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Real Interest Rate and Exchange Rate Divergences within the EZ12: Evidence Based at Mean Group Estimators

Divergencias de la tasa de interés real y la tasa de cambio dentro del EZ12: evidencia basada en estimadores de grupos medios

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Abstract

Since nominal interest rate and nominal exchange rate are common for the Euro-zone (EZ) members, inflation differentials initiate real interest rate and real exchange rate divergences with further spill-over effects. The aim of the research is to investigate in which extent national price level, real interest rate and real exchange rate, co-move or diverge from supranational EZ variables. The research results, based on heterogeneous dynamic macro-panel data of 12 initial EZ members in the period 1999Q1-2019Q4, confirm heterogeneous adjustment, as well as the lack of balancing towards equilibrium, as a sign of EZ vulnerability.

Key words: Euro-zone, price dynamics, real exchange rate, real interest rate, heterogeneous panel model.

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Resumen

Dado que la tasa de interés nominal y la tasa de cambio nominal son comunes para los miembros de la zona euro (EZ), los diferenciales de inflación inician divergencias en la tasa de interés real y en la tasa de cambio real con más efectos indirectos. El objetivo de la investigación es indagar en qué medida el nivel de precios nacional, la tasa de interés real y el tipo de cambio real se mueven conjuntamente o divergen de las variables EZ supranacionales. Los resultados de la investigación, basados en datos heterogéneos de macropanel dinámico de 12 miembros iniciales de la EZ en el período 1999Q1-2019Q4, confirman un ajuste heterogéneo, así como la falta de equilibrio hacia el equilibrio, como un signo de vulnerabilidad de la EZ.

Palabras clave: Eurozona, dinámica de precios, tipo de cambio real, tipo de interés real, modelo de panel heterogéneo.

JEL classification / Clasificación JEL: E52; E58.

1. Introduction

Monetary union as a rigid exchange rate arrangement assumes the sacrifice of a sovereign monetary policy of its members states, the loss of exchange rate policy and expenditure-switching adjustment mechanism. In addition to the fact that single monetary policy implies common nominal exchange rate and the absence of a exchange rate as a shock absorber, unified monetary policy with the common nominal interest rate also excludes real interest rate as an adjustment mechanism towards more favorable national macro-circumstances. It is of huge importance that supranational monetary policy doesn't amplify the shocks and produce pro-cyclic effects, which is unavoidable if members' economies are divergent and heterogeneous.

Monetary union cannot be sustainable with divergent price dynamics of its member countries. Unification of nominal variables at the monetary union level, such as nominal euro exchange rate and ECB's interest rate, does not exclude divergence of real variables at national levels. The divergence in price dynamics implies differences in real interest rates and real exchange rate, which induces further macro-imbalances. Therefore, an important issue within monetary union is to keep national price dynamics as convergent as possible. Otherwise, a vicious cycle is set in motion, culminating with amplified economic cycles. These are circumstances in which supranational monetary authority cannot function in 'one size fits all', but rather 'one size fits some' manner.

The aim of this paper is to identify the vulnerability of the EZ related with inflation divergence transmitted into real interest rate and real exchange rate divergences within the monetary union. This paper contributes to the literature by identifying and stressing vulnerability points of the EZ, namely national price dynamics as a trigger to real interest rate and real exchange rate divergences. The relations between national and supranational EZ variables are empirically investiged with Pooled Mean Group (PMG) and Mean Group (MG) estimators of the macro-panel model for 12 initial EZ members in the period 1999Q1-2019Q4. The research is performed in order to identify homogeneous long-run and heterogeneous short-run relations between national (inflation, real interest rate, real exchange rate) and supranational variables (EZ inflation, nominal ECB interest rate, nominal euro exchange rate), as well as the existence of adjustment towards equilibrium (cointegration) as a sign of stabilization mechanism within a monetary union. The absence of an adjustment mechanism and heterogeneity of the short-run and long-run

convergences towards the EZ variables will be signified as a systematic risk for a monetary union sustainability.

The paper is structured as follows: after Introduction part, Section 2 shows Literature survey related with the focussed research issue; Descriptive Analysis is presented in the Section 3; Empirical research is exposed through Methodological framework (Section 4) and following Discussion of crucial results (Section 5); finally, Concluding remarks are highlighted in the last Section 6.

2. Literature Review

Rigid exchange rate arrangements in the form of a currency board, an euroization/dollarization, as well as a monetary union, imply the loss of monetary autonomy. Under rigid monetary framework it is impossible to use exchange rate as a shock absorber and the loss of this important exchange rate role has been stressed during the global crisis period (Beker Pucar and Glavaški, 2020a; Marjanac, 2020). It is a well-known fact that countries in the EZ are extremely heterogeneous from an economic viewpoint. Countries with high GDP per capita levels and GDP growth rates, low unemployment rates and large external surpluses, coexist with others faring worse in mentioned indicators (Bonatti and Fracasso, 2017; De Grauwe, 2018).

The global crisis has highlighted already accumulated macroeconomic imbalances and vulnerability of the EZ in the pre-crisis period, culminating with the debt 2010 crisis. The EZ crisis was a combination of financial crisis and balance-of-payment crisis in some countries, with the sluggish growth in another countries within the monetary union. Europe was confronted with the mentioned difficulties before, but never all at the same time, in so many countries sharing a currency and consequently with limited adjustment mechanisms (Mongelli, 2013). The accumulation of imbalances in the first decade of the EZ became unsustainable and triggered a painful correction, which led to a double-dip recession in the EZ between 2009 and 2012 (Pierluigi and Sondermann, 2018). However, significant differences are evident in terms of their post-crisis adjustment. While some countries have regained a stable economic growth trajectory and pre-crisis output levels, other countries have experienced recurrent economic crisis (Stanišić, 2012; Bartlett and Prica, 2016; Ehmer, 2017; Onaran, 2018).

It has emerged that one currency cannot fit all unless the member countries move swiftly to address the underlying causes of economic divergence (Micossi, 2015). Namely, the common monetary framework cannot function adequately with divergent members subject to asymmetric shocks. The ECB's monetary decision-making was mostly criticized because it affects EZ members differently and could drive their economies out of alignment (Salvatore, 2002). The ECB's monetary policy is not effective if monetary transmission is asymmetric to the member states. Moreover, 'one-size-fits-all' monetary policy

created problems for peripheral economies that had different needs from the core countries. Asymmetric and heterogeneous response of EZ member states to ECB's monetary impulses, especially related to core-periphery dichotomy, German dominance hypothesis, and 'one size fits some' monetary policy are also emphasized in Kool (2005), Torben, Torben, and Kempa (2008), Petrova (2010), Micossi (2015), Wortmann and Stahl (2016), Botta, Tippet, and Onaran (2018), etc.

The stability of the monetary union implies the uniformity of the price dynamics among member states (Haan, 2010; Karanasos et al., 2016; Díaz Roldán, Pérez de la Cruz and Ramos-Herrera, 2018). In the run-up to the establishment of the monetary union, a marked process of convergence took place among all the countries that had decided to enter the EZ. Peripheral countries particularly succeeded in lowering their inflation and government deficits through contractionary monetary and fiscal policies, although initially these economies didn't meet the requirements for admission (Acocella and Pasimeni, 2018). After admission, there were no similar expectations and policies became less geared to control inflation. While nominal interest rates began to converge, inflation rose, practically in all countries, but particularly in peripheral EZ members (Busetti et al., 2007).

Real interest rates, i.e. common nominal interest rate adjusted with national inflation, could drastically diverge within the monetary union and in the wrong direction, thus emphasizing the boom-bust cycles. Inflation differentials cause different national short-term real interest rates, which affect domestic aggregate demand in each country differently (Angeloni and Ehrmann, 2004). This is especially worrying for heterogeneous and decentralized monetary union such as the EZ without automatic fiscal transfers. Greater convergence of interest rates than inflation produced lower real interest rates during the early years of the EZ, helping to fuel unsustainable capital inflows into lower income countries. In the pre-crisis period, markets were 'blind' to whether the EZ was truly an optimum currency area due to the prevailing assumption that a common currency entails shared risk (De Larosière, 2012; Franks et al., 2018). Due to shared risk beliefs, interest rates of EZ countries, from Germany to Greece, were on an almost identical trajectory in the pre-crisis period. It is only in 2009 that markets 'wake up' with the understanding that Greek bonds (later bonds of other peripheral economies) are not as secure as bonds of other EZ countries, mainly as a result of divergences between EZ members. When markets 'awoke' to accept the reality of the divergence of EZ countries in 2009 and 2010, long-term interest rates diverged between countries and rose sharply for the countries considered most at risk (Arghyrou, Gregoriou and Kontonikas, 2007).

The inflation divergences, which are at the root of the vicious cycle, exert pressure to the external equilibrium in its trade and capital aspect. From the trade aspect, higher inflation in the combination with unified nominal exchange rate means real exchange rate appreciation or worsened competitiveness. The outcome is rising current account deficit which is fundamental or structural in

its nature, hence with the necessity for adjustment. The external adjustment in a monetary union is constrained to painful expenditure-reducing adjustment, since expenditure-switching mechanism isn't available anymore (Issing, 2006). Expenditure-reducing adjustment, however, was successfully delayed due to the surplus in their capital accounts. Namely, real interest rate differentials generate destabilizing capital inflows or outflows. In that way countries with lower real interest rate attracts capital from the core, accompanied with higher credit demand, investment, with further inflationary pressures and macroeconomic overheating (Stockhammer, 2011; Lane and McQuade, 2013). The relation between current and capital account, as well as inflation divergences, shouldn't be observed independently from the two different (but interlinked) growth models within the EZ. Export-led growth model in the core vs credit-led growth in the periphery, generated persistent divergences in inflation, as well as real exchange rates. The excess of savings over investments in the core were channelled (through growing financial integration) towards higher inflationary periphery, thus fuelling overall divergence (Bibow, 2012; Fernandez-Villaverde et al., 2013; Johnston and Regan, 2016).

In some extent, diverging real variables according to inflation diversities are natural phenomenon in the monetary union. However, an inflation divergence calls for a coordination of national structural and fiscal policies for a single monetary policy to work without amplifying imbalances or in a pro-cyclic manner (Stundžienė, Ramirez and Pabsdorf, 2020). A supranational monetary authority should be supported to enforce stronger coordination of national policies in order to avoid misalignments and to provide stable growth for member states. If countries reach a consensus on fiscal union with financial transfers between member states, then these transfers can serve as a replacement for the missing flexible exchange rate and even as a substitute for a rigid labour market (Eichengreen, 1991; Feldstein, 1997; Horvath and Komarek, 2002; Verdun, 2007; Baldwin and Wyplosz, 2012; Pisani-Ferry, 2012; Beker Pucar and Glavaški, 2020b).

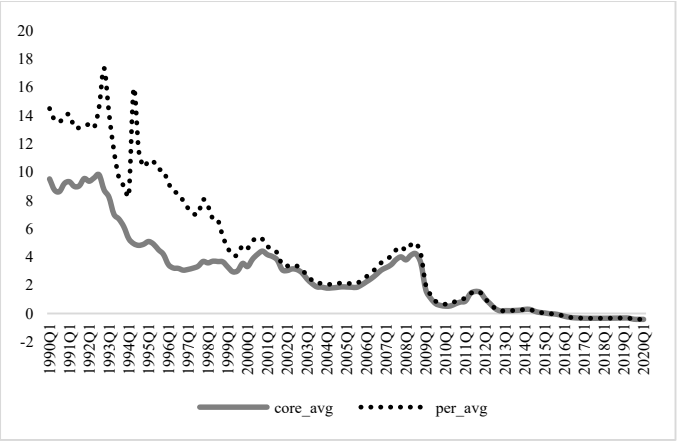
3. Descriptive Analysis

For the purpose of descriptive analysis, in order to shed more light into divergences within the EZ since 1990 (when monetary integration was initiated) until 2020, the figures are simplified showing the average of the core (Austria, Belgium, Finland, France, Germany, Luxembourg, Netherlands) and the periphery (Greece, Spain, Portugal, Ireland, Italy) of EZ12 countries. Showing the focused indicators for all (here analysed) initial EZ12 members would be space demanding. Thus, the heterogeneity will be stressed in the following empirical section with the estimated heterogeneous coefficients for each EZ12 member.

Figure 1 shows the nominal interest rate of the EZ12 members in the period from the beginning of monetary unification (early 1990s) to 2020. It is clear

that the interest rate of the peripheral EZ economies was on average higher than at the beginning of the 1990s, but that over time it converged towards the interest rate of the EZ core. Of course, with the formation of the EZ in 1999, nominal short-term interest rates are equalized or unified at the EZ level.

Figure 1. Nominal short-run interest rate in the EZ core and periphery in the period 1990-2020

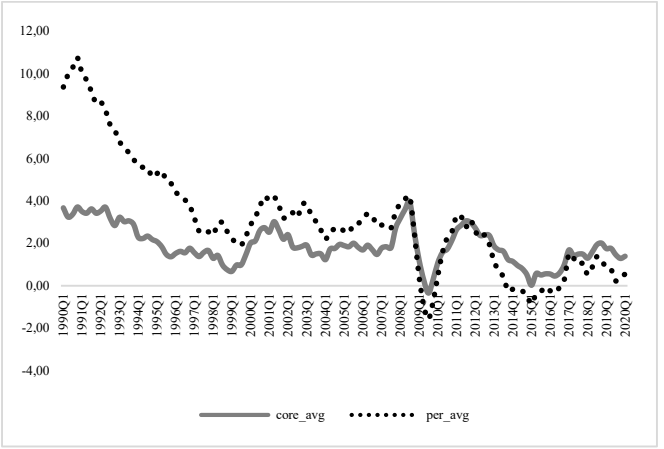


Note: core_avg – average for the EZ core; per_avg – average for the EZ periphery.
Source: authors according the quarterly data of IMF International Financial Statistics.

Figure 2 shows the average inflation rate for the EZ core and periphery in the same observed period. As expected, the inflation rate of the more vulnerable peripheral EZ economies was at a significantly higher level compared to the average inflation rate of the core. Monetary convergence in the period before joining the EZ, over time, brought the periphery inflation rate closer to the traditionally lower core inflation rate, but not completely. It could be noticed that from the formation of the EZ (1999) to the outbreak of the global crisis (2008), the inflation rate of the periphery has been at a higher level compared to the core. Higher inflation in certain monetary union members implies, as explained above, a series of chain repercussions in the direction of growing macro-divergences of the member states. Figure 2 also reflects that peripheral countries experienced painful restrictive adjustment in the post-global crisis period (average inflation rate is even below the average of the core).

Since the beginning of the 1990s, the higher inflation rate of peripheral countries has been transferred to a lower real interest rate as the basis for macroeconomic overheating (Figure 3). On the other hand, more stable core countries recorded higher real interest rates due to traditionally lower inflation. Since the formation of the EZ in 1999, the single monetary policy (i.e. common nominal short-term interest rate) combined with still evident

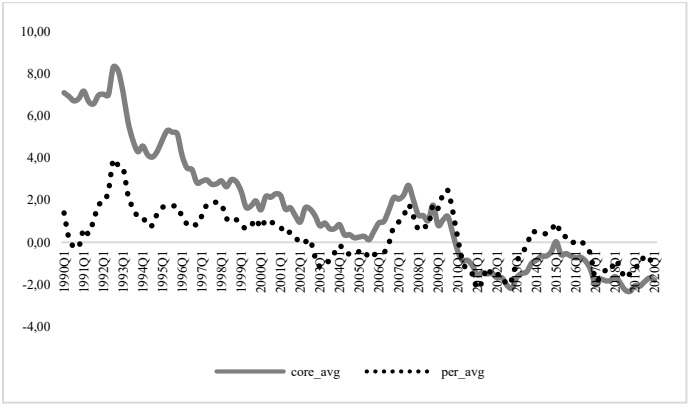
Figure 2. Average inflation rate for the EZ core and periphery in the period 1990-2020



Note: core_avg – average for the EZ core; per_avg – average for the EZ periphery.
Source: authors according the quarterly data of IMF International Financial Statistics.

inflation differentials (Figure 2), continue to generate a disparity in real interest rates. The situation changed in the second decade of the EZ functioning, when restrictive (deflationary) adjustment of the peripheral economies contributed to an increase of real interest rates as a reflection of their slowdown.

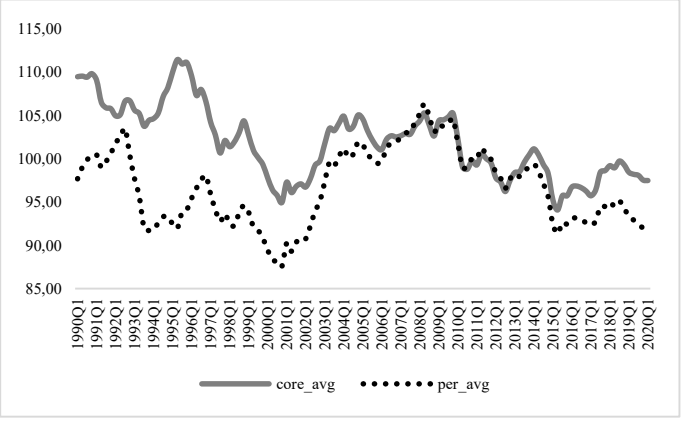
Figure 3. Real interest rate of the EZ core and periphery in the period 1990-2020



Note: core_avg – average for the EZ core; per_avg – average for the EZ periphery.
Source: authors according the quarterly data of IMF International Financial Statistics.

As previously emphasized, the inflation differential is a trigger for further asymmetries within the single currency area. Thus, the inflation differentials along with the common (euro) nominal exchange rate initiate the divergence of members' real exchange rates (Figure 4). Until the formation of the EZ in 1999, real exchange rates of peripheral countries recorded appreciation tendency as a sign of deteriorated competitiveness. Core countries have had lower inflation and higher real exchange rate, with consequently favourable competitiveness and current account position. With the exception of real exchange rate convergence in the years following the global crisis, it is evident that since the euro introduction real exchange rates of the periphery have inclined towards appreciation and worsening of their competitiveness.

Figure 4. Real effective exchange rate of the EZ core and the periphery in the period 1990-2020

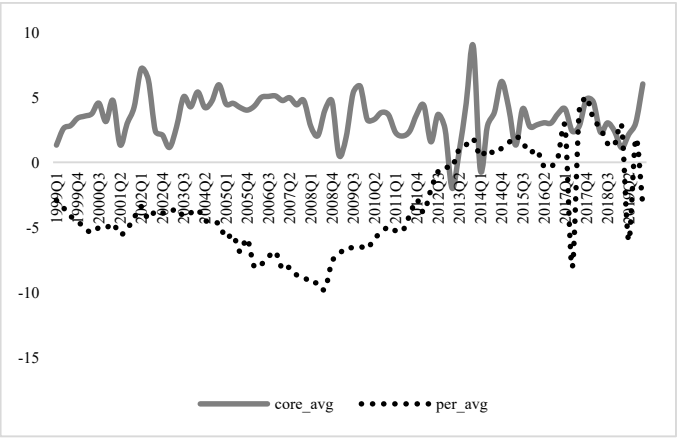


Note: core_avg – average for the EZ core; per_avg – average for the EZ periphery.
Source: authors according the quarterly data of IMF International Financial Statistics.

Quite expectedly, higher inflation and real exchange rate appreciation are compatible with current account deficit of the EZ periphery, which has been evident since the introduction of the euro in 1999 (Figure 5). Member states of the EZ has faced the global crisis with a huge asymmetry in terms of external position. Core countries recorded current account surplus, while peripheral countries recorded chronic and growing current account deficit. The situation was improved somewhat in the post-crisis period, but peripheral countries have continued to incline towards current account deficit.

The previous figures established (previously theoretically exposed) empirical links between nominal interest rates, inflation, real interest rates, real exchange rates and external position of the EZ members. It was pointed out that peripheral countries recorded negative indicators in terms of higher inflation, worsened competitiveness (appreciation of the real exchange rate),

Figure 5. Current account of the EZ core and the periphery in the period 1999-2020



Note: core_avg – average for the EZ core; per_avg – average for the EZ periphery.
Source: authors according the quarterly data of IMF International Financial Statistics.

lower real interest rates and current account deficits. We can conclude that monetary union is difficult to maintain with divergent price dynamics of its members. In order to shed more light into this issue, the next sections present the empirical investigation of the short-run, long-run convergence/divergence of national price dynamics, real interest rates and real exchange rates in relation to the unified EZ variables, as well as the insights to whether there is a balancing mechanism towards equilibrium between analysed national and supranational EZ variables.

4. Methodological Framework

The sample consists from 12 EZ initial members: Austria, Belgium, Finland, France, Germany, Luxembourg, Netherlands (mostly referred as the core), Greece, Spain, Portugal, Ireland, Italy (mostly referred as the periphery). The research period is 1999Q1-2019Q4. For model estimation are used quarterly variables obtained from IMF International Finance Statistics and Eurostat (Table 1). National variables (consumer price index, real interest rate, real effective exchange rate) are brought into a connection with the unified or supranational variables at the EZ level (EZ consumer price index, ECB's short-run interest rate, euro nominal effective exchange rate).

Macro-panel consists from 12 initial EZ members (N-dimension) in the time framework 1999Q1-2019Q4 (84 quarters as the T-dimension). One of the central findings from the large N and large T literature, however, is that

Table 1. Variables' sources and description

Symbol	Short description	Source
cpi	Consumer price index, all prices	IMF - International Finance Statistics
ezcpi	Harmonized consumer price index, Euro-Zone	IMF - International Finance Statistics
inf	CPI, all items, percentage change, corresponding period previous year, percent	IMF - International Finance Statistics
ezir	Money market rate, three-month, Euro-zone	Eurostat
rir	Real interest rate calculated as difference between ezir and inf	Authors' calculation
reer	Real effective exchange rate based on CPI, index	IMF - International Finance Statistics
ezneer	Nominal effective exchange rate, index, Euro-Zone	IMF - International Finance Statistics

Source: The authors.

the assumption of homogeneity of slope parameters is often inappropriate (Im, Pesaran and Shin, 2003). Therefore, in this research authors apply the techniques proposed by Pesaran, Shin and Smith (1997, 1999) to estimate non-stationary dynamic panels in which the parameters are heterogeneous across units. With the increase in time observations inherent in large N and large T dynamic panels, non-stationarity is also a concern. Recent papers by Pesaran, Shin and Smith (1999) offer two important new techniques to estimate non-stationary dynamic panels in which the parameters are heterogeneous across groups: the Mean-Group (MG) and Pooled Mean-Group (PMG) estimators. MG is based on estimation of N time-series regressions and averages coefficients, while PMG is based on equal long-run relationship across all panel units and averaging of coefficients (short-run adjustments).

The choice among these estimators faces a general trade-off between consistency and efficiency (Pesaran and Smith, 1995). Hausman test is applied to distinguish whether restriction related to homogeneous long-run relationship in PMG model is true. If long-run relationship is homogeneous, namely, if the restriction in PMG model is true, the estimates are efficient and consistent (PMG method gives efficient and consistent estimates). In contrary, heterogeneous long-run equilibrium relationships mean inconsistent PMG estimates. MG model assumes heterogeneous long-run equilibrium relationships and provides consistent estimates in both cases (Blackburne and Frank, 2007). Short-run adjustments are heterogeneous in both models. PMG and MG estimators are particularly useful in exploring adjustment mechanisms within the monetary union when the long run is given by conditions expected to be homogeneous across countries, while the short-run adjustment depends on member characteristics. The error correction (ec) coefficient or parameter (adjustment parameter or speed of adjustment) is expected to be significantly negative, in which case there is a long-term relation or convergence between the variables. Otherwise, there is no evidence of long-term relationship.

Thus, the research methodology in this paper is based on heterogeneous, non-stationary panel data framework, which allows the analysis on national adjustments across EZ members over the research period. Panel error-correction model is described as:

$$\Delta lt_{it} = \Phi_i(t - \theta_i lg_{it}) + \sum_{j=1}^{p-1} \lambda_{ij}^{*} \Delta lt_{i,t-1} + \sum_{j=0}^{q-1} \delta_{ij}^{*} \Delta \lg_{i,t-j} + \mu_i + u_{it} \quad (1)$$

where, Φ_i is error-correction parameter, indicating speed of adjustment to long-run equilibrium relationship for each EZ member state, θ_i is long — run relationship, λ_{ij}^{*} is coefficient of lagged dependent variable, δ_{ij}^{*} is short-run parameters for each panel unit (EZ member state), μ_i represents individual effects. Error-correction (ec) parameter, Φ_i, is the most important part of the model, showing speed of adjustment to long-run equilibrium relationship, in the case when Φ_i is significantly negative.

Since the root of divergence is price differential or price divergence at national vs supranational level of the monetary union, following model is estimated first:

$$\Delta cpi_{it} = \Phi_i \left(t - \theta_i ezcpi_{it}\right) + \sum_{j=1}^{p-1} \lambda_{ij}^{*} \Delta cpi_{i,\,t-j} + \sum_{j=0}^{q-1} \delta_{ij}^{*} \Delta ezcpi_{i,t-j} + \mu_i + u_{it} \quad (2)$$

Price divergence within the monetary union has spill-over effects to real interest rate and real exchange rate divergences. The model for identification of connection between national real interest rate and supranational ECB's short-run interest rate is:

$$\Delta rir_{it} = \Phi_i \left(t - \theta_i ezir_{it}\right) + \sum_{j=1}^{p-1} \lambda_{ij}^{*} \Delta rir_{i,t-1} + \sum_{j=0}^{q-1} \delta_{ij}^{*} \Delta ezir_{i,t-j} + \mu_i + u_{it} \quad (3)$$

The model of relation between national real exchange rate and supranational euro-nominal exchange rate is:

$$\Delta reer_{it} = \Phi_i \left(t - \theta_i ezneer_{it}\right) + \sum_{j=1}^{p-1} \lambda_{ij}^{*} \Delta reer_{i,t-1} + \sum_{j=0}^{q-1} \delta_{ij}^{*} \Delta ezneer_{i,t-j} + \mu_i + u_{it} \quad (4)$$

The procedure performed in order to obtain final estimates concerning long-run and short-run dynamic relationships, consists from the following empirical steps[2]: (i) test of cross-sectional dependence (CSD) with the null hypothesis of independence between panels (Table 2); the null is mostly rejected in macro-panels, along with the expected finding of significant CSD in the case of highly integrated monetary union members; (ii) the second step is panel unit root testing (PURT), namely, Im, Pesaran & Shin (IPS) second generation

[2] All estimations in this paper are carried out in STATA15.

panel stationarity test (cross-section IPS - CIPS) since it accounts for CSD (Table 3); (iii) Westerlund cointegration test between non-stationary variables, with the null hypothesis of no cointegration (Table 4); (iv) since cointegration has been confirmed, it is proceeded in the direction of MG and PMG estimations, and consequent Hausman test (Table 5); (v) the final step, estimation of homogeneous long-run (Table 5) and heterogeneous (country specific) short-run coefficients and error-term speed of adjustment parameters (Table 6).

5. Discussion of Results

As mentioned in the previous section, estimation procedure for macro-panel models first implies CSD test. Table 2 shows the results of Pesaran CD test with the null H_0: cross-sectional independence, against the alternative hypothesis - H_1: cross-sectional dependence between panels. For all examined variables at the national level (cpi, rir, reer), as well as at the supranational level (ezcpi, ezir, ezneer), p-value indicate the rejection of the null. There is a CSD between panels i.e. EZ members.

Table 2. Pesaran cross-sectional dependence (CD) test

Variables	1999Q1-2019Q4	
	CD test	p-value
cpi	72.85	0.000
rir	49.29	0.000
reer	54.27	0.000
ezcpi	74.90	0.000
ezir	74.90	0.000
ezneer	74.90	0.000

Source: Authors' estimations.

Since CSD is evident, which is highly expected having in mind integrated EZ members in the trade and financial aspect, the only acceptable PURT is the second generation Im, Pesaran and Shin (CIPS) test which accounts for CSD in the form of a single unobserved common factor. The results of the CIPS (model with the constant) for variables in the level and at the first differences are shown in Table 3. The results of CIPS PURT indicate the acceptance of the null Ho: non-stationary variable I(1) in the level, and the acceptance of the H_1: stationary variable I(0) for the first differences of the analysed variables.

Before the estimation of heterogeneous, dynamic and non-stationary macro-panel it is necessary to identify is there a long-run equilibrium relationship between observed national and supranational EZ variables, i.e. cointegration. For this purpose is used Westerlund cointegration test with

Table 3. Pesaran unit root test (CIPS)

Variable	Lags	In the level		First differences	
		$Z(\bar{t})$ -statistics	p-value	$Z(\bar{t})$ -statistics	p-value
cpi	0	0.467	0.680	-16.668	0.000
	1	3.300	1.000	-13.701	0.000
	2	2.086	0.981	-13.048	0.000
rir	0	-2.574	0.005	-16.353	0.000
	1	-4.946	0.000	-14.651	0.000
	2	-5.960	0.000	-12.205	0.000
reer	0	-0.621	0.267	-16.555	0.000
	1	-0.383	0.351	-12.307	0.000
	2	-0.105	0.458	-8.591	0.000
ezcpi	0	16.711	1.000	16.711	1.000
	1	16.711	1.000	16.711	1.000
	2	16.711	1.000	16.711	1.000
ezir	0	16.711	1.000	16.711	1.000
	1	16.711	1.000	16.711	1.000
	2	16.711	1.000	16.711	1.000
ezneer	0	16.711	1.000	16.711	1.000
	1	16.711	1.000	16.711	1.000
	2	16.711	1.000	16.711	1.000

Note: the variables ezcpi, ezir, ezneer, due to the uniformity at the EZ level show the signs of non-stationarity in the level (with the same values) in PURT framework; however, at the time series framework these time series are proved to be non-stationary in the level (these results are available upon request to the authors). The variables ezcpi, ezir, ezneer, due to the uniformity at the EZ level, show the signs of non-stationarity at the first differences within PURT framework; however, at the time series framework these time series are proved to be stationary after differencing (these results are available upon request to the authors).
Source: Authors' estimations.

the null H_0: no cointegration, against H_1: some panels are cointegrated. As the results show, p-values indicate the rejection of the null. Hence, at least some panels are cointegrated. In order to identify where the cointegration exist between analysed price, interest rate and exchange rate variables, it is proceeded in the direction of PMG or MG estimators.

Since PMG and MG estimators both serve as estimators for heterogeneous, non-stationary and dynamic macro-panel model, it is necessary to decide which estimator is more acceptable. The results of the Hausman test indicate that for the relation between national and supranational price (cpi and ezcpi) dynamics, the efficient PMG estimator under the null hypothesis is preferred, as well as in the case of relation between national real and supranational

Table 4. Westerlund cointegration test

Variables tested for cointegration	1999Q1-2019Q4	
	Statistic	p-value
Model (1) cpi & ezcpi	-1.9193	0.0275
Model (2) rir & ezir	-3.7967	0.0001
Model (3) reer & ezneer	2.5625	0.0052

Source: Authors' estimations.

nominal interest rates (rir and ezir). In the case of competitiveness convergence or divergence (reer and ezneer), the results of Hausman test indicate that consistent MG estimator, under the null hypothesis, is preferred. The macro-panel estimation of the models (2) (3) and (4) are presented with Table 5 and Table 6.

Estimated homogeneous coefficients obtained with PMG and MG estimators are given in Table 5. In the case of price dynamics the results indicate significantly positive long-run and short-run co-movements between national price dynamics and EZ price dynamics in the period 1999Q1-2019Q4. Homogeneous estimates for the EZ12 confirm the existence of weak cointegration since, according to the results, only 1% of national price dynamics is corrected each quarter towards the equilibrium. If we observe the results of real interest rate dynamics there is a co-movement in the long-run (significantly positive homogeneous long-run coefficient of 0.99). However, for the short-run relationship with the EZ variable the estimated coefficient is significantly negative indicating that rise of EZ money market rate initiate a decrease of national real interest rate, and vice versa. This finding is in accordance with the above mentioned vulnerabilities in the literature survey (Section 1), as well as descriptive analysis (Section 2). The vulnerability is emphasized in the sense that unified nominal interest rate in the combination with price divergences in its members, initiate negative relationship between EZ nominal and members' real interest rate variable. The results, thus, indicate that in the short-run there is evident divergence between unified EZ interest rate variable and national real interest rate variable, although in the long-run the divergence is achieved. Competitiveness variable i.e. real exchange rate dynamics indicate short-run significantly positive relationship with the EZ nominal (euro effective) exchange rate with the estimated coefficient 0.48. But in the long-run there is a long-run divergence. Moreover, the estimated homogeneous long-run coefficient of -1.09 (insignificantly negative) shows that a nominal euro depreciation in the long-run in average initiate a real exchange rate appreciation according to national price differentials. Except for the price dynamics, where cointegration parameter (i.e. adjustment towards equilibrium has been confirmed), for real

Table 5. Estimated homogeneous coefficients of PMG and MG estimators for EZ12 in the period 1999Q1-2019Q4

Model (1) Dep. var: *cpi* Indep. var: *ezcpi*	Homogeneous long-run relationship (θ)		$\Delta ezcpi$		Error correction (Φ_i)	
	Coef.	p-value	Coef.	p-value	Coef.	p-value
PMG	0.4293304	0.033	0.7149846	0.000	-0.011122	0.011
MG	0.9108158	0.000	0.6627766	0.000	-0.074691	0.000
Hausman test: $\chi 2(4) = 2.92$ p-value = 0.5715	PMG estimator, the efficient estimator under the null hypothesis, is preferred.					
Model (2) Depr: *rir* Indep. var: *ezir*	Homogeneous long-run relationship (θ)		$\Delta ezir$		Error correction (Φ_i)	
	Coef.	p-value	Coef.	p-value	Coef.	p-value
PMG	0.9988896	0.000	-4.110289	0.059	-4.414919	0.044
MG	1.00006	0.000	-4.345552	0.048	-4.646827	0.035
Hausman test: $\chi 2(1) = 0.00$ p-value = 0.9468	PMG estimator, the efficient estimator under the null hypothesis, is preferred.					
Mod Dep. var: *reer* Indep. var: *ezneer*	Homogeneous long-run relationship (θ)		$\Delta ezneer$		Error correction (Φ_i)	
	Coef.	p-value	Coef.	p-value	Coef.	p-value
PMG	3.411645	0.036	0.4799911	0.000	0.0034999	0.008
MG	-1.085712	0.557	0.4780585	0.000	-0.005986	0.304
Hausman test: $\chi 2(1) = 26.03$ p-value = 0.000	MG estimator, the consistent estimator under the null hypothesis, is preferred.					

Source: authors' estimations.

interest rate and real exchange rate there is no correction towards equilibrium since the speed of adjustment parameter is above -1 (real interest rate dynamics) or it is not statistically significant (real exchange rate dynamics). Therefore, the analysis of the estimated homogeneous coefficients for EZ12 in the period 1999Q1-2019Q4 points to the absence of correction towards equilibrium of national real interest rate and real exchange rate towards the EZ variables.

The main advantage of heterogeneous panels are estimates of each EZ member in the sense of a short-run and error correction (speed of adjustment) parameters. In the mentioned context, Table 6 shows these estimates for the initial EZ12 members. Namely, short-run convergence between prices at the national level and supranational level is confirmed, i.e. all short-run coefficients

are significantly positive. However, the error-correction term indicating correction towards long-run equilibrium is significantly negative (and in the expected range) only in the case of periphery countries – Greece, Spain, Portugal, Ireland, Italy. Price adjustments of the periphery countries could be connected with the abrupt restrictive (internal devaluation or expenditure-reducing) adjustment in the post-crisis period as a sign of correction towards the EZ price dynamics. However, correction towards equilibrium (cointegration) is not prevalent if we observe national real interest rate and exchange rate from one side and unified EZ interest and exchange rate from the other side. Only in the case of Luxembourg the results show the correction towards long-run interest rate equilibrium. Likewise, in the case of three core EZ members (Finland, Germany and Netherlands) the correction towards equilibrium or sustained long-run competitiveness convergence has been confirmed in the analysed period.

Table 6. Estimated heterogeneous coefficients for EZ12 in the period 1999Q1-2019Q4

EZ12 members	Model (1) Dependent variable: cpi Independent variable: ezcpi				Model (2) Dependent variable: rir Independent variable: ezir				Model (3) Dependent variable: reer Independent variable: ezneer			
	ec (Φ_i)	p	Δezcpi	p	ec (Φ_i)	p	Δezir	p	ec (Φ_i)	p	Δezneer	p
Austria	0.009	0.060	0.595	0.000	3.497	0.678	3.808	0.649	0.0475	0.003	0.375	0.000
Belgium	0.001	0.888	0.271	0.000	-6.810	0.607	-6.639	0.614	-0.014	0.484	0.468	0.000
Finland	-0.009	0.286	0.429	0.000	-15.976	0.091	-15.793	0.093	*-0.022*	0.034	0.557	0.000
France	-0.005	0.378	0.565	0.000	-4.664	0.590	-4.150	0.630	0.002	0.642	0.496	0.000
Germany	0.001	0.897	0.417	0.000	-3.039	0.721	-2.439	0.774	*-0.012*	0.010	0.590	0.000
Luxembourg	-0.003	0.413	0.628	0.000	*-0.120*	0.005	0.287	0.070	-0.010	0.685	0.338	0.000
Netherlands	-0.003	0.640	0.547	0.000	2.296	0.817	2.999	0.761	*-0.025*	0.044	0.517	0.000
Greece	*-0.024*	0.055	1.625	0.000	0.035	0.412	0.379	0.061	0.023	0.090	0.411	0.000
Spain	*-0.011*	0.105	1.406	0.000	-20.065	0.160	-19.787	0.164	0.011	0.438	0.419	0.000
Portugal	*-0.019*	0.021	1.145	0.000	-5.055	0.667	-4.697	0.687	-0.001	0.924	0.329	0.000
Ireland	*-0.048*	0.005	0.708	0.000	5.028	0.730	4.296	0.767	0.013	0.205	0.701	0.000
Italy	*-0.019*	0.028	0.238	0.000	-8.103	0.299	-7.585	0.328	0.012	0.067	0.529	0.000

Note: error correcting speed of adjustment term - ec (Φ_i) - is highlighted if it is significantly negative and between -1 and 0, under the prior assumption that the variables show a return to a long-run equilibrium.
Source: Authors' estimations.

While short-run convergence is evident between national and EZ price dynamics, as well as between national real exchange rate and EZ nominal euro exchange rate, the results cast doubt on the short-run divergence between

national real interest rate and nominal EZ interest rate. Heterogeneous estimates point to mostly absent correction towards equilibrium (insignificant, positive or oversized ec parameter) which is considered as the problem of the EZ long-run sustainability. Real variables, such as here analysed real interest rate and real exchange rate at the national level, should dominantly converge towards EZ unified variables in order to assume the monetary union sustainable. Unfortunately, these results doesn't support mentioned expectation.

6. Concluding Remarks

It is clear that, in order for the European currency area to work without generating unsustainable imbalances, inflation differential should be kept under control. In contrary, macroeconomic imbalances will unavoidably develop, whose later adjustment will endanger macroeconomic stability and growth for the whole monetary union. This research contributes to the vast literature in this area by highlighting one aspect of EZ vulnerability related with heterogeneous adjustment of selected national variables towards supranational variables of 12 initial EZ members. The loss of monetary sovereignty include unified nominal short-run interest rate and nominal euro exchange rate. However, the inflation divergence or differential initiate vicious cycle in which high inflationary members experience real exchange rate (appreciation) and real interest rate (lowering) divergences within the monetary union. The economic cycles are more pronounced with further encouraged macroeconomic overheating of inflationary prone members, and vice versa.

In heterogeneous, dynamic and non-stationary macro-panel framework, national price dynamics is brought into a connection with EZ price dynamics, national real interest rate in connection with ECB's nominal short-run interest rate, and national real exchange rate with nominal euro exchange rate. These relations are estimated for the period 1999Q1-2019Q4 with PMG and MG estimators. The estimates of homogeneous coefficients suggest that the short-run and long-run price dynamics is significantly positive related with the EZ price dynamics. Short-run co-movement is detected for the real exchange rate national and EZ nominal exchange rate variable, but this is not the case in the long-run. The diverging (significantly negative) relation between national real interest rate and EZ nominal interest rate is evident in the short-run. Hence, the homogeneous coefficients indicate a heterogeneity of the long-run and short-run co-movements, or even divergence, between national and supranational variables. Further insights into the estimates of heterogeneous coefficients of 12 analysed EZ members reinforce the impression of diversity within the EZ. Namely, with the exception of few EZ members in the case of price dynamics, there is no sign of adjustment towards equilibrium observing the error term or speed of adjustment parameters. Divergence or insignificant convergence towards equilibrium is considered as a source of EZ instability and as a trigger for further imbalances.

The EZ is de facto considered as heterogeneous and unsustainable without further reforms towards deeper economic integration. Monetary union without banking union and fiscal union, represents an open space for national discretionary steps, thus boosting the diversity and heterogeneity within the EZ. In the circumstances where crucial macro-indicators (as here focused inflation, real interest rate and real exchange rate) diverge too much, fertile ground for monetary union instability is created. EZ stability is strongly conditioned with tackling these diverging trend between member states. The policy creators at the monetary union level should find the way to restrain these differentials, however, it won't be an easy task since it implies limiting of discretionary policy space at the national level. Besides the constraining of discretionary space along with strengthening and deepening of European integration, it is of huge importance that Maastricht convergence criteria presents binding mechanism during functioning within the monetary union and not only the mechanism until euro adoption. Convergence criteria should not be viewed as a temporary adjustment aimed at adopting a common currency. Specifically, the common currency and monetary union are threatened per se if price convergence (above all) is not maintained in the long run.

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