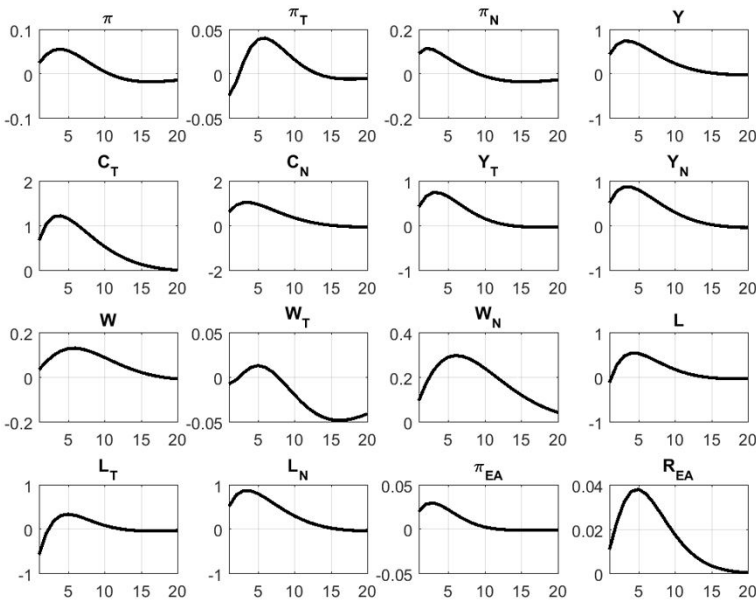
5 CALIBRATION OF THE MODEL

We set the values of the calibrated parameters accordingly to known empirical facts from the existing literature and characteristics of the modelled economies, in our case Slovenia and the euro area. The discount factor β is set to 0.99, following Smets and Wouters' (2003) paper. The degree of habit formation parameter h for Slovenia is set to 0.80 (as in Kilponen et al., 2015), while for the euro area it is set to 0.60 (as in Smets and Wouters, 2003), thus making Slovenia's consumption slower to respond and more persistent. The Slovene economy size parameter s is set to 0.01.⁷ The Frisch elasticity or the inverse of the elasticity of work effort for both economies has a typical parameter value of 2 (Smets and Wouters, 2003; Rabanal, 2009; Rabanal, 2012; Micallef and Cyrus, 2013). The elasticities of substitution between tradable and non-tradable goods for both, domestic (v_{TN}) and foreign ($v_{TN,*}$), economies, take the value of 0.44, following the values set by Stockman and Tesar (1995). The elasticities of substitution between domestic produced and foreign produced goods for both, domestic (v_{HF}) and foreign ($v_{HF,*}$) economies, take the value of 1.5, following Chari, Kehoe, and McGrattan (2002). Furthermore, the shares of important economic variables are calibrated as well. The share of government spending relative to GDP in Slovenia is set to 0.17 and for the euro area it is set to 0.20, while the average share of tradable goods in the consumption basket is set to 0.58 in Slovenia and 0.61 in the euro area. The Calvo wage parameters for both areas and both sectors are set to 0.81, while the price stickiness is set to 0.75, following the values set for Slovenia in Clancy, Jacquinot, and Lozej (2014) and Kilponen et al. (2015). The wage indexation parameters are set to 0.75, according to Rabanal (2012). The quality improvement parameters θ_z and $\theta_{z,*}$ for both economies are set to 0.25. The Taylor rule values inflation and output gap response parameters $\gamma_\pi = 1.5$ and $\gamma_y = 0.1$ take usual values when modelling the euro area monetary policy close to Fourçans and Vranceanu's (2004) estimation of the euro area parameters.

⁷ In comparison to the euro area the size of the Slovene economy is even smaller. The reason behind a slightly bigger economy size parameter is that very small numbers of the parameters could represent numerical difficulties for the model. These are shown in a very slow convergence after shocking the model or even in the inability of computing the responses of the shocks. However, 0.01 economy size parameter does not significantly influence the universum of both economies, which would be the case for small open economies.

The calibrated model is able to produce the HBS type of productivity shock. The following figure shows the impulse responses of the main macroeconomic variables to a 1 p.p. domestic tradable sector productivity shock, based on the calibrated model. The productivity shock increases the production of both sectors, tradable and non-tradable. As the quality improvement mechanism takes place, firms are compelled to raise wages since more sophisticated labour force is needed with the productivity picking up. The pick-up in wages increases inflation and consumption in both sectors. What is noteworthy is that inflation in the non-tradable sector increases more than in the tradable sector, thus providing a case for the HBS effect.

Figure 1: *Impulse responses of the main variables to a 1 p.p. domestic tradable sector productivity shock (deviations from steady state, in p.p.)*



6 ESTIMATION OF THE MODEL AND COMPARISON WITH THE CALIBRATED MODEL

With the obtained dataset and the calibration parameters set, the two-country two-sector DSGE model is ready to be estimated. Doing that, we use the Bayesian inference methodology. We set the prior distribution of the estimated parameters, given in Table 3. The prior and the posterior distribution of the estimated parameters and the shocks is presented in Table 3, while the figures with comparisons between the prior and the posterior distribution of the parameters are presented in Appendix A, and in Appendix B the dynamics of the exogenous shocks is presented. The Metropolis-Hastings MCMC algorithm is used with 300,000 steps and two sequential chains with the acceptance rate per chain of around 30%.

We estimate the quality improvement parameters θ_Z and θ_{Z^*} for both economies. The priors of both parameters were set to 0.25, while the estimates of both parameters took the values of 0.1676 and 0.2127, respectively. The estimated values of both quality improvement parameters are below the calibrated value of the parameter for the domestic economy in Masten (2008). Since Slovenia was catching up the average of the euro area and experienced higher growth and inflation, the estimate of the quality improvement mechanism had to be stronger during this period. With respect to the other estimated parameters, the shock persistence parameters seem to suggest that the productivity persistence parameters show less persistence than the demand shocks entering both the non-tradable and the tradable sector. The parameter Q_r of the monetary policy rule is estimated as well and takes the value of 0.6250, suggesting a relatively high persistence of the past interest rate.

In comparison to the calibrated model, the Calvo price and wage rigidity parameters (α 's) are estimated to be higher, meaning that the prices and wages respond slower to exogenous shocks. The values of the Calvo parameters are similar comparing the foreign or domestic economy.

Table 3: *Prior and posterior distribution of the estimated parameters and shocks*

Parameter	Calibration model values	Prior mode	Posterior mode	90% HPD interval		Prior distribution	Prior distribution
θ_Z	0.250	0.250	0.1676	0.1061	0.2268	inv. gamma	0.100
θ_{Z^*}	0.250	0.250	0.2127	0.1153	0.3393	inv. gamma	0.100
α_H	0.750	0.750	0.6259	0.5828	0.6676	beta	0.150
α_F	0.750	0.750	0.8955	0.8524	0.9355	beta	0.150
α_{H^*}	0.750	0.750	0.8742	0.7620	0.9975	beta	0.150
α_{F^*}	0.750	0.750	0.9200	0.8963	0.9412	beta	0.150
α_N	0.750	0.750	0.8519	0.8250	0.8746	beta	0.150
α_{N^*}	0.750	0.750	0.9550	0.9415	0.9686	beta	0.150
α_{WT}	0.810	0.810	0.9010	0.8395	0.9659	beta	0.070
α_{WT^*}	0.750	0.750	0.8249	0.7279	0.9198	beta	0.070
α_{WN}	0.810	0.810	0.8889	0.8392	0.9367	beta	0.070
α_{WN^*}	0.750	0.750	0.7920	0.6909	0.8920	beta	0.070
v_{TN}	0.440	0.500	0.5471	0.1888	0.8864	gamma	0.200
v_{HF}	1.500	1.500	1.1671	0.5602	1.7190	gamma	0.500
φ_H	0.500	0.500	0.2600	0.0614	0.4389	beta	0.200
φ_F	0.500	0.500	0.4762	0.2029	0.7278	beta	0.200
φ_{H^*}	0.500	0.500	0.4643	0.3093	0.6329	beta	0.100
φ_{F^*}	0.500	0.500	0.1014	0.0120	0.1864	beta	0.200
φ_N	0.500	0.500	0.3958	0.2158	0.6011	beta	0.100

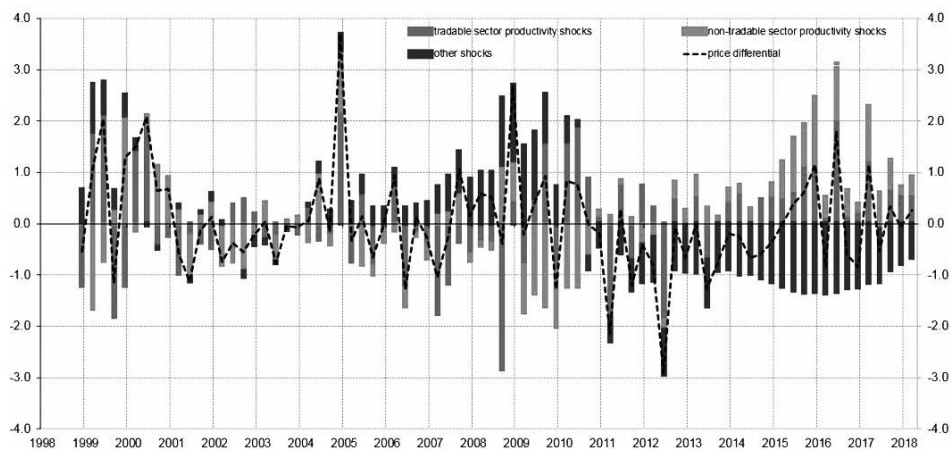
Parameter	Calibration model values	Prior mode	Posterior mode	90% HPD interval		Prior distribution	Prior distribution
φ_{N^*}	0.500	0.500	0.2926	0.1718	0.4120	beta	0.100
$\rho_{Z,T}$	0.750	0.750	0.3940	0.2721	0.5210	beta	0.100
ρ_{Z,T^*}	0.750	0.750	0.3958	0.2485	0.5370	beta	0.100
$\rho_{Z,N}$	0.750	0.750	0.5840	0.4225	0.7360	beta	0.100
ρ_{Z,N^*}	0.750	0.750	0.4358	0.2903	0.6000	beta	0.100
$\rho_{G,T}$	0.750	0.750	0.8392	0.6415	0.9662	beta	0.100
ρ_{G,T^*}	0.750	0.750	0.8468	0.7520	0.9511	beta	0.100
$\rho_{G,N}$	0.750	0.750	0.9030	0.6564	0.9918	beta	0.100
ρ_{G,N^*}	0.750	0.750	0.8062	0.6567	0.9330	beta	0.100
Q_T	0.750	0.750	0.6250	0.4788	0.7758	beta	0.100
ε_{MP}	-	0.4000	0.1266	0.1113	0.1417	inv. gamma	0.1000
ε_Z	-	0.5000	0.1840	0.1509	0.2156	inv. gamma	0.2000
$\varepsilon_{Z,T}$	-	0.7000	0.2593	0.2211	0.2978	inv. gamma	0.2000
ε_{Z,T^*}	-	0.5000	0.3710	0.2322	0.5064	inv. gamma	0.2000
$\varepsilon_{Z,N}$	-	0.7000	0.2472	0.2126	0.2803	inv. gamma	0.2000
ε_{Z,N^*}	-	0.5000	0.5192	0.2784	0.7470	inv. gamma	0.2000
$\varepsilon_{G,T}$	-	1.0000	0.5061	0.4420	0.5733	inv. gamma	0.2000
ε_{G,T^*}	-	1.0000	0.4088	0.3539	0.4595	inv. gamma	0.2000
$\varepsilon_{G,N}$	-	1.0000	0.6004	0.5109	0.6883	inv. gamma	0.2000
ε_{G,N^*}	-	1.0000	0.4032	0.3538	0.4484	inv. gamma	0.2000

Source: Author's calculations.

6.1 Impulse response functions and the historical shock decomposition

In this subsection, we present the historical shock decomposition and impulse response functions. The purpose of both is to provide a description of the severity of shocks that influence the macroeconomic variables. Figure 2 shows the contributions of the exogenous shocks onto the price differential between the non-tradable and tradable sectors through time. It is evident that the inflation differential between the non-tradable and tradable sectors has been influenced by productivity components. As the financial crisis lingered on in the second wave after 2010, the difference between the non-tradable and tradable dynamics turned to be negative, implying a slowdown in the tradable sector productivity. Only with the start of the recovery of the Slovene economy in 2015, the difference between the inflation of both sectors returned to positive figures and has continued the pattern from before the financial crisis in 2008 by being affected with positive tradable sector productivity shocks.

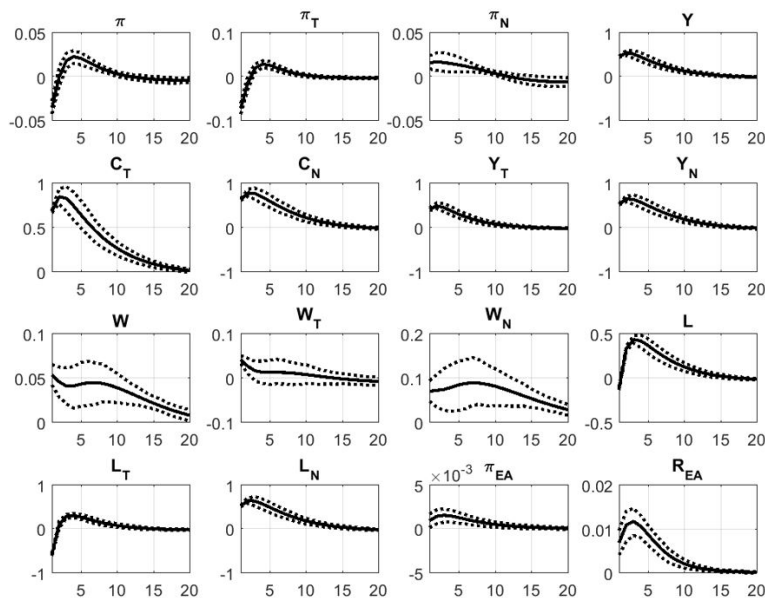
Figure 2: *Historical shock decomposition in the inflation differential between the non-tradable and the tradable sector (deviations from steady state, in p.p.)*



Note: Tradable productivity shocks are the sum of the contributions of the country-specific domestic tradable sector shocks $\varepsilon_{Z,T}$ and ε_{Z,T^} , and the common productivity shock ε_Z . The non-tradable sector productivity shocks $\varepsilon_{Z,N}$ and ε_{Z,N^*} are depicted separately. Other shocks are the sum of the contributions of the government spending shocks ($\varepsilon_{G,T}$, ε_{G,T^*} , $\varepsilon_{G,N}$ and ε_{G,N^*}) and the monetary policy shock ε_{MP} . Source: Author's calculations.

It is more intuitive to look at the impulse response functions in order to understand the effects of productivity shocks. Figures (3-6) show the responses of the main macroeconomic variables to different exogenous shocks and depict a 20-period horizon. In studying the impulse responses, we will only consider the productivity shocks that hit the two economies. Figure 3 displays the impulse responses of the main variables to a 1 p.p. domestic tradable sector productivity shock $\varepsilon_{Z,T}$. When a positive productivity shock hits the tradable sector, tradable and non-tradable inflation increases in Slovenia, causing the overall inflation to increase. This is due to a wage increase in the tradable sector via quality improvement mechanism that increases the need for more demanding inputs in the production process, thus increasing the marginal costs, as wages increase the marginal costs increase, causing the inflation to increase. The Harrod-Balassa-Samuelson type productivity shock causes the increase of output and consumption as well. Under the implementation of quality improvement mechanism and under the price and wage frictions the HBS effect seems to hold, based on the impulse responses, the effects on the euro area macroeconomic variables are small.

Figure 3: Impulse responses of the main variables to a 1 p.p. domestic tradable sector productivity shock (deviations from steady state, in p.p.)



The same pattern is observed when we analyse a 1 p.p. common tradable sector technology shock ε_{z^*} shown in Figure 4. Similar effects happen when a 1 p.p. foreign tradable sector productivity shock ε_{z^*,T^*} hits the rest of the euro area (Figure 5). The difference is that this time the quality mechanism works abroad, so that spillovers come with a lag and in smaller magnitude. As a consequence, marginal costs do not increase in the domestic country, but positive effects from the price increase abroad make the tradable sector more profitable, increasing production, consumption, price and wages in the domestic country.

Figure 4: *Impulse responses of the main variables to a 1 p.p. common euro area tradable sector productivity shock (deviations from steady state, in p.p.)*

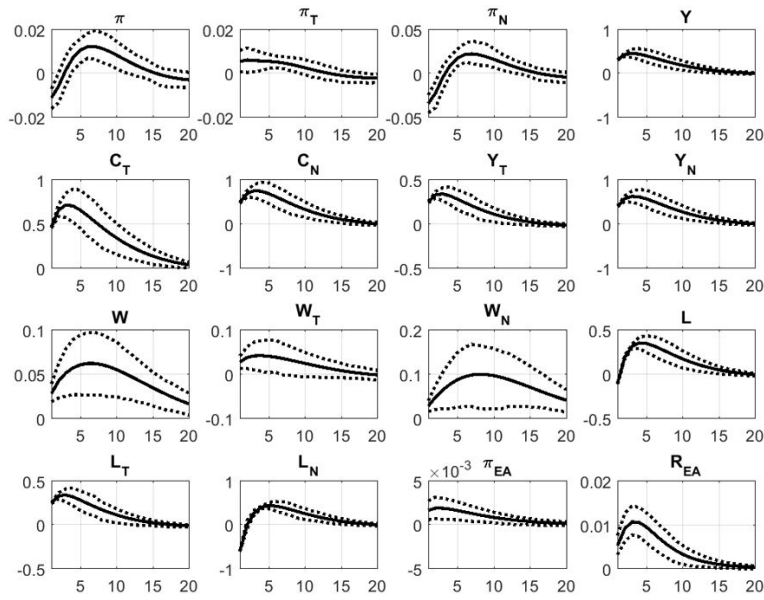
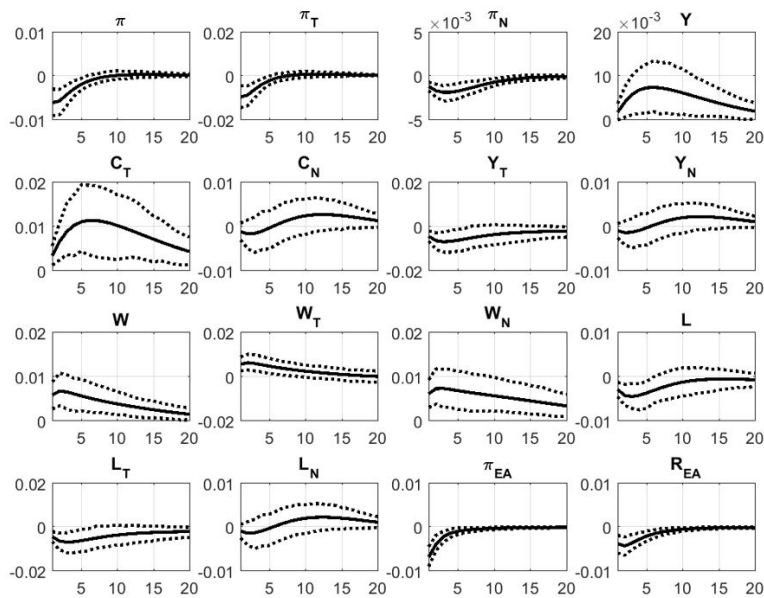
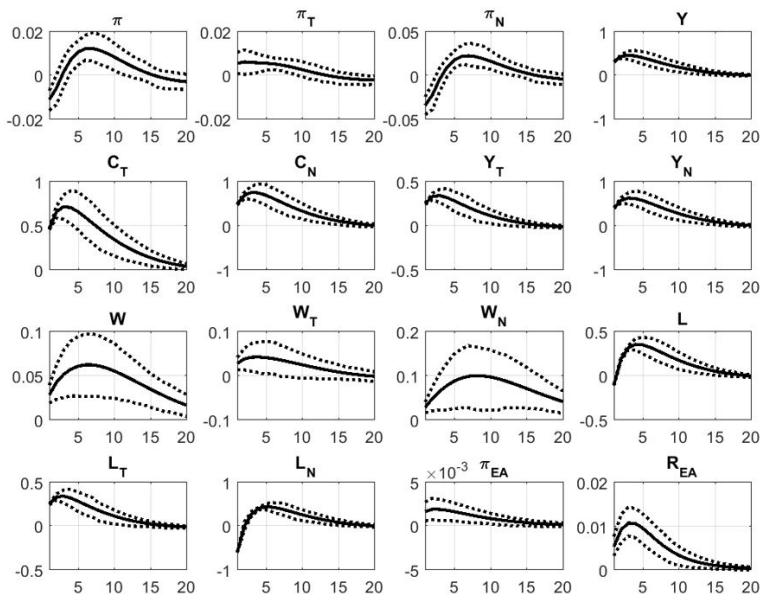


Figure 5: *Impulse responses of the main variables to a 1 p.p. foreign tradable sector productivity shock (in p.p. deviations from steady state)*



We are left to study the effects of the non-tradable sector productivity shocks, as they are depicted in Figure 6. In contrast to the tradable sector productivity shocks, the domestic non-tradable sector productivity shock $\varepsilon_{Z,N}$ does not enter the quality improvement mechanism. Consequently, it acts more as a (classical productivity) shock that decreases marginal costs and lowers non-tradable sector inflation, while the tradable sector marginally increases since the labour supply moves from the non-tradable sector to the tradable sector. The sectoral and the overall output, as well as the consumption, increase.

Figure 6: *Impulse responses of the main variables to a 1 p.p. domestic non-tradable sector productivity shock (deviations from steady state, in p.p.)*



6.2 Policy implications and way forward

The HBS effect is typically used to explain inflation differentials for countries experiencing a catching-up process. As the relatively poorer countries adopt new technologies in those sectors that are open to international trade (i.e., the tradable sector), they will experience higher productivity growth in the tradable sector, increased wages via quality mechanism, and consequently a higher inflation in sectors that are not open to international trade, as is the non-tradable sector. Therefore, the HBS effect hypothesis could help to explain higher inflation rates in the non-tradable sector than in the tradable sector, hence leading to higher overall inflation.

Another important issue to point out is that the HBS effect theory does not explain the possible sources of productivity differentials between different sectors and countries. As

the HBS is often associated with catching-up and convergence phases of less developed countries, there is a possibility that a catching-up process could take place without the HBS effect. This happens if productivity growth in both sectors (i.e., tradable and non-tradable) is equally high. Additionally, some countries that already experience high productivity levels may for various reasons (i.e., economic policies that are conducive to technological innovation) also experience relatively high productivity growth in the tradable sector. Importantly, in those countries structural rigidities and different degrees of competition⁸ can affect productivity growth differentials between sectors and overall productivity growth in a way that favours either positive or negative inflation differentials.

Despite wage setting being typical for the DSGE model setting, following Calvo (1983) and later on Christiano (2005) labour market frictions, some issues could still arise in that respect. The wage setting in the non-tradable sector could be to a large extent governed by the non-market forces and other structural rigidities since a large part of the non-tradeable sector is comprised of the public sector. In our case, the model does not structurally distinguish between the private and the public sector and would consequently not be able to consider various types of non-market forces. However, it does provide some distinction in a sense of having two different (estimated) rigidity parameters of the wage setting equation for the non-tradable and the tradable sector. Based on the estimation figures the non-tradable sector wages seem to be more rigid than those in the tradable sector. They are slower in responding to exogenous shocks, which would to some extent simulate the differences between the private and the public sector. This issue could go beyond the scope of the present paper, but it could represent an additional way forward to extend the model into a more complex one by additionally restricting and dividing the modelled labour market, as well as the government sector.

Nonetheless, the continued process of convergence processes in the euro area should lead to a decline in inflation dispersion amongst the euro area countries due to a price level and income convergence in the long-run. On the other hand, other structural factors such as differences in the degrees of wage and price rigidities and divergent degree of competition in domestic markets may have also contributed to the observed inflation differentials and their persistence. In this respect, the relative degree of market competition seems to be an important parameter in explaining the size and volatility of relative price responses to symmetric shocks across euro area countries.

7 CONCLUSION

This paper draws conclusions based on a construction of a theoretical two-country two-sector DSGE model with both economies operating in a common monetary union. We were able to produce and show the existence of the HBS effect in a calibrated and estimated structural dynamic setting of the DSGE model by introducing a quality improvement mechanism that helps to explain why prices grow when productivity increases, especially in

⁸ i.e., the private vs. the public sector.

catching-up economies like the new EU member states in 2000. The quality improvement mechanism affects marginal costs by requiring the use of more advanced inputs in the production process. Quality improvement of goods overcomes a typical open economy theoretical specification that reduces the relative prices of domestic tradable goods relative to the foreign prices, and consequently worsens the terms of trade for the domestic economy. Despite showing the presence of the HBS effect, the effect *per se* is not large enough to pose significant risks to central banks in their quest for price stability.

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APPENDICES

Appendix A: Prior and posterior distribution

Figure A1: Prior (dashed line) and posterior distribution (solid line) of the estimated shocks

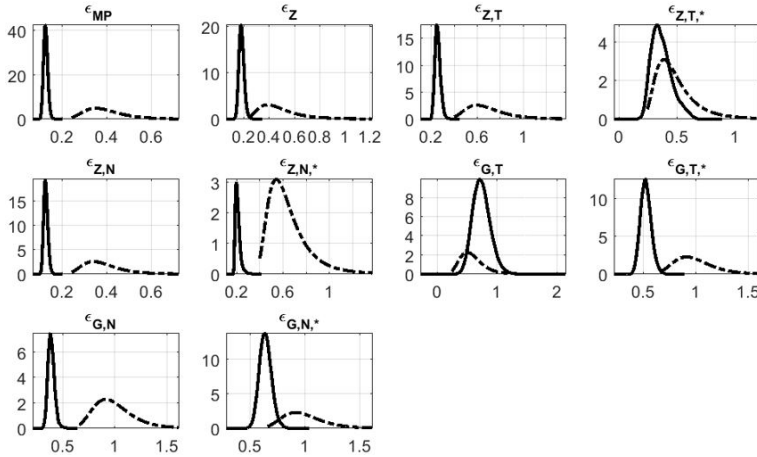
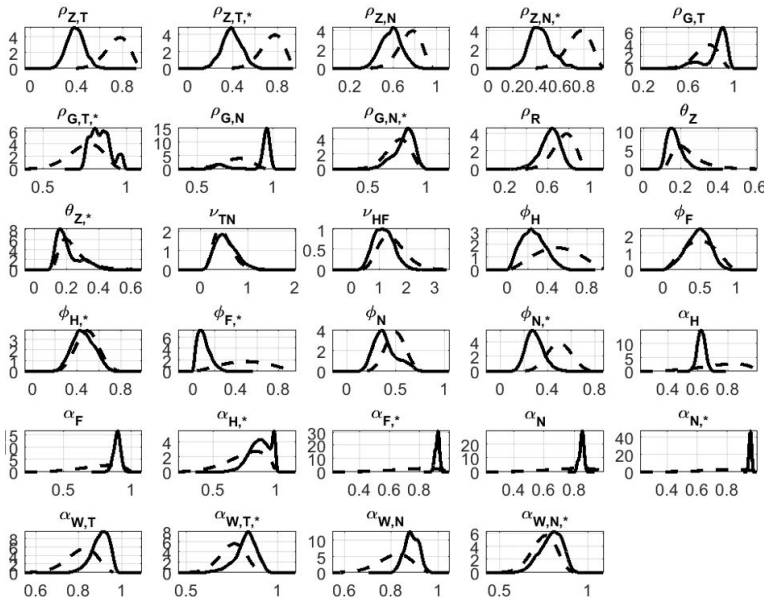


Figure A2: Prior (dashed line) and posterior distribution (solid line) of the estimated parameters



Appendix B: Exogenous shocks

Figure B1: *Exogenous shocks*

