Original scientific paper
UDC: 339.743(4-67 EU)
doi: 10.18045/zbefri.2016.2.393

Backus–Smith puzzle and the European Union: It's not just the nominal exchange rate*[1]

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Abstract

The goal of our research is testing of presence and background examination of Backus–Smith puzzle in the EU. The research is based on the technique of econometric analysis of panel data, i.e. on the estimation of one-way/two-way error component models and models without effects. The results of the research have shown that: (a) there is serious evidence on presence of the Backus–Smith puzzle in the EU, (b) its background comprises both nominal exchange rate and inflation differential, and (c) empirical data rejects complete risk sharing assumption strongly and decisively, but this does not explain the Backus–Smith puzzle. The basic conclusion of our research is that nominal exchange rate movements are not the only source of Backus–Smith puzzle in the EU, as is the case in OECD members states.

Key words: *Backus–Smith puzzle, real exchange rate, complete risk sharing, incomplete risk sharing*

JEL classification: *E21, F44, C33*

1. Introduction

Backus et al. (1992) have tried to rely on modified and extended real business cycle theory in order to check whether it is able to comprise both the comovements studied in closed-economy macroeconomics and posted international comovements, including correlations across countries of fluctuations in macroeconomic

* Received: 18-12-2015; accepted: 17-06-2016

[1] The paper presents the results of a study conducted as part of the project III47010: *Social Transformation in the process of European integration – a multidisciplinary approach*, funded by the Ministry of Education and Science, Republic of Serbia, 2011–2015.

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aggregates and movements in the trade balance. Quantitative studies of closed economy have shown that stochastic model with single aggregate technology shock can explain the magnitude of fluctuations in consumption and investment and the correlations of these fluctuations with output. World economy model is the extension of Kydland-Prescott closed economy model, and it is composed of two countries with large number of identical consumers and the same production technologies. The countries produce the same goods, and their technologies and preferences have the same parameters and structure. Although technologies have identical mathematical form, the difference still exists in two important segments: the labor input consists only of domestic labor, and production is exposed to technological shocks typical for the given country. In other words, the authors have developed a model based on real business cycle theory in closed economy, with the aim to explore the effect of technological shocks on aggregate fluctuations.

Rearranging and modifying the basic model, including derivation of a competitive model of world economy with homogenous product and labour which is not internationally mobile, have significantly changed the character of aggregate fluctuations. Theoretical model developed by Backus et al. (1992: 754–760) suggests higher correlation of consumption between the countries, lower correlation of outputs and far higher volatility of investments and trade balance than the real data shows. Introduction of small trade barriers into the model leads to great reduction in volatility of investments and net export; yet, the discrepancy pertaining to consumption and output still remains quite high. Namely, all experiments with theoretical model, including the introduction of trade barriers, as well as different alternative adjustment of model parameters, lead to the conclusion that consumption correlation between the countries should be significantly higher than their outputs correlation. On the other hand, empirical data indicate completely opposite relation – output correlation is mainly higher than the consumption correlation. Since this finding is a robust one compared to numerous changes of theoretical model, Backus et al. (1992: 772) have denoted it as consumption/output anomaly. It is also known as international consumption correlation puzzle, and is one of six greatest puzzles in international economy (Obstfeld and Rogoff, 2001).

Consumption/output anomaly signalises that majority of questions addressing the international version of the neoclassical business cycle framework require further theoretical development. These questions doubtlessly include: influence of international trade to the effect of technological shocks to aggregate fluctuations, behaviour of relative prices for tradable goods, correlation of relative prices and trade balance, and surely the consumption/output anomaly. Baxter and Crucini (1993), Cardia (1991), Mendoza (1991), Devereux et al. (1992), Stockman and Tesar (1995) tried to give answers to these questions. In addition, numerous authors (Del Negro, 2002; Hess and Shin, 2000; Crucini and Hess, 1999; Crucini, 1999; Hess and Shin, 1998; Asdrubali et al., 1996; van Wincoop, 1995) had been exploring regional data for certain countries, searching for additional proof of existence of consumption/output anomaly at intranational level, at the same time seriously denying the complete risk sharing.

Still, one paper which is, inter alia, dedicated to research of causes for small correlations of aggregate consumption fluctuations across countries deserves specific attention. Backus and Smith (1993) developed a mathematical model covering two cases: (a) countries trade and consume one tradable good, and (b) in addition to the mentioned tradable good, each of the countries produce and consume one non-tradable good. The result of confrontation between these two model variants is reflected in the following: (a) consumption between the countries is perfectly correlated in the case when we have only tradable good, and (b) in the case of existence of non-tradable goods, logarithm of the consumption growth rate ratio is positively (perfectly) correlated with logarithm of the real exchange rate growth. Therefore, if the model comprises only tradable good, the consumption for any pair of countries should be perfectly correlated. Also, inclusion non-tradable goods into the model implies the existence of monotone increasing relation between logarithms of the real exchange rate growth and logarithm of the consumption growth rate ratio along any equilibrium path. Such theoretical findings lead to the conclusion that presence of non-tradable goods is an important mechanism which reduces the consumption growth rate correlation. In other words, not even a complete risk sharing between the countries, when real bilateral exchange rate is variable, will ensure the perfect positive correlation of their consumption growth.

Although Backus and Smith (1993) explained the consumption/output anomaly quite successfully, they generated a completely new puzzle at the same time, since the empirical research conducted for a sample of eight OECD countries has shown that relation between the consumption growth rate ratio and the real exchange rate growth is contrary to theoretical model (Backus and Smith, 1993: 309–313). The research results show that the relative consumption growth rate is negatively, while the real exchange rate growth is positively auto-correlated. In addition, pairs of OECD countries with relatively stable consumption ratios do not have stable real exchange rates. Although, according to the model, the difference between the consumption growth rates is positively correlated with the real exchange rate growth, the analysis results reveal negative or almost zero correlation. This phenomenon is known as the Backus–Smith puzzle (Petrović, 2013).

Our paper is dedicated to research of the existence and backgrounds of the Backus–Smith puzzle in the European Union (EU) in the period between 2000 and 2011. During the research, we have tested the hypothesis that nominal exchange rate is the primary driving force behind the Backus–Smith puzzle.

The paper is composed of six parts. Section I is an introduction. In Section II we provide for a review of most important papers addressing the Backus–Smith puzzle. Section III contains the review of a mathematical model, which served as theoretical background for our empirical research, and econometric methodology. Section IV provides a description of the data and empirical analysis, while Section V presents the empirical results. Finally, Section VI concludes.

2. Literature review

Chari et al. (2002) explored one of the central puzzles in international business cycles, i.e. the phenomenon that fluctuations in real exchange rates are volatile and persistent. The research is based on general equilibrium, sticky price model which can generate real exchange rates that are appropriately volatile and persistent. Basic lack of their model is the Backus–Smith puzzle: the model implies high correlation between the relative consumption and real exchange rate, which is not the case when real data is taken into account. The paper shows that complete asset market is closely related with relation between the real exchange rate and relative consumption, which creates the puzzle. Disturbances, such as sticky prices, sticky wages, and trading frictions in goods markets do not endanger the mentioned relation. Besides, the analysis shows that the most widely used forms of asset market incompleteness and habit persistence do not eliminate puzzle. Devereux et al. (2012) did not reveal the mentioned relation, regardless of whether they relied on floating nominal exchange rate regimes, fixed exchange rates, or common currencies, thereby deepening the existing puzzle.

Using professional forecasts for 28 countries for the period between 1990 and 2010, Obstfeld (2007) also examined more recent data for a wider set of countries. He found a negative association between average consumption growth differentials and real exchange rate changes.

Taking into account that Backus–Smith puzzle has challenged the international transmission models for more than two decades, Corsetti et al. (2011), examining 20 OECD countries, divided the Backus–Smith statistic into its dynamic components at different frequencies. Using the spectral analysis, they have reached the results showing that proofs for Backus–Smith puzzle are even more stressed at business cycle and lower frequencies than suggested by contemporaneous correlation. These findings indicate the fact that correlation between relative consumption and real exchange rate is significantly negative for many countries, exactly in those frequencies which are most favourable for the assessment of properties and characteristics of international business cycle models.

Specific approach to researches of consumption–real exchange rate anomaly is based on the development of world economy model which consists of two countries of equal size each specialized in the production of an intermediate, perfectly tradable good, where each of the countries produce also non-tradable good (Corsetti et al., 2008). Non-tradable good is either consumed or used in production of intermediate tradable goods which are available to domestic consumers. The research was conducted for two cases: (a) for the economy with low trade elasticity and (b) for the economy with high trade elasticity and shock persistence. Under both approaches the model accounts for the low and negative correlation between the real exchange rate and relative consumption in the data (Backus–Smith puzzle). Corsetti et al. (2009) again find evidence against conditional risk-sharing, since, following productivity shock, US consumption growth and real appreciation occur together.

Analysing the Backus–Smith puzzle, Benigno and Thoenissen (2008) included into the canonical international business cycle model both an incomplete financial markets structure as well as a non-traded goods sector. Calibration of such a model in a standard way confirms the Backus–Smith puzzle. Presence of non-traded goods sector enables that real exchange rate appreciates reacting to productivity shock in the domestic traded goods sector (Harrod-Balaasa-Samuelson effect), while limited options for risk sharing, upon such productivity shock, cause faster growth of consumption in the domestic than in foreign country.

Another research (Kollmann, 1995) based on data for the USA, Japan, France, UK, Italy, Canada and Sweden, has confirmed through cointegration techniques that existing international real business cycle models with complete asset markets fail to adequately capture the trend behaviour of consumption and real exchange rates. The paper casts doubts on the empirical validity of this relationship between high-frequency consumption and real exchange rate movements as well.

Ravn (2001) tested relation between the consumption growth rates and changes in real exchange rate for the OECD countries panel, trying to explore whether there are empirical proofs for the connection between the differential of the expected marginal rate of substitutions of consumptions and the expected change of real exchange rate. The research results have shown that in these equations the consumption growth is most commonly statistically significant, which cannot be said for the real exchange rate. In addition, the results showed great robustness with regard to: introduction of non-separabilities into the utility function, decomposing of consumption, changes in selection of partnership countries and introduction of habit persistence. In other words, the research created doubts in crucial role which the real exchange rate plays in a number of recent international macroeconomic models.

Head et al. (2004) explored the link between relative international marginal utilities and the real exchange rate, relying on models of marginal utility that include government spending, leisure, real money balances, or external habit. The research was conducted in two ambient areas with incomplete asset markets, as follows: (a) with a stochastic discount rate and (b) with endogenous market segmentation. The obtained results are negative with one, conspicuous exception-the model with external habit yields significant parameter estimates with signs consistent with theory.

Using panel data for 12 EMU member states, Hadzi-Vaskov (2008) showed that nominal exchange rate is the main source of the Backus–Smith puzzle. If nominal exchange rate fluctuations are eliminated, the consumption growth rate ratio is positively correlated with changes of real exchange rate. The analysis in relatively flexible exchange rate regimes has shown that inflation differential is positively, while nominal exchange rate is negatively correlated with relative consumption growth rates. In addition, Hess and Shin (2010), examining the data for OECD countries, decomposed the dynamics of real exchange rate to nominal exchange rate and inflation differential. Findings they reached indicate that movements in nominal exchange rate are the main source for Backus–Smith puzzle. Robustness of these results has been confirmed through introduction of incomplete risk sharing, as well as with researching of data for the USA countries using the same currency, which implies constant nominal exchange rate. Backus–Smith puzzle, according to some findings, can be explained by a simple model in which a subset of households trade in complete financial market, while the remaining households do not participate in asset markets, and just consume their current labour income (Kollmann, 2010).

Solution of Backus–Smith puzzle was offered by Opazo (2006), extending the two-country, two good international business cycle models with internationally incomplete financial markets to incorporate public signals about future innovations to total factor productivity. In this constellation of circumstances, positive signals increase the relative present value of domestic lifetime income, enabling faster growth of current consumption with respect to current output, which results in appreciation of real exchange rate, thus offering a solution for the consumption–real exchange rate anomaly. Adjustment of model for the USA economy versus the rest of the industrialised world shows correlation between the real exchange rate and relative consumption, which is quite similar to empirically established correlation. Selaive and Tuesta (2003) tried to solve the Backus–Smith puzzle stressing the importance of international financial frictions. Enriching the previous models with a particular incomplete asset market structure in which the net foreign asset position affects the real exchange rate, they obtain results that the interaction of incomplete markets and imperfect financial integration may deliver very low cross-correlations between real exchange rate and relative consumptions. Throughout the paper they have emphasised the importance of net foreign assets explaining the low cross-correlation between real exchange rate and relative consumptions.

Research Backus–Smith puzzle in simple dynamic general equilibrium open economy model (Benigno and Thoenissen, 2003) showed that simple forms of market incompleteness combined with wealth effects are enough to solve the puzzle. Although standard models of international risk sharing with complete asset markets implies positive relation between the relative consumption growth and real exchange rate depreciation, the obvious absence of empirical evidence for such relation requires research on risk-sharing indicators with incomplete asset markets. Such research generally implies that the association holds in forecasts, rather than realizations. Many models with incomplete asset markets implies positive correlation between the expected relative consumption growth and real depreciation rate.

Corsetti et al. (2006) used structural vector autoregression with long-run restrictions in order to identify shocks to traded-sector productivity in G7 countries. Their results indicate negative consumption growth/real depreciation correlation for the US and Japan-conditional on this shock. On the other hand, for Germany, the UK, or Italy, the analysis provided for higher support for conditional risk sharing – for these countries a shock to traded sector productivity is followed by persistent increases in relative consumption, as well as persistent real exchange rate depreciation.

Relying on trade costs and incomplete asset markets, Ghironi and Melitz (2005) developed a two-country, stochastic, general equilibrium model of international trade and macroeconomic dynamics, wanting to reproduce key features of international business cycles, including the resolution of the Backus–Smith puzzle. Their results indicate high negative correlation between relative consumption spending and the real exchange rate, and quite high correlation between relative consumption and the consumption based real exchange rate at the same time. This second result is still significantly changed with the change of model parameters.

A well-known paper (Mandelman et al., 2010) has showed that introduction of investment-specific technology shocks (IST) into standard international real business cycle model and their calibration to explain most of the observed macroeconomic fluctuations, can address the four well-known puzzles in the literature, including the Backus–Smith puzzle. Besides, replacement of econometrically estimated IST processes in the model leads to the case when IST shocks become powerless to explain any of the existing puzzles.

3. Methodology

3.1. Theoretical model

Our empirical research is based on theoretical stochastic world economy model, composed of several countries. Namely, the model structure is composed of I countries ($i = 1, 2, 3, ..., I$), consumption of which is described through representative consumers bahviour living in a time interval $t = 0, 1,..., T$ (Backus and Smith, 1993: 300). The model is drafted in such way that all countries trade with one tradable good, while at the same time each country is attributed production and consumption of one non-tradable good. Endowment quantities of goods in country i are denoted as w_i and x_i for tradable and non-tradable goods, respectively. Prices of goods in time period t are denoted as q_0 (tradable good) and q_i (for non-tradable good in country i). Besides, prices $p_i(q_0, q_i)$ and quantity $c_i(a_i, b_i)$ indexes are defined as linear homogenous functions, where quantity index is designed in such way that utility function for some monotonous increasing function υ can be expressed as $u[a_i, b_i] = \upsilon[c_i(a_i, b_i)]$ for all values a_i and b_i.

If we formulate real bilateral exchange rate as:

$$e_{ij} \equiv E_{ij} \frac{p_j(q_0, q_j)}{p_i(q_0, q_i)}, \tag{1}$$

where E_{ij} stands for nominal exchange rate (price for one currency unit of country j expressed in currency units of country i), the key relation for this emiprical research (Backus–Smith complete risk sharing equation) can be expressed as:

$$\ln gc_i - \ln gc_j = \gamma^{-1} \ln ge_{ij}, \tag{2}$$

where g stands for variables growth rates it denotes, while γ stands for constant coefficient of relative risk aversion (The Arrow-Pratt measure of relative risk-aversion- RRA) (Hess and Shin, 2010: 171; Ravn, 2001: 10; Kollmann, 1995: 194; Backus and Smith, 1993: 306; Obstfeld, 1986: 20). Very important implication of equation (2) is perfect correlation of logarithm of consumption growth rates ratio in countries i and j and logarithm of real exchange rate growth. In addition, according to a very similar equation derived by Hess and Shin (2010: 171), correlation of the mentioned values should at worst be positive and high. Yet, empirical data quite often speaks completely opposite, which actually is the essence of Backus–Smith puzzle.

More complete research of causes of possibly present Backus–Smith puzzle imposed a need to extend the original Backus–Smith model. Theory of aggregate risk sharing indicates that if households have access to the complete market for financial assets, they can, by pooling together their risk, completely insure themselves against the non-aggregate uncertainty in their resources (Hess and Shin, 2000: 534). Since households can share non-aggregate risk, according to theory of aggregate risk sharing, change in household consumption should be perfectly correlated to aggregate changes in consumption. This approach has been extended by economists towards the comparison of correlation of consumption and output between the countries and between regions of one country.

Bearing in mind that comprehensive literature has questioned complete risk sharing (Del Negro, 2002; Hess and Shin, 2000; Crucini and Hess, 1999; Crucini, 1999; Hess and Shin, 1998; Asdrubali et al. 1996; van Wincoop, 1995), following Hess and Shin (2010: 172), Hess and Shin, (2000: 542–543) and Crucini (1999: 74), we introduced a different type of consumers into the model, i.e. we introduced consumers who simply spend their income and do not participate in the international risk sharing. If all consumers behaved in this way, difference in consumption growth rates between countries would reflect the difference in growth rates of their outputs, i.e. we could put down that (Hess and Shin, 2010: 172):

$$\ln gc_i - \ln gc_j = \ln gy_i - \ln gy_j + v_{ij}, \tag{3}$$

where y_i and y_j respectively denote incomes in countries i and j, while v_{ij} stands for preference shocks and other measurement errors. Bearing in mind the fact that risk share is incomplete, i.e. that there are consumers who share and those who do not share risk existing simultaneously, by combining equations (2) and (3), the consumption growth rates differential can be presented in the following way (Hess and Shin, 2010: 172):

$$\ln gc_i - \ln gc_j = \theta\gamma^{-1} \ln ge_{ij} + (1-\theta)(\ln gy_i - \ln gy_j) + v_{ij}, \tag{4}$$

where □ stands for a part of consumption corresponding to risk sharing in presence of non-tradable goods (equation 2), while $(1 - \theta)$ represents the remaining consumption occurring according to “rule of thumb” pattern (equation 3). Equation (4) shows that incomplete risk sharing reduces correlation of consumption growth differential and real exchange rate, but it also shows that this one is still positive. By replacing (1) in (2) and (4), we obtain (Hess and Shin, 2010: 172):

$$\ln gc_i - \ln gc_j = \gamma^{-1} \ln gE_{ij} - \gamma^{-1}(\ln gp_i - \ln gp_j) + v_{ij}, \tag{5}$$

$$\begin{aligned} \ln gc_i - \ln gc_j &= \theta\gamma^{-1} \ln gE_{ij} - \theta\gamma^{-1}(\ln gp_i - \ln gp_j) + \\ &+ (1-\theta)(\ln gy_i - \ln gy_j) + v_{ij} \end{aligned} \tag{6}$$

Equation (2), (5), (4) and (6) are theoretical basis for the conduct of this research. Namely, econometric check of their empirical grounds enables us to test the baseline hypothesis and to answer all related important questions.

3.2. Econometric methodology

Taking into account that non-stationary testing in panels deserves greater attention only if panels are *macro panels* (Baltagi, 2005: 237), as well as the fact that this research is based on only twelve time observations (*micro panels*), this empirical research is based on application of standard one-way and two-way error component panel models. One-way error component model in general terms has the following specification (Baltagi, 2005: 11):

$$y_{it} = \alpha + X'_{it}\beta + \mu_i + v_{it},\ i = 1,...,N;\ t = 1,...,T;\ v_{it} \sim \text{IID}(0, \sigma_v^2), \tag{7}$$

where i stands for the index for cross-section units, t index for time periods, α is a scalar, β is $K \times 1$ vector, X_{it} is the it observation on K explanatory variables, μ_i denotes the time-invariant unobservable individual effect and v_{it} denotes the remainder disturbance. The X_{it} are assumed independent of the v_{it} for all i and t. The presence of individual effects of μ_i actually indicates heterogeneity of intercept α which is caused by individual (cross-section) specific effect not included in the regression. If μ_i are fixed parameters, then the model is the one-way fixed effects error component model. Otherwise, μ_i is deemed a random variable, a model known as the one-way random effects error component model, which implies introduction of assumptions that $\mu_i \sim \text{IID}(0, \sigma_\mu^2)$, as well as X_{it}, μ_i and v_{it} are independent of each other for all i and t. In case of the fixed effects error component model, estimations are most commonly obtained by estimation of Within regression, which is based on the application of OLS to the following specification (Baltagi, 2005: 12–13):

$$y_{it} - y_{i\bullet} = \beta(x_{it} - x_{i\bullet}) + (v_{it} - v_{i\bullet}), \tag{8}$$

where $y_{i\bullet} = \Sigma_{t=1}^{T} y_{it}/T$; $x_{i\bullet} = \Sigma_{t=1}^{T} x_{it}/T$ and $v_{i\bullet} = \Sigma_{t=1}^{T} v_{it}/T$, which enables estimation of the slope coefficient vector $\tilde{\beta}$. Estimations of parameters α and μ_i are obtained as $\tilde{\alpha} = y_{\bullet\bullet} - \tilde{\beta}x_{\bullet\bullet}$; $\tilde{\mu}_i = y_{i\bullet} - \tilde{\alpha} - \tilde{\beta}x_{i\bullet}$, where $y_{\bullet\bullet} = \Sigma_{i=1}^{N}\Sigma_{t=1}^{T} y_{it}/NT$ and $x_{\bullet\bullet} = \Sigma_{i=1}^{N}\Sigma_{t=1}^{T} x_{it}/NT$ with arbitrary restriction that $\Sigma_{i=1}^{N}\mu_i = 0$ in order to avoid the dummy variable trap. If it is about random effects error component model, estimations of regression parameters are obtained by applying GLS. GLS estimator can be obtained as a weighted least squares by pre-multiplying the regression (7) by $\sigma_v\Omega^{-1/2}$ (where Ω variance–covariance matrix of the total disturbances $\upsilon_{it} = \mu_i + v_{it}$) and performing OLS on the resulting transformed regression (Baltagi, 2005: 15). Application of this technique requires that $\Omega^{-1/2}$ is known, that is, that variance components σ_μ^2 and σ_v^2 are known, which usually is not the case. Alternatively, variance components σ_μ^2 and σ_v^2 must be estimated, which is most commonly carried out by applying *Wallace – Hussain*, *Amemiya* and *Swamy – Arora* methods. This estimation method of random effects error component model is known as feasible GLS.

The two-way error component model, in addition to all stated for the one-way error component model, also implies heterogeneity of intercept α which is caused by time specific effect that is not included in the regression. Its main form is:

$$y_{it} = \alpha + X'_{it}\beta + \mu_i + \lambda_t + v_{it},\ i = 1,..., N;\ t = 1,..., T;\ v_{it} \sim \text{IID}(0, \sigma_v^2), \tag{9}$$

where λ_t denotes the individual-invariant unobservable time effect. If μ_i and λ_t are fixed parameters, the two-way fixed effects error component model is estimated most commonly by estimation of Within regression applying OLS to (Baltagi, 2005: 34):

$$(y_{it} - y_{i\bullet} - y_{\bullet t} + y_{\bullet\bullet}) = (x_{it} - x_{i\bullet} - x_{\bullet t} + x_{\bullet\bullet})\beta + (\nu_{it} - \nu_{i\bullet} - \nu_{\bullet t} + \nu_{\bullet\bullet}), \qquad (10)$$

where $y_{\bullet t} = \Sigma_{i=1}^{N} y_{it}/N$; $x_{\bullet t} = \Sigma_{i=1}^{N} x_{it}/N$ and $v_{\bullet t} = \Sigma_{i=1}^{N} v_{it}/N$, thus generating the estimation of the slope coefficient vector $\tilde{\beta}$. Estimations of parameters α, μ_i and λ_t are obtained as $\tilde{\alpha} = y_{\bullet\bullet} - \tilde{\beta}x_{\bullet\bullet}$; $\tilde{\mu}_i = (y_{i\bullet} - y_{\bullet\bullet}) - \tilde{\beta}(x_{i\bullet} - x_{\bullet\bullet})$ and $\tilde{\lambda}_t = (y_{\bullet t} - y_{\bullet\bullet}) - \tilde{\beta}(x_{\bullet t} - x_{\bullet\bullet})$. This procedure implies arbitrary restrictions that $\Sigma_{i=1}^{N} \mu_i = 0$ and $\Sigma_{t=1}^{T} \lambda_t = 0$ to avoid the dummy variable trap. If μ_i and λ_t are random variables, the two-way random effects error component model is estimated in the way which, generally speaking, is very similar to the described procedure for the one-way random effects error component model. The difference is that now an additional assumption is introduced stating that $\lambda_t \sim \text{IID}(0, \sigma_\lambda^2)$, and that X_{it}, μ_i, λ_t and v_{it} are independent of each other for all i and t. This time it is necessary to estimate separately all three variance components (σ_μ^2, σ_λ^2, σ_v^2), which is usually conducted through *Wallace – Hussain*, *Amemiya* and *Swamy - Arora* methods for the two-way error component model. After the estimation, pre-multiplying of regression (9) is applied by $\sigma_v\Omega^{-1/2}$ (well known *Fuller–Battese* transformation), which is followed by application of OLS to such transformed data.

4. Data and empirical analysis

We have calculated the consumption growth differential as a ratio of annual indexes of real per capita final consumption in certain countries. Nominal exchange rate is defined as a number of domestic currency units being traded for one foreign currency unit. The annual index of nominal bilateral exchange rate is computed in such way that value exceeding one indicates depreciation of domestic currency. The annual index of real bilateral exchange rate was calculated by using nominal bilateral exchange rate and harmonized indexes of consumer prices in domestic and foreign country, so that value exceeding one would denote depreciation of domestic currency. Inflation differential was quantified as negative logarithm of ratio of domestic and foreign annual harmonized indexes of consumer prices, so according to equation (5) it can be expected to have positive relation between inflation differential and consumption growth differential. Finally, economic growth differential is equal to ratio of domestic and foreign annual index of real per capita GDP. Complying with equations (2), (5), (4) and (6), we applied natural logarithms of mentioned variables. The list of variables and data sources is shown in the following Table, while any detailed information on the method of their construction is available upon request.

Table 1: Variables used in empirical research

Variable	Label	Source
Natural logarithm of the real per capita final consumption growth rate differential	LNGCIGCJ	Author's calculation based on data downloaded from epp.eurostat.ec.europa.eu/portal/page/portal/statistics/themes
Natural logarithm of bilateral real exchange rate index	LNGEIJ	Author's calculation based on data downloaded from epp.eurostat.ec.europa.eu/portal/page/portal/statistics/themes
Natural logarithm of bilateral nominal exchange rate index	LNGNIJ	Author's calculation based on data downloaded from epp.eurostat.ec.europa.eu/portal/page/portal/statistics/themes
Natural logarithm of the inflation rate differential	LNGPIGPJ	Author's calculation based on data downloaded from epp.eurostat.ec.europa.eu/portal/page/portal/statistics/themes
Natural logarithm of the real per capita GDP growth rate differential	LNGYIGYJ	Author's calculation based on data downloaded from epp.eurostat.ec.europa.eu/portal/page/portal/statistics/themes

Source*:* Author's calculation

Empirical framework for our research is quite simple. The first part of the research refers to complete risk sharing case, where we decomposed real exchange rate to nominal exchange rate and inflation differential. This part of the analysis is actually testing of equations (2) and (5), with the aim to test the presence of Backus–Smith puzzle in the EU. In the second part of the research, we tried to test whether its possible presence can be explained by abandoning the assumption on complete risk sharing (equations 4 and 6). Therefore, this empirical framework provides the possibility to: (a) analyse the presence of Backus–Smith puzzle in the EU, (b) observe separately the influence of nominal exchange rate and inflation differential to the consumption growth differential and (c) try to explain Backus–Smith puzzle through restrictive and disputed complete risk sharing assumption.

5. Empirical results and discussion

Our empirical research was conducted for 27 EU member states (annual observation for period 2000–2011) and it is, as already emphasised, an empirical testing of equations (2), (5), (4) and (6). We applied econometric testing for two sets of panel data. The first sample was drafted in such way that we took the mentioned five countries (Slovenia, Cyprus, Malta, Slovakia and Estonia), using exchange rates of their ex currencies. The second sample, analogously to preliminary analysis, is composed in such a way that we have assumed that these five countries have been the Eurozone members states from the beginning, and we applied Euro instead of their ex currencies. The most important results of econometric testing for equations (2) and (5), using their ex currencies are shown in Table A1 (Appendix). From a total of 10 shown models for equation (2), 5 regression coefficients are either negative or statistically insignificant (topside of Table A1 – models 1, 4, 8, 9 and 10). In the remaining models, the regression coefficient value varies between 0.030 (model 2) to 0.070 (model 3), implying the RRA between 14.29–33.33, which is incredibly high value indicating certain defect of complete risk sharing models, which is why we cannot accept these regressions as evidence of empirical grounds for equation (2). The consistency with equation (2) would imply significantly higher values of regression coefficients (0.25–0.33) (Hess and Shin, 2010: 176). In addition, regression coefficient in representative model 7 is 0.055, and in the case of calculation of White cross-section (White period), robust coefficient covariance estimator is statistically insignificant (significant at the significance level of 5%). Even if we neglect the mentioned statistical insignificance, the coefficient value is so low to accept model 7 as estimation of equation (2) (RRA-18, 18).

Decomposition of real exchange rate to nominal rate and inflation differential (bottom part of Table A1) gives results which are, at first sight, contrary to findings of preliminary correlation analysis. Namely, nominal exchange rate is negative or insignificant in seven out of ten cases (models 1, 2, 4, 5, 8, 9 and 10). Nominal exchange rate is positive and significant only in three cases. Yet, bearing in mind that its value is very low (0.032 – 0.043; RRA: 23.26-31.25), we can conclude with high certainty that these models have serious deficiency. Also, in representative model 7, if we apply White cross-section (White period) robust coefficient covariance estimator, the nominal exchange rate is not significant (it is significant at 10%).

As for inflation differential, it is positive and statistically significant in six cases (models 2, 3, 5, 6, 7 and 10), while the intensity of its influence varies to great extent (0.047–0.923). Regression coefficient in model 7 amounts to 0.149 and implies RRA of approximately 6.7, which is high, but not incredibly high value. Such result could indicate that nominal exchange rate is primary driving force behind the Backus–Smith puzzle.

Yet, abandoning of complete risk sharing assumption (Table A2) shows that omission of relevant explanatory variable is a key lack of previous models. Namely, in all 10 shown models, the coefficient for real exchange rate was either negative (model 7), or insignificant (all other models). On the other hand, economic growth differential has in all equations very high positive influence, which is significant at the significance level of 1%. In addition, 7 out of 10 models, including representative model 3, meets the condition of equation (4) that coefficient for economic growth differential must be positive and lower than 1. Not only do these results deny the complete risk sharing assumption, but they also show that large majority of consumers in the EU behaves according to “rule of thumb” template, i.e. they simply spend their income and do not participate in international risk sharing. Taking into account our findings, less than 1% of consumers participate in international risk sharing.

Findings do not significantly change when we decompose the real exchange rate (bottom part of Table A2). The nominal exchange rate is significant and negative in model 7, while in all other models, including representative model 4, it is insignificant. In addition, inflation differential is either negative or significant (models 3, 4, 5, 6, 8, 9 and 10), or insignificant. Finally, coefficients for economic growth differential are mainly high, positive and significant at the significance level of 1%, which is an extremely severe departure from complete international risk sharing. In other words, econometric testing of equations (4) and (6) resulted in estimation of models, with significantly higher determination coefficients, which indicate several important facts: (a) by including economic growth differential into the model, we do not succeed in explaining the Backus–Smith puzzle, (b) inflation differential is also, in addition to nominal exchange rate, one of driving forces behind the Backus–Smith puzzle, and (c) empirical data strongly denies the complete risk sharing assumption showing that great majority of consumers follow the "rule of thumb" template.

We tested the robustness of these findings by repeating the whole analysis, under the assumption that Slovenia, Cyprus, Malta, Slovakia and Estonia have been the Eurozone member states from the beginning, so we applied Euro instead of their ex currencies (Table A3). Although somewhat different, the obtained results do not affect previous conclusions. Namely, real exchange rate is more commonly positive and statistically significant than when we applied ex currencies (topside of Table A3-models 2, 3, 4, 5, 6, 7, 9 and 10), where coefficient values are still so low that estimated models cannot be accepted as empirical evidence for equation (2) (RRA 12.82-38.46).

In addition, decomposition of real exchange rate brings somewhat different results which do not affect the most important conclusions (bottom part of Table A3). Nominal exchange rate is more commonly positive and significant than in the case when we applied ex currencies (models 2, 4, 5, 6, 7 and 10), but coefficient values are still very low. On the other hand, coefficients for inflation differential greatly vary, they are positive and statistically significant in six cases (models 2, 3, 5, 6, 7 and 10), just as we applied ex currencies. In addition, coefficient values in representative model 7 implies high, but not absolutely incredibly RRA of 6.67, which can lead to the conclusion that inflation differential moves in pro-cyclic manner. However, abandonment of the complete risk sharing assumption completely clarifies this obscurity.

Inclusion of economic growth differential into the regression model shows again that complete risk sharing equations have specification error, i.e. that in the background of Backus–Smith puzzle holds both nominal exchange rate, and inflation differential (Table A4). Real/nominal exchange rate is statistically significant and negative only in model 7, while in majority of other models it is insignificant and negative. In addition, inflation differential is negative and significant in 7 cases (models 3, 4, 5, 6, 8, 9 and 10), while it is insignificant in other models. Economic growth differential coefficient is very high in all models, statistically significant and positive, regardless of whether we apply real exchange rate or its components. All incomplete risk sharing models have significantly higher determination coefficients than the complete risk sharing equations.

Although this research is in terms of methodology, structure, goals and sample countries differs to certain extent from most researches presented in the literature review; it is still possible to make some parallels between them. Firstly, the results of this research which are in favour of presence of Backus–Smith puzzle in 27 EU member states match with most presented papers, since most of them indicate its presence. Secondly, there is partial compatibility of these results and findings presented in a group of papers (Kollmann, 2010; Opazo, 2006; Selaive and Tuesta, 2003), taking into account that they do not challenge the presence of Backus–Smith puzzle, but rather offer certain theoretical explanations for it. Thirdly, although matches can be observed with Hadzi-Vaskov (2008) and Hess and Shin (2010), the main difference from them is that this research did not succeed in locating the nominal exchange rate as the main source of the Backus–Smith puzzle. Finally, with regard to one group of papers (Benigno and Thoenissen, 2003; Corsetti et al., 2006; Ghironi and Melitz, 2005; Mandelman et al., 2010), there is a mismatch because in these researches partial presence of Backus–Smith puzzle is revealed.

6. Conclusions

The results of empirical research we conducted state that we should reject our hypothesis. Results of this analysis unequivocally confirm the presence of Backus–Smith puzzle in 27 EU member states, regardless of whether those are complete or incomplete risk sharing analysis. There are three main conclusions which can be derived from these findings, and these include: (a) that there is solid evidence that Backus–Smith puzzle is present in the EU, (b) that its backgrounds contain both nominal exchange rate, and inflation differential, and (c) that empirical data strongly and conclusively rejects complete risk sharing assumption, but this does not explain Backus–Smith puzzle. Such results are to great extent compatible to the expected ones formulated based on the so far empirical studies, since there are relatively rare researches which partially question the presence of Backus–Smith puzzle. Key contribution of these results is that they provide the basis for rejection of possibility to explain the presence of Backus–Smith puzzle in EU through dynamics of nominal exchange rate or through incomplete risk sharing, which has been offered in relatively newer literature as an explanation for some OECD countries. This is quite significant if we bear in mind that this research is to our knowledge the only analysis of this phenomenon in the EU. Key limitation of this analysis is found in relatively short time period it pertains to. Taking into account lack of empirical studies for the EU, future research should be focused on clarification of several important and interesting issues. Firstly, why do nominal exchange rate and inflation have differential contribution according to Backus–Smith puzzle in EU? Secondly, why international risk sharing is still incomplete. Thirdly, why is the share of "rule of thumb" consumers in EU still so high? In addition, future research should be based on longer time period, and it would be purposeful to extend the analysis to all European Countries during the, 'pre-' and 'post-' adoption period of the Euro. Although this theory does not have any direct implications on the EU policy makers, it would be purposeful to take into account in formulation of exchange rate policy that consumption will not necessarily increase in the countries whose currency is really depreciated, in order to achieve the remaining macroeconomic goals.

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Backus–Smith nedoumica i Europska unija: to nije samo nominalni valutni tečaj[1]

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Sažetak

Cilj ovoga rada jest testiranje prisutnosti i ispitivanje pozadine Backus–Smith nedoumice u EU. Istraživanje se temelji na tehnikama ekonometrijske analize panel podataka, odnosno na ocjenjivanju modela s individualnim i vremenskim efektima, kao i modela bez komponenti slučajne greške. Rezultati istraživanja pokazuju: (a) da postoje ozbiljni dokazi o prisustvu Backus–Smith nedoumice u EU, (b) da je u njenoj pozadini kako nominalni valutni tečaj tako i inflacijski diferencijal i (c) da empirijski podaci snažno i uvjerljivo odbacuju pretpostavku o potpunoj raspodjeli rizika, ali da to ne objašnjava Backus–Smith nedoumicu. Temeljni zaključak ovog istraživanja jest da nominalni valutni tečaj nije jedini izvor Backus–Smith nedoumice u EU, kao što je to slučaj u zemljama članicama OECD-a.

Ključne riječi: *Backus–Smith nedoumica, realni valutni tečaj, potpuna raspodjela rizika, nepotpuna raspodjela rizika*

JEL klasifikacija: *E21, F44, C33*

[1] U radu su prikazani rezultati studije provedene u sklopu projekta III47010: *Društvene transformacije u procesu europskih integracija – multidisciplinarni pristup*, financiranog od strane Ministarstva prosvjete, znanosti i tehnološkog razvoja, Republika Srbija, 2011. – 2015.

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Appendices

Table A1: Complete risk sharing equations with ex currencies

$\ln gc_i - \ln gc_j = \gamma^{-1} \ln ge_{ij}$										
	No Error Component		The One-way Error Component Model				The Two-way Error Component Model			
	PLS		FECS	RECS			FE	RE		
	O	O AR(1)	O	SA	WH	WK	O	SA	WH	WK
	(model 1)	(model 2)	(model 3)	(model 4)	(model 5)	(model 6)	(model 7)	(model 8)	(model 9)	(model 10)
C	0.015*	0.017*	0.016*	0.015*	0.016*	0.016*	**0.016***	0.015*	0.015*	0.015*
	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.002)	**(0.0009)**	(0.006)	(0.006)	(0.005)
LNGEIJ	-0.009	0.030**	0.070*	0.018	0.033**	0.037**	**0.055*(.)(**)**	0.005	0.019	0.022
	(0.015)	(0.014)	(0.016)	(0.015)	(0.015)	(0.015)	**(0.016)**	(0.015)	(0.015)	(0.015)
R^2	*0.0001*	*0.256*	*0.182*	*0.0005*	*0.002*	*0.002*	***0.302***	*0.00004*	*0.0006*	*0.0008*
Adjusted R^2	*-0.0003*	*0.255*	*0.107*	*0.0002*	*0.001*	*0.002*	***0.235***	*-0.0004*	*0.0002*	*0.0004*
$\ln gc_i - \ln gc_j = \gamma^{-1} \ln gE_{ij} - \gamma^{-1}\left(\ln gp_i - \ln gp_j\right) + v_{ij}$										
C	0.014*	0.024*	0.018*	0.015*	0.016*	0.017*	**0.017***	0.015*	0.015*	0.016*
	(0.001)	(0.003)	(0.001)	(0.001)	(0.001)	(0.002)	**(0.001)**	(0.004)	(0.006)	(0.005)
LNGNIJ	0.006	-0.030**	0.043*	0.013	0.024	0.032**	**0.038**(.)(***)**	0.005	0.017	0.024
	(0.016)	(0.012)	(0.016)	(0.015)	(0.016)	(0.016)	**(0.016)**	(0.016)	(0.016)	(0.016)
LNGPIGPJ	-0.052**	0.923*	0.213*	-0.016	0.047**	0.110*	**0.149*(.)(*)**	-0.048**	0.010	0.052**
	(0.021)	(0.041)	(0.025)	(0.020)	(0.022)	(0.023)	**(0.024)**	(0.021)	(0.022)	(0.022)
R^2	*0.004*	*0.366*	*0.200*	*0.001*	*0.002*	*0.009*	***0.310***	*0.003*	*0.0004*	*0.002*
Adjusted R^2	*0.003*	*0.365*	*0.127*	*0.0002*	*0.001*	*0.008*	***0.243***	*0.003*	*-0.0003*	*0.001*

Notes: We formed panel sample by coupling the Eurozone non-member states with all other EU member states, paying attention not to repeat the pairs. We did not couple the Eurozone member states because they use the same currency. Since the analysis covers the period of twelve years and that we have total of 215 pairs of countries (cross-section units), the overall number of observations in panel (balanced) sample is 2,580. For Slovenia, Cyprus, Malta, Slovakia and Estonia we applied exchange rates of their ex currencies. The signs PLS, FECS, RECS, FE and RE respectively stand for panel least squares, fixed effects cross-section, random effects cross-section, fixed effects and random effects. The signs O and AR(1) indicate ordinary coefficient covariance estimator and the fact that disturbance follows the first-order autoregression process. We used SA, WH and WK respectively to denote Swamy – Arora, Wallace – Hussain and Wansbeek – Kapteyn estimator of component variances. Bold model is the model selected as a representative one based on statistical testing results. Bold models contain parentheses next to regression coefficients, containing the signs for statistical significance in case of calculation of White cross-section and White period robust coefficient covariance estimator, where (.), (*), (**) and (***) respectively represent statistical insignificance, and significance at 1%, 5% and 10% significance levels. Generally, (*), (**) and (***) denote significance at 1%, 5% and 10% significance levels, respectively. Standard errors are given in parentheses below the coefficients. The table shows only 10 selected models out of estimated 31 models for equation 2, and 31 models for equation 5. Econometric testing was conducted by applying statistical packages EViews 5.1 and STATA 12.0, and detailed results are available at request.

Source: Author's calculation

Table A2: Incomplete risk sharing equations with ex currencies

$\ln gc_i - \ln gc_j = \theta\gamma^{-1} \ln ge_{ij} + (1-\theta)(\ln gy_i - \ln gy_j) + v_{ij}$										
	No Error Component		The One-way Error Component Model				The Two-way Error Component Model			
	PLS		FEP	REP			FE	RE		
	O	O AR(1)	O	SA	WH	WK	O	SA	WH	WK
	(model 1)	(model 2)	(model 3)	(model 4)	(model 5)	(model 6)	(model 7)	(model 8)	(model 9)	(model 10)
C	-0.002*	-0.001**	**-0.001****	-0.001	-0.001	-0.001	-0.002*	-0.001	-0.001	-0.001
	(0.0006)	(0.0007)	**(0.0005)**	(0.002)	(0.002)	(0.002)	(0.0006)	(0.002)	(0.002)	(0.002)
LNGEIJ	0.004	0.003	**-0.009(.)(.)**	-0.008	-0.008	-0.008	-0.030*	-0.008	-0.008	-0.010
	(0.008)	(0.009)	**(0.008)**	(0.008)	(0.008)	(0.008)	(0.009)	(0.008)	(0.008)	(0.008)
LNGYIGYJ	1.025*	1.02*	**0.992*(*)(*)**	0.995*	0.994*	0.994*	1.039*	0.995*	0.994*	0.998*
	(0.012)	(0.014)	**(0.012)**	(0.012)	(0.012)	(0.012)	(0.015)	(0.012)	(0.012)	(0.012)
R^2	*0.735*	*0.744*	***0.756***	*0.722*	*0.722*	*0.722*	*0.777*	*0.722*	*0.721*	*0.718*
Adjusted R^2	*0.735*	*0.743*	***0.754***	*0.722*	*0.722*	*0.721*	*0.755*	*0.722*	*0.721*	*0.717*
$\ln gc_i - \ln gc_j = \theta\gamma^{-1} \ln gE_{ij} - \theta\gamma^{-1}(\ln gp_i - \ln gp_j) + (1-\theta)(\ln gy_i - \ln gy_j) + v_{ij}$										
C	-0.002*	-0.001***	-0.001*	**-0.001**	0.001	-0.001	-0.002*	-0.001	-0.001	-0.002
	(0.0006)	(0.0007)	(0.0005)	**(0.002)**	(0.002)	(0.002)	(0.0006)	(0.002)	(0.002)	(0.002)
LNGNIJ	0.009	0.0007	-0.0004	**0.0003(.)(.)**	0.0002	0.0001	-0.031*	0.0004	0.0002	-0.004
	(0.008)	(0.009)	(0.009)	**(0.008)**	(0.008)	(0.008)	(0.009)	(0.008)	(0.008)	(0.009)
LNGPIGPJ	-0.014	0.018	-0.035*	**-0.033*(.)(*)**	-0.033*	-0.033*	-0.019	-0.033*	-0.033*	-0.032*
	(0.011)	(0.016)	(0.011)	**(0.011)**	(0.011)	(0.011)	(0.014)	(0.011)	(0.011)	(0.011)
LNGYIGYJ	1.024*	1.022*	0.988*	**0.991*(*)(*)**	0.990*	0.990*	1.037*	0.991*	0.990*	0.996*
	(0.012)	(0.014)	(0.012)	**(0.012)**	(0.012)	(0.012)	(0.015)	(0.012)	(0.012)	(0.012)
R^2	*0.736*	*0.744*	*0.757*	***0.723***	*0.723*	*0.723*	*0.777*	*0.723*	*0.723*	*0.718*
Adjusted R^2	*0.735*	*0.743*	*0.755*	***0.723***	*0.723*	*0.723*	*0.755*	*0.723*	*0.723*	*0.717*

Notes: We formed panel sample by coupling the Eurozone non-member states with all other EU member states, paying attention not to repeat the pairs. We did not couple the Eurozone member states because they use the same currency. Since the analysis covers the period of twelve years and that we have total of 215 pairs of countries (cross-section units), the overall number of observations in panel (balanced) sample is 2,580. For Slovenia, Cyprus, Malta, Slovakia and Estonia we applied exchange rates of their ex currencies. The signs PLS, FEP, REP, FE and RE respectively stand for panel least squares, fixed effects period, random effects period, fixed effects and random effects. The signs O and AR(1) indicate ordinary coefficient covariance estimator and the fact that disturbance follows the first-order autoregression process. We used SA, WH and WK respectively to denote Swamy - Arora, Wallace - Hussain and Wansbeek - Kapteyn estimator of component variances. Bold model is the model selected as a representative one based on statistical testing results. Bold models contain parentheses next to regression coefficients, containing the signs for statistical significance in case of calculation of White cross-section and White period robust coefficient covariance estimator, where (.), (*), (**) and (***) respectively represent statistical insignificance, and significance at 1%, 5% and 10% significance levels. Generally, (*), (**) and (***) denote significance at 1%, 5% and 10% significance levels, respectively. Standard errors are given in parentheses below the coefficients. The table shows only 10 selected models out of estimated 42 models for equation 4, and 42 models for equation 6. Econometric testing was conducted by applying statistical packages EViews 5.1 and STATA 12.0, and detailed results are available at request.

Source: Author's calculation

Table A3: Complete risk sharing equations with Euro

$\ln gc_i - \ln gc_j = \gamma^{-1} \ln ge_{ij}$										
	No Error Component		The One-way Error Component Model				The Two-way Error Component Model			
	PLS		FECS	RECS			FE	RE		
	O	O AR(1)	O	SA	WH	WK	O	SA	WH	WK
	(model 1)	(model 2)	(model 3)	(model 4)	(model 5)	(model 6)	(model 7)	(model 8)	(model 9)	(model 10)
C	0.015*	0.017*	0.016*	0.016*	0.016*	0.016*	**0.016***	0.015*	0.015*	0.015*
	(0.001)	(0.002)	(0.0010)	(0.001)	(0.001)	(0.002)	**(0.0009)**	(0.006)	(0.006)	(0.005)
LNGEIJ	0.005	0.036*	0.078*	0.030**	0.045*	0.048*	**0.058*(.)(**)**	0.011	0.026***	0.028***
	(0.016)	(0.014)	(0.016)	(0.015)	(0.015)	(0.015)	**(0.016)**	(0.015)	(0.015)	(0.015)
R^2	*0.00004*	*0.256*	*0.183*	*0.002*	*0.003*	*0.004*	***0.303***	*0.0002*	*0.001*	*0.001*
Adjusted R^2	*-0.0003*	*0.256*	*0.109*	*0.001*	*0.003*	*0.003*	***0.236***	*-0.0002*	*0.0007*	*0.001*
$\ln gc_i - \ln gc_j = \gamma^{-1} \ln gE_{ij} - \gamma^{-1}\left(\ln gp_i - \ln gp_j\right) + v_{ij}$										
C	0.015*	0.024*	0.018*	0.015*	0.016*	0.017*	**0.017***	0.015*	0.015*	0.016*
	(0.001)	(0.003)	(0.001)	(0.001)	(0.001)	(0.002)	**(0.001)**	(0.004)	(0.006)	(0.005)
LNGNIJ	0.021	-0.028**	0.050*	0.028***	0.036**	0.043*	**0.041**(.)(***)**	0.014	0.023	0.029***
	(0.016)	(0.012)	(0.016)	(0.015)	(0.016)	(0.016)	**(0.016)**	(0.016)	(0.016)	(0.016)
LNGPIGPJ	-0.042**	0.924*	0.218*	-0.004	0.057**	0.116*	**0.150*(.)(*)**	-0.040***	0.015	0.055**
	(0.021)	(0.041)	(0.025)	(0.020)	(0.022)	(0.023)	**(0.024)**	(0.021)	(0.022)	(0.022)
R^2	*0.005*	*0.366*	*0.201*	*0.002*	*0.003*	*0.010*	***0.310***	*0.003*	*0.0008*	*0.003*
Adjusted R^2	*0.004*	*0.365*	*0.128*	*0.001*	*0.002*	*0.009*	***0.243***	*0.003*	*0.00007*	*0.002*

Notes: We formed panel sample by coupling the Eurozone non-member states with all other EU member states, paying attention not to repeat the pairs. We did not couple the Eurozone member states because they use the same currency. Since the analysis covers the period of twelve years and that we have total of 215 pairs of countries (cross-section units), the overall number of observations in panel (balanced) sample is 2,580. For Slovenia, Cyprus, Malta, Slovakia and Estonia we applied exchange rates of Euro. The signs PLS, FECS, RECS, FE and RE respectively stand for panel least squares, fixed effects cross-section, random effects cross-section, fixed effects and random effects. The signs O and AR(1) indicate ordinary coefficient covariance estimator and the fact that disturbance follows the first-order autoregression process. We used SA, WH and WK respectively to denote Swamy - Arora, Wallace - Hussain and Wansbeek - Kapteyn estimator of component variances. Bold model is the model selected as a representative one based on statistical testing results. Bold models contain parentheses next to regression coefficients, containing the signs for statistical significance in case of calculation of White cross-section and White period robust coefficient covariance estimator, where (.), (*), (**) and (***) respectively represent statistical insignificance, and significance at 1%, 5% and 10% significance levels. Generally, (*), (**) and (***) denote significance at 1%, 5% and 10% significance levels, respectively. Standard errors are given in parentheses below the coefficients. The table shows only 10 selected models out of estimated 30 models for equation 2, and 30 models for equation 5. Econometric testing was conducted by applying statistical packages EViews 5.1 and STATA 12.0, and detailed results are available at request.

Source: Author’s calculation

Table A4: Incomplete risk sharing equations with Euro

$\ln gc_i - \ln gc_j = \theta\gamma^{-1} \ln ge_{ij} + (1-\theta)(\ln gy_i - \ln gy_j) + v_{ij}$										
	No Error Component		The One-way Error Component Model				The Two-way Error Component Model			
	PLS		FEP	REP			FE	RE		
	O	O AR(1)	O	SA	WH	WK	O	SA	WH	WK
	(model 1)	(model 2)	(model 3)	(model 4)	(model 5)	(model 6)	(model 7)	(model 8)	(model 9)	(model 10)
C	-0.002*	-0.001**	**-0.001****	-0.001	-0.001	-0.001	-0.002*	-0.001	-0.001	-0.001
	(0.0006)	(0.0007)	**(0.0005)**	(0.002)	(0.002)	(0.002)	(0.0006)	(0.002)	(0.002)	(0.002)
LNGEIJ	0.004	0.002	**-0.010(.)(.)**	-0.009	-0.009	-0.009	-0.026*	-0.009	-0.009	-0.010
	(0.008)	(0.009)	**(0.008)**	(0.008)	(0.008)	(0.008)	(0.009)	(0.008)	(0.008)	(0.008)
LNGYIGYJ	1.025*	1.023*	**0.992*(*)(*)**	0.995*	0.994*	0.994*	1.038*	0.995*	0.995*	0.997*
	(0.012)	(0.014)	**(0.012)**	(0.012)	(0.012)	(0.012)	(0.015)	(0.012)	(0.012)	(0.012)
R^2	*0.735*	*0.744*	***0.756***	*0.722*	*0.722*	*0.722*	*0.776*	*0.722*	*0.721*	*0.719*
Adjusted R^2	*0.735*	*0.743*	***0.754***	*0.722*	*0.722*	*0.722*	*0.755*	*0.722*	*0.721*	*0.718*
$\ln gc_i - \ln gc_j = \theta\gamma^{-1} \ln gE_{ij} - \theta\gamma^{-1}(\ln gp_i - \ln gp_j) + (1-\theta)(\ln gy_i - \ln gy_j) + v_{ij}$										
C	-0.002*	-0.001***	-0.001*	**-0.002**	-0.001	-0.001	-0.002*	-0.002	-0.001	-0.002
	(0.0006)	(0.0007)	(0.0005)	**(0.002)**	(0.002)	(0.002)	(0.0006)	(0.002)	(0.002)	(0.002)
LNGNIJ	0.010	0.0002	-0.001	**-0.0004(.)(.)**	-0.0006	-0.0006	-0.027*	-0.0004	-0.0006	-0.003
	(0.008)	(0.009)	(0.009)	**(0.009)**	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
LNGPIGPJ	-0.013	0.018	-0.035*	**-0.033*(.)(*)**	-0.034*	-0.034*	-0.016	-0.033*	-0.034*	-0.032*
	(0.011)	(0.016)	(0.011)	**(0.011)**	(0.011)	(0.011)	(0.014)	(0.011)	(0.011)	(0.011)
LNGYIGYJ	1.023*	1.022*	0.988*	**0.991*(*)(*)**	0.990*	0.990*	1.036*	0.991*	0.990*	0.995*
	(0.012)	(0.014)	(0.012)	**(0.012)**	(0.012)	(0.012)	(0.015)	(0.012)	(0.012)	(0.012)
R^2	*0.736*	*0.744*	*0.757*	***0.723***	*0.723*	*0.723*	*0.776*	*0.723*	*0.723*	*0.719*
Adjusted R^2	*0.735*	*0.743*	*0.755*	***0.723***	*0.723*	*0.723*	*0.755*	*0.723*	*0.723*	*0.718*

Notes: We formed panel sample by coupling the Eurozone non-member states with all other EU member states, paying attention not to repeat the pairs. We did not couple the Eurozone member states because they use the same currency. Since the analysis covers the period of twelve years and that we have total of 215 pairs of countries (cross-section units), the overall number of observations in panel (balanced) sample is 2,580. For Slovenia, Cyprus, Malta, Slovakia and Estonia we applied exchange rates of Euro. The signs PLS, FEP, REP, FE and RE respectively stand for panel least squares, fixed effects period, random effects period, fixed effects and random effects. The signs O and AR(1) indicate ordinary coefficient covariance estimator and the fact that disturbance follows the first-order autoregression process. We used SA, WH and WK respectively to denote Swamy - Arora, Wallace - Hussain and Wansbeek - Kapteyn estimator of component variances. Bold model is the model selected as a representative one based on statistical testing results. Bold models contain parentheses next to regression coefficients, containing the signs for statistical significance in case of calculation of White cross-section and White period robust coefficient covariance estimator, where (.), (*), (**) and (***) respectively represent statistical insignificance, and significance at 1%, 5% and 10% significance levels. Generally, (*), (**) and (***) denote significance at 1%, 5% and 10% significance levels, respectively. Standard errors are given in parentheses below the coefficients. The table shows only 10 selected models out of estimated 41 models for equation 4, and 41 models for equation 6. Econometric testing was conducted by applying statistical packages EViews 5.1 and STATA 12.0, and detailed results are available at request.

Source: Author's calculation