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The euro and inflation in Croatia: much ado about nothing?

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Article**
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Abstract

This paper aims to shed some light on the issue of euro-induced inflation in the case of the Croatian euro changeover. Applying the synthetic control method, we were unable to find unambiguous and robust evidence of such an impact on the aggregate level. Focusing on a wide array of products and services, we found no impact of the euro on most price subcategories except those related to food, clothes and restaurant prices. The findings for the latter two categories seem particularly robust, surviving a battery of alternative specifications such as the generalized synthetic control and matrix completion method. Placebo tests reveal considerable ambiguity vis-à-vis the exact timing of the euro effect on prices, probably reflecting the fact that Croatia had been a highly euroized economy years before the de iure changeover.

Keywords: euro changeover, euro area, Croatia, inflation, synthetic control method, causal inference

1 INTRODUCTION

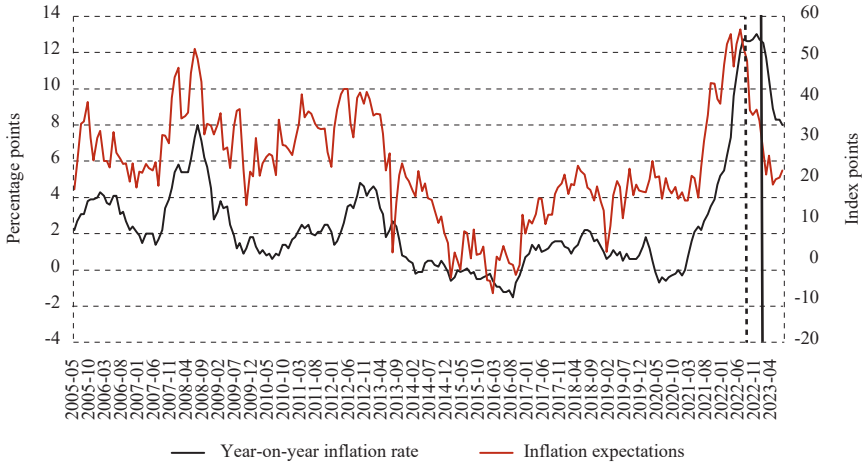
On January 1, 2023, Croatia officially entered the eurozone, becoming its 20th member state. Although the entire process of Croatian euro integration has been extensively debated through the prism of Optimum Currency Area theory (Deskar-Škrbić, Kotarac and Kunovac, 2020; Brkić and Šabić, 2018) as well as of the expected reduction in the cost of borrowing (Kunovac and Pavić, 2018), and the stimulus for international trade (Bukovšak, Ćudina and Pavić, 2018), the attention of the general public has been directed mainly to the potential inflationary effects of the euro changeover (Pufnik, 2018).

Unlike all previous euro area enlargements, the changeover in Croatia was managed in conditions of extreme inflationary pressures. The circumstances were highly conditioned by the prolonged and substantial quantitative easing by the FED and ECB after the global financial crisis, the recent disruption of supply chains, as well as a considerable base effect due to abrupt and stringent lockdown policies around the globe.

This type of setting has been particularly problematic in a country such as Croatia. Its past experiences with hyperinflation episodes have heavily determined the general framework of monetary policy, using the nominal HRK/EUR exchange rate as an anchor to stabilize inflation expectations. On the other hand, in recent months the Harmonized Index of Consumer Prices (HICP) inflation rate has spiked. Croatian consumers reacted to this shock by gradually increasing their inflation expectations to a historical maximum. This pattern is clearly visible in figure 1.

FIGURE 1

HICP inflation (year-on-year) rates and inflation expectations in Croatia



Note: Vertical dotted line corresponds to September 2022 (start of obligatory dual display of prices). Vertical full line corresponds to January 2023 (euro changeover). Inflation expectations are quantified as the response balance to question 6 from the EU Consumer Survey (see section 3 for details).

Source: Eurostat and European Commission.

Ever since the stabilization program in October 1993, Croatian monetary authorities have successfully maintained price stability, so the newcoming double-digit inflation rate seemed a black swan event for Croatian consumers. They rightly noticed the correlation between these inflationary pressures and the timing of the Croatian euro changeover. For example, European Commission (2022) reports that, among the EU countries outside the euro area, Croatia had the highest share of citizens who were concerned about abusive price setting and malpractice during the euro changeover (81% of respondents fully or partially agreed with that claim). Likewise, the same percentage of Croatian citizens firmly believed that the euro would increase prices. However, does this correlation between an inflation spike and the timing of the euro introduction indeed imply causality? Did the euro changeover itself trigger abusive price setting and rounding effects?

Under the conditions of the just described inflationary pressures, it seems extremely complex to conduct a proper signal extraction study and quantify the exact extent to which the Croatian inflation can be attributed to other tendencies, and how much it is a direct consequence of euro-related factors such as menu costs, rounding of prices to increase retail profits, etc.

This paper provides an initial attempt to examine if there are direct causal effects of the 2023 euro changeover on inflation in Croatia. In doing so, we examine a wide set of 14 price categories to enable a granular perspective on the issue. Our results reveal than the euro conversion did not have a robustly significant effect on

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aggregate inflation. The same holds for most inflation subcategories considered, except for food, clothing and restaurant charges, which significantly increased at the beginning of the conversion.

The remainder of this paper is organized as follows. Section 2 reviews the well-established reasons for the common (mis)perception that previous euro changeovers acted as inflation triggers. Section 3 discusses data specificities and the methodological framework, while Section 4 presents the empirical results of the study. Finally, section 5 provides some policy implications and directions for future research.

2 EURO CHANGEOVER AS A POTENTIAL INFLATION TRIGGER

On the first day of 2002, euro coins and banknotes were introduced in 12 European countries with a total population of more than 300 million people. This was the largest-ever monetary changeover operation in the world (Stenkula, 2004). As such, it attracted wide attention from the general public, the media, and the academia. Although the official inflation rate in 2003 remained fairly stable, consumers' perceptions of inflation were significantly upward-biased (Antonides, 2008). In subsequent years, there was a proliferation of empirical studies on the topic. Four major factors were shown to have led the consumers to overestimate the importance of euro changeover in driving the general price increase (see e.g. Sturm et al. (2009) for an excellent literature review). This section will briefly pinpoint the main empirical findings.

2.1 MEDIA EFFECT

At the outset of the 2002 euro changeover, the media started to build up public expectations vis-à-vis the inflationary effects of euro introduction. The general atmosphere could be best described through the German lens, and their extremely frequent usage of the word "Teuro", a portmanteau term composed of "teur" (expensive) and the word "euro" (Lamla and Lein, 2015). And indeed, formal econometric studies identified a significant media effect on the accuracy of inflation expectations. Lamla and Lein (2014) found that negatively toned media reports about inflation (describing inflation as "bad") triggered an upward bias of consumers' inflation expectations.

In the context of such media reports, an expectation was formed in the general public that retailers would seize the opportunity to unduly increase prices in order to boost their profit margins. Experimental evidence speaks in favor of such a self-fulfilling prophecy (Traut-Mattausch et al., 2004; Greitemeyer et al., 2005), finding inflation expectations to be a significant driver of inflation perceptions and of the noticed gap between actual and perceived inflation rate.

Dräger (2014) also found a marginally significant media effect, establishing a causal chain from negatively toned media articles to inflation expectations, and then to actual inflation developments. Lamla and Lein (2015) similarly detected that agents' inflationary perceptions were highly dependent on the news about

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rising inflation. Lamla and Lein (2015) clearly establish the euro introduction as a structural break in the observed relationship. The media effect is negligible before 2002, and highly significant afterwards.

2.2 FREQUENTLY BOUGHT GOODS HYPOTHESIS

Although the general price increase was not significantly influenced by euro introduction, some effects were noticed for frequently bought goods (Lunn and Duffy, 2015). Del Giovane and Sabbatini (2006) defined frequently bought goods as those purchased at least once a month: food, tobacco, everyday household products, newspapers, fuels, and services such as local transport, postal and banking services, restaurants and coffee shops, recreational and cultural services. The prices of these goods did indeed spike in 2002 (Del Giovane and Sabbatini, 2006; Lunn and Duffy, 2015). Some of these inflationary pressures were caused by menu charges, while in other cases retailers were seen to have rounded off their prices upwards. As a consequence, agents seem to have attached too large a weight to these categories of goods, producing largely and systematically biased perceptions of actual inflation rates.

This pattern is possibly a result of the availability heuristic (Kahneman and Tversky, 1979), meaning that agents systematically overweight the price changes of low-cost goods purchased on a frequent basis, often via out-of-pocket purchases (Del Giovane and Sabbatini, 2006; Dziuda and Mastrobuoni, 2009).

2.3 METHODOLOGICAL ISSUES CONCERNING INFLATION MEASUREMENT

In euro area countries, inflation is measured via the Harmonised Index of Consumer Prices (HICP). A Laspeyres-type index, HICP is calculated by attaching consumption weights to individual item categories. However, these weights are updated rather infrequently, i.e. every five years (Antonides, 2008). Therefore, it comes as no particular surprise that the price indices of only a few item subcategories significantly explain the general consumers' inflation perceptions. *Nota bene*, some of the most prominent frequently bought goods (such as food and drinks) are not among them.

2.4 COMPARISON EFFECTS

A study by Fessel GfK (2004) revealed that even two years after the introduction of euro, as many as 74% of Austrian consumers still mentally converted the euro prices to Austrian schillings. By fixing the reference prices to two years before, they inevitably neglected the secular tendency of price increases, and consequentially generated upwardly biased inflation perceptions.

Similar cognitive biases were noticed in the relationship between the consumers' perceived inflation rate and the complexity of the conversion rates of their domestic currency vs. the euro. For example, the euro conversion rate of the German mark was 1.95583. Ehrmann (2006) suggests that German consumers used a simple rule of thumb when assessing euro prices after the conversion; they multiplied the displayed

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euro prices by two. This alone, *ceteris paribus*, induced an overestimation of 2.26%. More complex conversion rates, such as Austrian, Dutch, French, and Italian, triggered their consumers to err much more in their price comparisons.

After explaining the main driving forces of the euro-induced inflation perception gap, the following section will introduce our methodological approach to quantifying the euro effect on Croatian inflation.

3 METHODOLOGY AND DATA

Previous studies of the relationship between euro changeover and inflation can mostly be divided into two methodological strands. The first one focuses on time series analysis such as Granger causality and cointegration tests on macroeconomic data (Antonides, 2008; Del Giovane and Sabbatini, 2009; Dziuda and Mastrobuoni, 2009; Dräger, 2014; Lamla and Lein, 2015). The other one is more concerned with micro experiments (Traut-Mattausch et al., 2004; Greitemeyer et al., 2005). Both approaches are perfectly plausible and add to our understanding of the phenomenon at hand. We aim to reconcile the two by offering a setup of a quasi-natural experiment using macroeconomic data. In assessing the impact of a policy intervention or an exogeneous shock (such as a currency changeover) on social and economic outcomes, we follow the rationale of biomedical experiments to inspect whether the observed relationship between euro changeover and inflationary pressures can be attributed to pure correlation or causality. In this strand of research, after identifying the treatment sample, researchers should pay particular attention to the choice of proper control (comparison) sample. Ideally, the control units should be exactly the same as the treatment entities vis-à-vis a set of fundamentally important characteristics, but should not be exposed to the treatment of interest. In social sciences, units of analysis are often regions or countries, so appropriate comparison units frequently do not exist (George and Bennet, 2005; Abadie, Diamond and Hainmueller, 2015). In this particular case, Croatia stands out as an exemplar of sub-optimal efficiency of economic transition, a peculiar economic structure dominated by tourism-related activities, and étatism (Stojčić, 2012). Having that in mind, it seems extremely difficult to find proper comparison unit(s) for Croatia. To circumvent this kind of problem, Abadie and Gardeazabal (2003) and Abadie, Diamond and Hainmueller (2010; 2015) had introduced the Synthetic Control Method (SCM), a data-driven procedure aimed at constructing a counterfactual (synthetic control) as a weighted combination of potential comparison entities. Such synthetic control is conceptualized to exhibit the underlying characteristics of the treatment entity of interest better than any other single comparison unit. Within a very short period, SCM became an indispensable tool in many sciences, such as economics (Abadie, 2021; Campos, Coricelli and Moretti, 2019), health studies (Bouttell et al., 2018), sociology (Vagni and Breen, 2021), etc.

3.1 SYNTHETIC CONTROL METHOD

Being unable to observe a counterfactual Croatia that did not go through the euro changeover, we use the relevant macroeconomic data from all other EU economies.

As the remaining 26 economies share the EU single market with Croatia and have a harmonized set of institutional rule and policy frameworks, they seem potentially plausible candidates for this purpose. Suppose that we observe a panel dataset consisting of $J + 1$ countries ($j = 1, 2,..., J + 1$), where the first country ($j = 1$) is the treated one. In our case, we are interested in the effect of an intervention (euro changeover) on Croatian inflation. Therefore, Croatia is the treated unit. The remaining EU economies ($j = 2, 3, ..., 27$) are not affected by the treatment, and as such comprise the donor pool, i.e. they are potential candidates for comparison. We observe a balanced panel, i.e. all units are observed across periods $t = 1, 2,..., T$. To be exact, our dataset spans from 2005M05 to 2023M07 (conditioned by data availability). As the intervention (euro changeover) occurred in January 2023, the time span consists of $T_0 = 212$ monthly pre-treatment periods and $T_1 = 7$ post-treatment monthly periods ($T = T_0 + T_1 = 219$).

The goal is to construct a synthetic control that resembles Croatia much more than any individual EU economy in terms of a selected set of variables. As the dependent (target) variables in the model, we use aggregate HICP inflation (*hicp* hereinafter), and its 13 subcomponents based on the *European Classification of Individual Consumption according to Purpose* (ECOICOP): food inflation (*food* hereinafter), inflation of non-acoholic beverages (*nonalc*), alcoholic beverages, tobacco and narcotics (*alc*), clothing and footwear (*clothing*), housing, water, electricity, gas and other fuels (*housing*), household equipment and routine household maintenance (*furnish*), health (*health*), transport (*transport*), communication (*commun*), recreation and culture (*recr*), education (*educ*), restaurants and hotels (*rest*), and miscellaneous goods and services (*misc*). We aim to estimate a separate synthetic control model for each of these 14 variables, constructing 14 different counterfactuals.

We use the following set of inflation covariates: output gap obtained by applying the Hodrick-Prescott filter on the industrial production index (2015=100) (*gap* hereinafter), inflation expectations (*exp*), and the HICP subcomponent related to the prices of electricity, gas, and other fuels (*fuel* hereinafter). The first two variables are commonly found in various sorts of New-Keynesian Phillips curve specifications (e.g. Basistha and Nelson, 2007; Jašová, Moessner and Takáts, 2020; Panovska and Ramamurthy, 2022), while the latter variable proxies energy prices that are also widely accepted as an inflation driver.[1] The target inflation variables, along with energy prices, are expressed as year-on-year (*y-o-y*) growth rates. For each of the 14 inflation categories we use *gap*, *exp*, and *fuel* as auxiliary covariates to construct a proper counterfactual.

Inflation expectations are derived from the EU Consumer Survey, in the form of a response balance (weighted difference between the shares of positive and negative answers) on the following survey question (see European Commission (2023) for details).

[1] Ideally, one would use oil prices on the global market as an exogenous inflation determinant (e.g. Wen, Zhang and Gong, 2021; Li and Guo, 2022), but SCM requires input data that vary across entities. As national HICP electricity, gas, and other fuels prices are closely positively correlated to the global market oil prices, we made an empirical compromise and continued the analysis with the former variable. In a similar vein, industrial production is used for the calculation of output gaps instead of GDP to ensure monthly frequencies of data.

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By comparison with the past 12 months, how do you expect that consumer prices will develop in the next 12 months? They will: a) increase more rapidly, b) increase at the same rate, c) increase at a slower rate, d) stay about the same, e) fall, f) don't know.

Industrial production indices and all inflation data are obtained from Eurostat, while inflation expectations are made publicly available by the European Commission.

The stated predictors of inflation are conceptualized through a $k \times 1$ vector of preintervention values for Croatia (denoted X_1), and we introduce X_0 as a $k \times J$ matrix comprising the same variable observations for other EU economies. Synthetic control is obtained as a weighted average of comparison units (Abadie and Gardeazabal, 2003; Abadie, Diamond and Hainmueller, 2010; 2015). The vector of weights $W = (w_2, w_3 \ldots w_{J+1})'$ comprises nonnegative elements ($0 \leq w_j \leq 1$) for $j = 2, 3, \ldots, J+1$ and the weights sum up to 1 ($w_2 + w_3 + \ldots + w_{J+1} = 1$). Optimal weights W^* are determined as the value of W that minimizes the discrepancy between the pre-changeover characteristics of Croatia and its synthetic control:

$$\sum_{m=1}^{k} v_m \left(X_{1m} - X_{0m} W \right)^2 \tag{1}$$

where X_{1m} is the value of the m-th variable for Croatia, X_{0m} is a $1 \times J$ vector of m-th variable's values for the comparison units, and v_m is the non-negative weight (relative importance) attached to the m-th variable. The latter should take on large values for variables that closely correlate with the outcome variable for the treated entity.

Finally, estimating the causal effect of an intervention ($\hat{\tau}_{1t}$) comes down to comparing the post-changeover inflation in Croatia and the post-changeover inflation of its synthetic control:

$$\hat{\tau}_{1t} = Y_{1t} - \hat{Y}_{1t} = Y_{1t} - \sum_{j=2}^{J+1} w_j^* Y_{jt} \tag{2}$$

where Y_{jt} is the outcome of entity j at time t, Y_1 is a $T_1 \times 1$ vector of post intervention outcomes for the treated entity, and $\hat{Y}_{1t}$ is the SCM-estimated (synthetic) outcome without the treatment.

Although SCM is a powerful and widely applied tool for policy evaluations, it has its limitations. Most importantly, it does not allow formal econometric testing of the significance of the causal effect. To counteract that, we also use a relatively novel conformal inference method introduced by Ben-Michael, Feller and Rothstein (2021): Augmented Synthetic Control Method (ASCM).

In practice, it is often a very hard task to construct a proper counterfactual using SCM. ASCM is specifically designed to correct for the bias of SCM and improve the quality of the counterfactual. Ben-Michael, Feller and Rothstein (2021) conceptualized the ASCM framework as follows:

$$\hat{Y}_{1t}^{aug} = \sum_{j=2}^{J+1} w_j^* Y_{jt} + \left(X_1 - \sum_{j=2}^{J+1} w_j^* X_j \right) \cdot \hat{\eta}_x + \left(Z_1 - \sum_{j=2}^{J+1} w_j^* Z_j \right) \cdot \hat{\eta}_z \qquad (3)$$

where $\hat{Y}_{1t}^{aug}$ is the ASCM synthetic outcome (in this case counterfactual Croatian inflation rate, without the euro changeover), X_j is a vector or pre-changeover outcomes for the j-th EU economy, and X_1 is a vector of pre-changeover outcomes of Croatia. This kind of notation is adopted to emphasize that pre-treatment outcomes are used as input (independent variables) in the model. In the same manner, Z_1 and Z_j are vectors of corresponding auxiliary covariates, while $\hat{\eta}_x$ and $\hat{\eta}_z$ are coefficients obtained through a ridge regression of the control post-treatment outcomes on centered pre-treatment outcomes, with a tuning parameter that penalizes the distance between ASCM weights and the conventional SCM weights. The idea of this estimator is to increase the pre-treatment fit of the classic SCM model (decrease its bias), while minimizing extrapolation from the convex hull (see Ben-Michael, Feller and Rothstein (2021) for details). It is important to highlight that ASCM weights w_j^* (as opposed to the standard SCM model (Abadie and Gardeazabal, 2003; Abadie, Diamond and Hainmueller, 2010; 2015)) are allowed to take negative values. Going back to our choice of the donor pool (26 remaining EU economies), it would be expected that ASCM attaches very small (or even negative) weights to core EU economies (e.g. Austria, Germany, France, etc.) whose economic sizes and structures do not positively and significantly correlate with the Croatian economy. Instead of *handpicking* the EU economies with economic structures similar to the Croatian (e.g. with a considerable share of tourism in GDP), we opted for letting the data speak for itself. Should those economies really comprise the optimal donor pool, ASCM would assign them the largest weights.

All estimations are performed in R Studio via packages *Synth*, *augsynth,* and *MSCMT.*

The reliability of ASCM results critically depends on the accuracy of its pre-treatment fit. Our estimates of a post-changeover euro effect on inflation are only as valid as our pre-changover estimate of synthetic counterfactual is similar to the actual Croatian inflation rate. For that purpose, we used the following approach. For the ASCM model with *hicp* as the dependent varable, we used *fuel*, *exp*, and *gap* as the potential pool of auxiliary covariates. We chose the combination that minimized the average pre-treatment bias (difference between actual and synthetic outcome). Average bias is a standard part of the estimation procedure in *augsynth* R package. For the remaining 13 inflation categories (*food*, *nonalc*, *alc*, *clothing*, *housing*, *furnish*, *health*, *transport*, *commun*, *recr*, *educ*, *rest*, and *misc*), we add *hicp* to the pool of auxiliary covariates, and again choose the combination that minimizes the average pre-treatment bias.

To inspect if the obtained ASCM results are robust enough, reaserchers usually resort to conducting placebo specifications across time and entities. A placebo test implies conducting the exact same analysis for a time period or cross-section unit where the expected effect of the intervention is equal to zero (non-rejection of the

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null hypothesis). In our case, a placebo test implies testing the effect of euro changeover in a country that has not actually undergone it, or testing its effect in a time period that cannot be related to the actual changeover. Observational studies often tend to under-report the results of placebo tests (so-called *inverse p-hacking*) to corroborate their initial results (Dreber, Johannesson and Yifan, 2023). To address this issue properly, we conduct a series of placebo tests, extensively report their results and discuss them in detail.

3.2 CAVEATS

The end-point of the observed time span is conditioned by the latest available data at the moment of writing. One might question the appropriateness of SCM analysis for a dataset with $T_1 = 7$ post-intervention periods. However, SCM is specifically designed to assess a smaller dataset (Gilchrist et al., 2023) compared to e.g. financial econometrics or machine learning techniques. Having that in mind, previous empirical SCM studies have routinely been conducted on smaller post-intervention sample sizes (e.g. Sills et al., 2015; Tkalec, Žilić and Recher, 2017; Gharehgozli, 2017). Likewise, we postulate that our SCM framework is also economically relevant because empirical studies of the 2002 euro changeover found that the impact of this monetary conversion on inflation (if any) was short-lived (Sturm et al., 2009; Pufnik, 2018).

Additionally, let us briefly discuss the utilization of y-o-y growth rates of all price variables. This step seemed very important in our empirical setting because it takes adequate account of any seasonal effects and working day adjustments, and it conceptually matches inflation expectations derived from consumer surveys (expected price development during the 12 months horizon). Finally, using growth rates of macroeconomic variables in SCM applications is rather standard (Opatrný, 2017; Boiciuc and Orțan, 2020).

4 EMPIRICAL RESULTS

We start by applying the ASCM framework to synthetize the counterfactual time series of Croatian inflation rate and test its (dis)similarity with the actual inflation rate after the euro changeover.

Our baseline ASCM estimates are given in table 1 and figure A1 in the appendix. Our results seem to corroborate the finding from previous euro area enlargements that euro changeovers were specifically related to price increases of food (Brachinger, 2008; and Lunn and Duffy, 2015), clothing (Cavallo, Neiman and Rigobon, 2015; Rõõm and Urke, 2014), and restaurant services (Sturm et al., 2009; Pufnik, 2018). It should be noted that, aiming to shed additional light on these inflation categories and reduce bias as much as possible, we considered an additional set of auxiliary covariates. Inflation in *food* was (in addition to *fuel*, *exp*, *gap*, and *hicp*) modelled with lower-level inflation categories related to: meat (*meat*), fish and seafood (*fish*), milk, cheese and eggs (*milk*), fruit (*fruit*), vegetables (*veg*), coffee, tea and cocoa (*coffee*), wine (*wine*), beer (*beer*), tobacco (*tobacco*). *Clothing*

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category is further augmented with its corresponding subcategories of inflation: clothing (*cloth*) and footwear (*foot*), while *rest* is modelled with the addition of catering services (*cater*), restaurants, cafés and the like (*rest_caf*), and accommodation services (*accomm*). Detailed specifications of all examined models are given in the note below figure A1.

Table 1

ASCM baseline estimations (January to July 2023)

	January	February	March	April	May	June	July
hicp	**1.704**	0.974	1.589	0.508	1.199	**2.062**	**2.038**
	(**0.038**)	(0.291)	(0.155)	(0.601)	(0.235)	(**0.038**)	(**0.014**)
food	0.065	0.203	0.823	2.748	**3.927**	**4.889**	**3.615**
	(0.986)	(0.934)	(0.648)	(0.127)	(**0.019**)	(**0.005**)	(**0.028**)
nonalc	0.202	-1.845	-1.570	-0.002	1.971	3.038	2.653
	(0.864)	(0.315)	(0.390)	(0.977)	(0.296)	(0.089)	(0.113)
alc	1.077	-0.522	-2.041	-1.794	-1.449	-1.294	-1.374
	(0.577)	(0.826)	(0.282)	(0.343)	(0.498)	(0.545)	(0.516)
clothing	**8.225**	**5.901**	3.294	3.419	2.121	4.385	**7.374**
	(**0.005**)	(**0.014**)	(0.202)	(0.174)	(0.441)	(0.094)	(**0.005**)
housing	4.362	3.626	0.800	-1.105	-1.182	-0.703	-0.086
	(0.244)	(0.371)	(0.930)	(0.718)	(0.681)	(0.812)	(0.953)
furnish	1.463	1.014	0.181	-1.211	0.699	1.165	**2.154**
	(0.061)	(0.197)	(0.817)	(0.117)	(0.380)	(0.131)	(**0.019**)
health	2.386	1.795	1.539	1.782	2.831	**4.098**	**4.364**
	(0.188)	(0.324)	(0.385)	(0.366)	(0.169)	(**0.023**)	(**0.019**)
transport	-0.835	-0.373	-0.761	-1.722	-1.421	0.198	1.109
	(0.577)	(0.751)	(0.592)	(0.300)	(0.352)	(0.901)	(0.479)
commun	-1.623	-1.662	-1.034	-0.097	0.167	-0.979	1.647
	0.277)	(0.277)	(0.521)	(0.962)	(0.911)	(0.540)	(0.291)
recr	-0.802	-2.032	-3.410	**-3.965**	**-4.310**	-3.545	-0.533
	(0.549)	(0.188)	(0.056)	(**0.033**)	(**0.023**)	(0.075)	(0.789)
educ	1.970	1.718	2.299	2.465	2.084	2.683	3.560
	(0.235)	(0.277)	(0.192)	(0.178)	(0.239)	(0.174)	(0.061)
rest	**4.340**	3.701	**4.391**	**5.276**	**6.890**	**9.087**	**7.024**
	(**0.028**)	(0.052)	(**0.038**)	(**0.038**)	(**0.014**)	(**0.005**)	(**0.009**)
misc	1.501	-0.049)	0.269	0.298	1.219	0.915	0.930
	(0.103)	(0.930)	(0.756)	(0.732)	(0.188)	(0.371)	(0.366)

Note: Table entries are gaps between actual and synthetic values of corresponding variables. Positive gaps imply that actual values are greater than the synthetic ones. P-values are given in parentheses. Bold entries are significant at the 5% level.

Source: Author's calculation.

A glance at the results suggests that there is not much evidence of a euro effect on inflation. Aggregate HICP inflation reacted mildly in January, and then an intensification of the euro effect is again observed in June and July. Most of the considered subcategories did not react significantly. The only substantial and robust effect is observed for *food*, *clothing*, and *rest*. The reaction of food prices was not

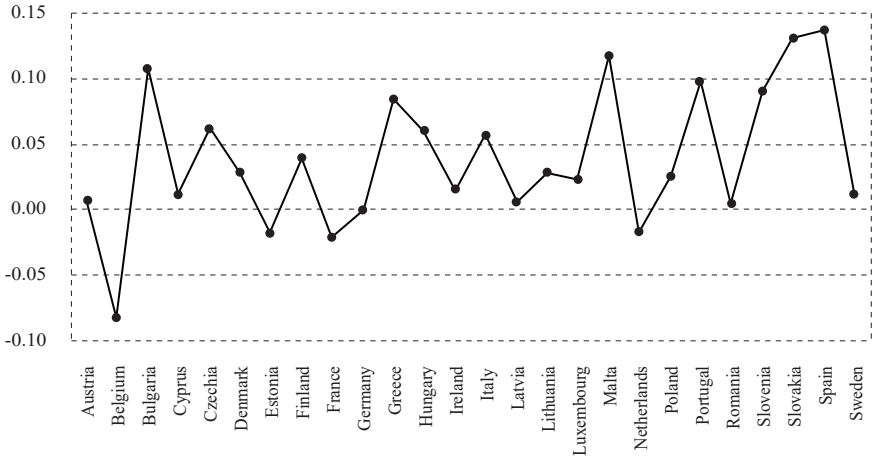
instantaneous, but characterized by a delay. It became significant only during the last three months of the sample, with a magnitude of 3.615 to 4.889%. As far as clothing prices are concerned, their difference between the actual and counterfactual Croatia is 8.225% in January, and then 5.901% in the following month. Restaurant prices seem to be roughly 4-9% higher due to the euro changeover, and the euro effect was much more persistent throughout the post-intervention period than was the case with other price categories.

The observed euro effect mostly intensifies in June and July (particularly for the *rest* category), which is probably related to the general concept of tourism-led inflation (Tkalec and Vizek, 2016).

ASCM chooses donor weights that optimize pre-treatment fit. For brevity, we do not report the full set of results, but provide only the average obtained country weights in figure 2. The highest weights are obtained for Spain (0.136), Slovakia (0.131), Malta (0.117), Portugal (0.0979), and Slovenia (0.090). These are either Mediterranean countries with comparable tourism-oriented economies, or Central and Eastern European post-transition countries that had similar historical, politico-economic and institutional trajectories as Croatia.

FIGURE 2

Average ASCM country weights



However, it remains to be seen whether this phenomenon is causally related or purely fortuitous. In that context, the literature suggests conducting placebo tests across entities and across time. For example, should similar results be observed for *food*, *clothing* and *rest* categories of other countries (that have not adopted the euro in January 2023), this would undermine the plausibility of the observed euro-induced inflation effect.

Table 2

ASCM placebo specifications across countries (January to July 2023)

	January	February	March	April	May	June	July
hicp	0.862	0.220	-0.439	-1.225	-0.348	0.700	0.905
	(0.315)	(0.817)	(0.704)	(0.225)	(0.761)	(0.460)	(0.282)
food	-1.402	-0.719	0.210	2.590	**4.231**	**4.850**	3.442
	(0.451)	(0.718)	(0.930)	(0.117)	(**0.019**)	(**0.005**)	(0.056)
nonalc	-0.612	-2.586	-2.417	-0.793	0.886	2.662	2.688
	(0.657)	(0.136)	(0.164)	(0.568)	(0.549)	(0.113)	(0.108)
alc	0.795	-0.825	-2.113	-2.496	-1.738	-1.836	-1.922
	(0.695)	(0.690)	(0.258)	(0.216)	(0.404)	(0.343)	(0.315)
*clothing**	**8.225**	**5.901**	3.294	3.419	2.121	4.385	**7.374**
	(**0.005**)	(**0.014**)	(0.202)	(0.174)	(0.441)	(0.094)	(**0.005**)
housing	1.024	-0.102	-1.555	-4.839	-5.390	-4.619	-3.682
	(0.878)	(0.911)	(0.648)	(0.225)	(0.207)	(0.225)	(0.286)
*furn**	1.463	1.014	0.181	-1.211	0.699	1.165	**2.154**
	(0.061)	(0.197)	(0.817)	(0.117)	(0.380)	(0.131)	(**0.019**)
health	2.561	2.029	1.754	1.802	3.153	**5.098**	**5.287**
	(0.178)	(0.272)	(0.315)	(0.347)	(0.136)	(**0.019**)	(**0.019**)
transport	0.143	1.034	1.717	0.866	-0.112	1.376	2.172
	(0.958)	(0.568)	(0.333)	(0.554)	(0.948)	(0.352)	(0.160)
commun	-2.028	-2.431	-2.058	-0.566	-0.586	-1.993	0.860
	(0.239)	(0.169)	(0.258)	(0.700)	(0.695)	(0.263)	(0.592)
*recr**	-0.802	-2.032	-3.410	**-3.965**	**-4.310**	-3.545	-0.533
	(0.549)	(0.188)	(0.056)	(**0.033**)	(**0.023**)	(0.075)	(0.789)
educ	1.564	1.156	1.313	1.476	1.178	1.577	2.260
	(0.319)	(0.451)	(0.390)	(0.366)	(0.446)	(0.324)	(0.188)
rest	**4.222**	3.531	**4.176**	**5.265**	**6.417**	**8.837**	**6.821**
	(**0.028**)	(0.052)	(**0.042**)	(**0.042**)	(**0.009**)	(**0.005**)	(**0.009**)
misc	1.808	0.682	0.737	0.985	1.521	0.618	0.770
	(0.099)	(0.455)	(0.418)	(0.300)	(0.127)	(0.488)	(0.413)

Note: Table entries are gaps between actual and synthetic values of corresponding variables. Positive gaps imply that actual values are greater than the synthetic ones. P-values are given in parentheses. Bold entries are significant at the 5% level.

** Denotes specifications with no MSPEs three times larger than the Croatian one (leaving the baseline ASCM results intact).*

Source: Author's calculation.

To shed some light on this issue, Abadie et al. (2010) and Abadie, Diamond and Hainmueller (2015) suggest augmenting the baseline model with additional estimates, i.e. repeating the analysis with $J = 26$ more iterations. In each of them, another country is set as the placebo intervention entity. The idea is to see if falsely setting any of the remaining 26 economies as intervention entities would generate better pre-treatment fit than the Croatian case with the actual euro conversion. As suggested by Abadie et al. (2010) and Abadie, Diamond and Hainmueller (2015), in each considered model, we calculate the mean squared prediction error (MSPE), and we identify countries with MSPEs several times higher than that the Croatian

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one. For these countries, our model was clearly not able to adequately reproduce the time dynamics of inflation prior to 2023.

As Abadie, Diamond and Hainmueller (2010: 502) state, placebo runs with poor fit prior to the intervention can hardly provide adequate information to measure the relative size of the shock after the intervention. In placebo tests across countries, we exclude all countries with MSPEs at least three times higher than the Croatian MSPE. As revealed by table 2, placebo tests across countries leave our previous conclusions mostly intact. The effect of euro introduction seems to be considerable only for *food*, *clothing* and *rest*. It should be noted that, this time, the effect of *hicp* is not significant at all (see table 1 vs. table 2).

The results of placebo tests across time are shown in tables 3-5. For placebo estimates we artificially set the intervention date before the actual timing of euro changeover. To be specific, we chose 2022M12 (one month before the actual changeover), 20022M09 (when the obligation of displaying dual prices (kuna vs. euro) was officialy introduced in Croatia), and 2015M05 as the month when the Croatian *y-o-y* HICP inflation rate was zero.[2] This should serve as an adequate placebo test, especially having in mind that the euro conversion was introduced in circumstances of double-digit inflation rates.

Placebo specifications across time reveal a lot of ambiguity concerning the exact timing of the euro effect on prices. This does not come as such a surprise. Croatian integration to the euro area has been a long process, involving a more demanding procedure than previous countries entering the euro area. In June 2017, the Croatian Excessive Deficit Procedure was officially closed, so the Government could introduce the Euro adoption strategy in May 2018. After an intense bilateral cooperation with the ECB, the Croatian kuna was included in the ERM II mechanism in July 2020, and the EU Council finally made a positive decision regarding the Croatian euro adoption in July 2022. It should also be noted that Croatia is secularly characterized by deposit and credit euroization (Dumičić, Ljubaj and Martinis, 2018). Finally, Misztal (2017) found that Croatian inflation (both aggregate and related to individual ECOICOP subcategories) is a highly persistent phenomenon, so shocks should typically take a relatively long time to absorb. In that sense, any change that occurred due to the euro was certainly not an abrupt one-time intervention, but a gradual, possibly smooth transition process.

[2] We also considered the following placebo intervention dates: 2002M06, 2022M10, 2022M11, along with 2020M07 when Croatia entered the ERM2 mechanism and 2014M05 when the ECB released its first convergence report for Croatia (and declared that Croatia satisfies the Maastricht criterion of inflation stability). The results are qualitatively very similar to those reported in tables 3-5.

Table 3

ASCM results (January to July 2023): placebo estimations across time (2015M05 as intervention date)

	January	February	March	April	May	June	July
hicp	2.678	1.626	2.478	0.853	0.506	1.174	1.298
	(0.355)	(0.595)	(0.397)	(0.769)	(0.81)	(0.636)	(0.554)
food	4.521	3.286	2.543	3.220	3.441	**4.811**	3.721
	(0.157)	(0.306)	(0.372)	(0.215)	(0.149)	**(0.025)**	(0.074)
nonalc	1.124	-3.245	-3.583	-3.264	-2.031	0.215	-1.607
	(0.736)	(0.339)	(0.413)	(0.463)	(0.62)	(0.95)	(0.463)
alc	2.783	1.040	-0.778	-0.455	-0.454	0.287	0.141
	(0.215)	(0.579)	(0.678)	(0.851)	(0.843)	(0.959)	(0.992)
clothing	**8.871**	**6.440**	2.785	3.413	1.813	4.148	**7.803**
	(0.008)	**(0.033)**	(0.421)	(0.174)	(0.636)	(0.083)	**(0.008)**
housing	-22.051	-16.597	-12.641	-27.614	-29.643	-20.988	-15.951
	(0.612)	(0.562)	(0.653)	(0.388)	(0.372)	(0.397)	(0.512)
furn	**6.726**	**5.535**	**4.894**	**3.677**	**3.762**	**3.114**	**3.022**
	(0.008)	**(0.008)**	**(0.008)**	**(0.008)**	**(0.008)**	**(0.008)**	**(0.008)**
health	-4.891	-5.445	-4.343	-5.334	-3.745	-1.526	-2.173
	(0.099)	(0.066)	(0.165)	(0.215)	(0.355)	(0.711)	(0.57)
transport	-0.613	-0.533	-0.916	-0.845	-1.627	-0.587	0.558
	(0.727)	(0.744)	(0.694)	(0.645)	(0.463)	(0.744)	(0.835)
commun	-0.076	-0.094	0.471	1.884	1.886	-0.362	3.159
	(0.975)	(0.975)	(0.818)	(0.405)	(0.397)	(0.851)	(0.207)
recr	-6.616	-7.152	-8.661	-9.315	**-8.989**	**-5.424**	2.099
	(0.231)	(0.165)	(0.14)	(0.058)	**(0.033)**	**(0.149)**	(0.545)
educ	13.190	13.044	13.313	12.737	12.811	13.079	13.782
	(0.223)	(0.231)	(0.223)	(0.24)	(0.248)	(0.231)	(0.223)
rest	**12.742**	**12.243**	**13.025**	**11.675**	**11.423**	**12.661**	**9.611**
	(0.033)	**(0.033)**	**(0.033)**	**(0.033)**	**(0.025)**	**(0.017)**	**(0.025)**
misc	**3.894**	2.993	**2.967**	2.476	2.331	1.888	1.904
	(0.017)	(0.05)	**(0.025)**	(0.05)	(0.074)	(0.091)	(0.099)

Note: Table entries are gaps between actual and synthetic values of corresponding variables. Positive gaps imply that actual values are greater than the synthetic ones. P-values are given in parentheses. Bold entries are significant at the 5% level.

Source: Author's calculation.

TABLE 4

ASCM results (January to July 2023): placebo estimations across time (2022M09 as intervention date)

	January	February	March	April	May	June	July
hicp	**3.285**	**2.245**	**2.821**	1.683	**2.210**	**3.117**	**2.998**
	(0.005)	**(0.038)**	**(0.043)**	(0.215)	**(0.048)**	**(0.01)**	**(0.005)**
food	1.832	1.994	2.338	**4.398**	**4.890**	**5.469**	3.203
	(0.378)	(0.359)	(0.282)	**(0.033)**	**(0.01)**	**(0.005)**	(0.067)
nonalc	2.052	-0.339	0.642	2.290	3.811	**4.546**	3.525
	(0.297)	(0.809)	(0.727)	(0.301)	(0.062)	**(0.014)**	(0.053)
alc	0.946	-0.674	-2.200	-1.948	-1.599	-1.388	-1.437
	(0.627)	(0.756)	(0.278)	(0.321)	(0.459)	(0.536)	(0.512)
clothing	7.889	5.817	3.118	3.143	2.098	3.728	7.265
	(0.005)	(0.019)	(0.187)	(0.158)	(0.373)	(0.091)	(0.005)
housing	5.608	4.200	1.014	-2.075	-2.172	-1.993	-0.969
	(0.474)	(0.565)	(0.938)	(0.689)	(0.651)	(0.641)	(0.77)
furn	**2.542**	**1.932**	1.136	-0.299	1.425	**1.600**	**2.469**
	(0.01)	**(0.033)**	(0.196)	(0.684)	(0.1)	**(0.043)**	**(0.005)**
health	2.516	1.926	1.670	1.929	2.990	**4.239**	**4.506**
	(0.182)	(0.301)	(0.388)	(0.349)	(0.172)	**(0.024)**	**(0.019)**
transport	-0.216	-0.013	-0.837	-1.878	-1.846	-0.042	0.702
	(0.809)	(0.952)	(0.574)	(0.244)	(0.263)	(0.947)	(0.651)
commun	-1.781	-1.922	-0.374	0.529	0.879	-0.322	2.579
	(0.254)	(0.23)	(0.852)	(0.742)	(0.569)	(0.861)	(0.124)
recr	-1.670	-2.882	-4.296	-4.707	**-4.951**	-4.009	-0.692
	(0.378)	(0.163)	(0.053)	(0.033)	**(0.024)**	(0.067)	(0.77)
educ	1.971	1.721	2.179	2.330	1.919	2.477	3.333
	(0.603)	(0.636)	(0.569)	(0.541)	(0.612)	(0.522)	(0.397)
rest	**7.230**	**6.572**	**7.063**	**7.692**	**9.500**	**11.415**	**9.530**
	(0.01)	**(0.01)**	**(0.01)**	**(0.014)**	**(0.01)**	**(0.005)**	**(0.01)**
misc	**3.126**	1.891	1.727	1.115	1.649	1.383	1.158
	(0.01)	(0.11)	(0.11)	(0.268)	(0.1)	(0.201)	(0.273)

Note: Table entries are gaps between actual and synthetic values of corresponding variables. Positive gaps imply that actual values are greater than the synthetic ones. P-values are given in parentheses. Bold entries are significant at the 5% level.

Source: Author's calculation.

Table 5

ASCM results (January to July 2023): placebo estimations across time (2022M12 as intervention date)

	January	February	March	April	May	June	July
hicp	**1.988**	1.196	1.884	0.768	1.429	**2.275**	**2.234**
	(0.024)	(0.212)	(0.108)	(0.472)	(0.189)	**(0.028)**	**(0.005)**
food	0.280	0.353	1.023	2.935	**4.014**	**4.961**	**3.604**
	(0.901)	(0.882)	(0.559)	(0.113)	**(0.024)**	**(0.005)**	**(0.028)**
nonalc	-0.018	-2.062	-1.764	-0.213	1.533	2.949	2.625
	(0.981)	(0.255)	(0.354)	(0.896)	(0.382)	(0.108)	(0.132)
alc	1.103	-0.491	-2.010	-1.754	-1.148	-1.276	-1.362
	(0.571)	(0.844)	(0.288)	(0.368)	(0.509)	(0.552)	(0.524)
clothing	**8.193**	**6.030**	3.455	3.351	2.372	4.265	**7.397**
	(0.005)	**(0.009)**	(0.16)	(0.156)	(0.349)	(0.08)	**(0.005)**
housing	4.264	3.606	0.971	-1.116	-1.014	-0.719	-0.274
	(0.335)	(0.462)	(0.939)	(0.741)	(0.741)	(0.802)	(0.915)
furn	**1.755**	1.190	0.488	-0.790	0.936	1.357	**2.262**
	(0.028)	(0.156)	(0.491)	(0.349)	(0.264)	(0.118)	**(0.009)**
health	2.431	1.840	1.588	1.836	2.889	**4.155**	**4.422**
	(0.184)	(0.311)	(0.382)	(0.358)	(0.17)	**(0.024)**	**(0.019)**
transport	-0.822	-0.596	-1.142	-2.081	-1.851	-0.048	0.814
	(0.566)	(0.632)	(0.472)	(0.217)	(0.259)	(0.892)	(0.608)
commun	-1.749	-1.682	-0.932	-0.004	0.254	-0.966	1.789
	(0.269)	(0.311)	(0.604)	(1.000)	(0.868)	(0.594)	(0.269)
recr	-0.868	-2.090	-3.474	**-4.006**	**-4.354**	-3.561	-0.498
	(0.528)	(0.203)	(0.057)	**(0.033)**	**(0.024)**	(0.075)	(0.811)
educ	1.980	1.726	2.335	2.504	2.130	2.737	3.618
	(0.245)	(0.292)	(0.203)	(0.193)	(0.245)	(0.179)	(0.066)
rest	**4.950**	**4.365**	**4.982**	**5.787**	**7.391**	**9.592**	**7.653**
	(0.024)	**(0.033)**	**(0.028)**	**(0.028)**	**(0.009)**	**(0.005)**	**(0.009)**
misc	**1.963**	0.501	0.695	0.594	1.495	1.238	1.218
	(0.028)	(0.604)	(0.462)	(0.495)	(0.127)	(0.212)	(0.212)

Note: Table entries are gaps between actual and synthetic values of corresponding variables. Positive gaps imply that actual values are greater than the synthetic ones. P-values are given in parentheses. Bold entries are significant at the 5% level.

Source: Author's' calculation.

As a final robustness check, we utilize alternative ASCM estimators for constructing outcome weights. To be specific, we use SCM augmented with matrix completion (Athey et al., 2021), the generalized synthetic control methods (Xu, 2017) and the Becker and Klößner (2018) method. The results (see appendix) are again mostly very comparable to the baseline model (table 1), with the major exception that the euro effect on *food* is not significant. It should be noted that the Becker and Klößner (2018) method provides added value in terms of both accuracy and estimation speed. However, it does not allow for statistical inference in the manner we are interested in. Table A3 in the appendix illustrates that the gap between actual and synthetic inflation takes the largest (positive) value for *clothing* and

rest, which is in line with our initial results. Although we are unable to test the statistical significance of these discrepancies, we might conclude that they corroborate our initial insights.

Further on, we also made an effort to model lower-level ECOICOP inflation subcomponents within the categories where we find rather robust evidence of a significant euro effect (*food*, *clothing*, and *rest*). This type of granular perspective might potentially enable us to obtain a deeper understanding of the economic mechanisms at hand. Here we again optimize the model fit by using a set of auxiliary covariates that minimize the average pre-treatment fit (*fuel*, *exp*, *gap*, and *hicp* are considered as potential covariates). The results are presented in table 6 and figure A2 in the appendix. The note below figure A2 specifies the exact set of covariates used for each inflation category.

Table 6 reveals that the prices of coffee, wine, clothing, footwear, catering, restaurants and cafés, and accommodation have indeed reacted the most intensively to the euro changeover. However, the average biases reported in figure A2 suggest that most of lower-level ECOICOP inferences are to be taken with caution since the obtained fit is largely questionable. The official EU statistics hardly provides decent auxiliary covariates that are able to capture the dynamics of inflation at such low level of aggregation.

Summarizing all the obtained evidence, it seems that the euro effect on inflation at the aggregate level is heavily dependent on the model specification and the underlying methodological framework. The majority of inflation subcategories do not offer evidence of a euro effect. The only three inflation categories that exhibit a substantial euro effect are *food*, *clothing* and *rest*. To grasp the magnitude of the observed effect on these constructs, we graphically depict the shares of price increases in 2023 attributable to euro changeover. As figure 3 shows, the observed impact is the most intensive for *clothing* in July 2023, where the euro accounts for 61.97% of *y-o-y* inflation. Namely, the official inflation rate for this category in January 2023 was 11.90%, and the euro effect accounts for a discrepancy of 7.37% between actual and counterfactual Croatia (see table 2). On average in the seven observed months, euro accounts for 46.14% of inflation in *clothing*, 32.72% of inflation in *rest*, and 15.72% of inflation in *food*. Very similar results are obtained for alternative ASCM estimators (appendix).

Table 6

ASCM estimations for lower-level ECOICOP inflation categories (January to July 2023)

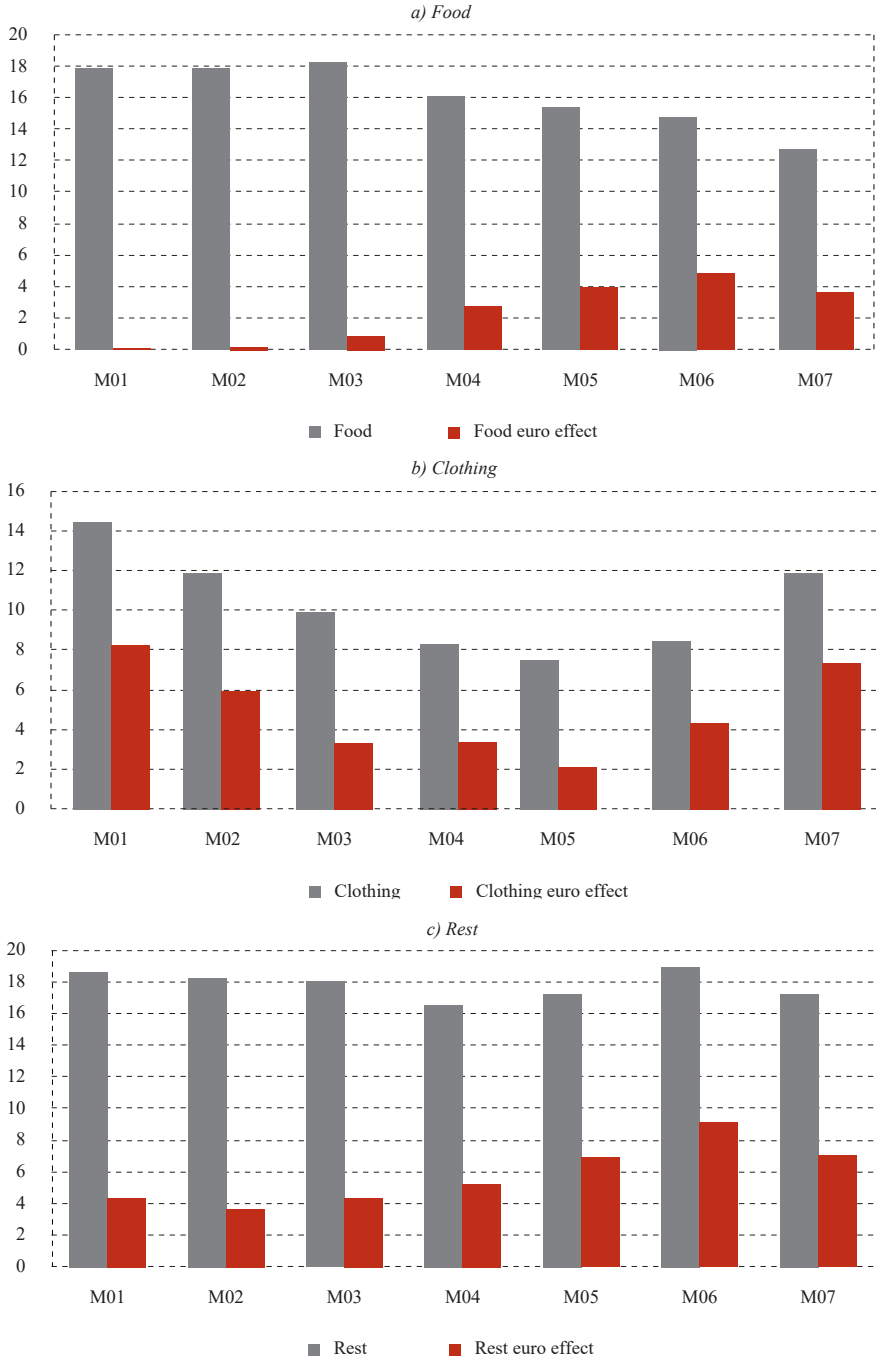
	January	February	March	April	May	June	July
meat	-1.283	-2.973	-0.734	2.335	0.091	0.432	-1.780
	(0.521)	(0.178)	(0.770)	(0.362)	(0.986)	(0.915)	(0.484)
fish	-1.923	-3.275	-4.825	**-5.100**	-1.459	1.442	-0.095
	(0.404)	(0.146)	(0.070)	(**0.047**)	(0.535)	(0.559)	(0.972)
milk	-2.491	-1.951	0.767	0.471	4.049	4.818	1.808
	(0.352)	(0.507)	(0.803)	(0.854)	(0.164)	(0.117)	(0.432)
fruit	-4.303	-3.349	1.101	2.744	3.368	4.127	2.787
	(0.277)	(0.380)	(0.779)	(0.455)	(0.366)	(0.296)	(0.455)
veg	-8.104	-4.751	2.806	3.644	4.121	7.153	7.649
	(0.136)	(0.357)	(0.601)	(0.446)	(0.408)	(0.178)	(0.141)
coffee	-1.677	-1.464	-2.774	2.215	**6.952**	**5.684**	**4.821**
	(0.371)	(0.441)	(0.211)	(0.329)	(**0.014**)	(**0.014**)	(**0.023**)
juice	0.157	-1.986	-0.516	-1.538	1.077	2.895	2.394
	(0.901)	(0.441)	(0.831)	(0.592)	(0.685)	(0.244)	(0.300)
wine	-0.528	-0.290	0.727	2.099	**5.995**	**3.565**	**5.966**
	(0.770)	(0.869)	(0.709)	(0.329)	(**0.005**)	(**0.080**)	(**0.005**)
beer	**3.788**	3.975	-0.751	-1.279	-0.452	0.967	3.097
	(**0.047**)	(0.052)	(0.718)	(0.521)	(0.812)	(0.568)	(0.080)
tobacco	-0.927	-1.655	-2.002	-2.913	-2.302	-1.474	-3.132
	(0.765)	(0.545)	(0.502)	(0.357)	(0.446)	(0.592)	(0.347)
cloth	**8.285**	**6.095**	3.391	3.044	1.403	3.844	**6.031**
	(**0.005**)	(**0.028**)	(0.239)	(0.291)	(0.610)	(0.192)	(**0.028**)
foot	**7.504**	3.174	1.657	1.126	2.055	2.582	**7.947**
	(**0.014**)	(0.310)	(0.582)	(0.681)	(0.512)	(0.385)	(**0.009**)
cater	**4.486**	**3.314**	**3.236**	**4.180**	**4.397**	**5.376**	**5.883**
	(**0.005**)	(**0.014**)	(**0.014**)	(**0.009**)	(**0.005**)	(**0.005**)	(**0.005**)
rest_caf	**5.289**	**3.131**	**3.325**	**4.224**	**4.380**	**5.399**	**5.818**
	(**0.005**)	(**0.014**)	(**0.014**)	(**0.005**)	(**0.005**)	(**0.005**)	(**0.005**)
accomm	2.670	4.605	4.833	-0.029	6.069	**13.572**	**8.008**
	(0.399)	(0.150)	(0.131)	(0.977)	(0.066)	(**0.014**)	(**0.033**)

Note: Table entries are gaps between actual and synthetic values of corresponding variables. Positive gaps imply that actual values are greater than the synthetic ones. P-values are given in parentheses. Bold entries are significant at the 5% level.

Source: Author's calculation.

FIGURE 3

Price increases attributable to the euro changeover, 2023



Source: Author's calculation.

Although we are not aware of a study dealing with conversion-related inflation that uses the ASCM methodology, it is easy to notice that previous studies also found only a negligible fraction of inflation increase that can be attributed to the conversion. For example, Sturm et al. (2009) find the overall effect to be between 0.05 and 0.23 percentage points. Pufnik (2018) provides a very informative literature review on that topic, highlighting a series of papers with very similar findings that closely correlate to our finding that there was no dramatic effect on overall inflation. Likewise, recent policy reports and preliminary analyses have also noted a negligible effect of the currency changeover on Croatian inflation. According to the simulations of Falagiarda et al. (2023), Croatian inflation in January 2023 would have been only 0.4 percentage points lower without euro introduction (had the prices followed the dynamics of previous 10 years). Falagiarda et al. (2023) also perform an analysis of micro data, finding that the prices of as many as 65% of products have remained the same in January 2023 as in the previous month. That percentage was even higher (85%) in February in comparison to January.

The only three inflation constructs that exhibit a significant intervention effect are *food*, *clothing* and *rest*. All three constructs were also identified as conversion-related in previous euro area enlargements. For example, Brachinger (2008) and Lunn and Duffy (2015) identify frequently bought goods such as food as one of the main reasons for a euro-induced inflation perception gap in previous euro area enlargements.

Further on, Cavallo, Neiman and Rigobon (2015) find that web-shop clothing prices after the Latvian euro changeover rapidly converged to those of western European countries. Likewise, Rõõm and Urke (2014) find similar evidence for the Estonian case. On the other hand, previous studies uniformly identified restaurant prices as very susceptible to euro conversion shocks (see Sturm et al. (2009) and Pufnik (2018) for detailed comparisons of the estimated euro effects). These inferences can at least to some extent be explained by menu costs associated with the monetary conversion (Fabiani et al., 2007).

These results should also be interpreted with regard to the idiosyncracies of Croatian euro conversion. As opposed to previous enlargements, Croatia entered the euro area in a period of very high inflation rates. This is important for at least three reasons. Extreme values of inflation typically move economic agents away from *rational expectations.* Concepts such as *bounded rationality* and *rational inattention* are usually used to explain the consumers' limited capacity to process volatile and frequently updated price information, which gives the sellers a short-run market power that may lead to price increases (Ehrmann, 2006). Second, extreme events such as the recent post-pandemic period usually induce biased inflation expectations (Sorić, Lolić and Matošec, 2020), which ultimately may feed into actual price increases. Third, the Croatian Government has responded to extreme inflationary pressures through a series of five anti-inflationary packages, administratively limiting the prices of basic foodstuffs, electricity and gas. This may be

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one of the reasons why a stronger euro effect was not found for *food*, as well as why the euro effect was mostly not significant for other ECOICOP categories (e.g. *housing* and *transport*). A glance at table 6 reveals that indeed the euro did not have much of an effect on food categories that (at least partially) had a price ceiling imposed by the Government (e.g. *meat, milk, fruit*, and *veg*).

Although the econometric framework of this study does not allow for a formal examination of the efficiency of obligatory dual pricing from September 2022 onward, this strategy has probably decreased the information processing requirements for consumers and made it easier to react to possible unfair price rounding. Previous studies of euro-related inflationary impact also postulated that euro area enlargements should lead to certain spillover effects of prices among member states. In that context, two theoretical concepts are particularly important. The first one is the *law of one price* (LOP), postulating that (under certain conditions) the prices of identical goods and services should be the same when expressed in the same currency. Glushenkova and Zachariadis (2016) noticed that the euro area is an ideal setup to test this theory, and found that LOP density functions indeed exhibit lower cross-country dispersion after the euro introduction.

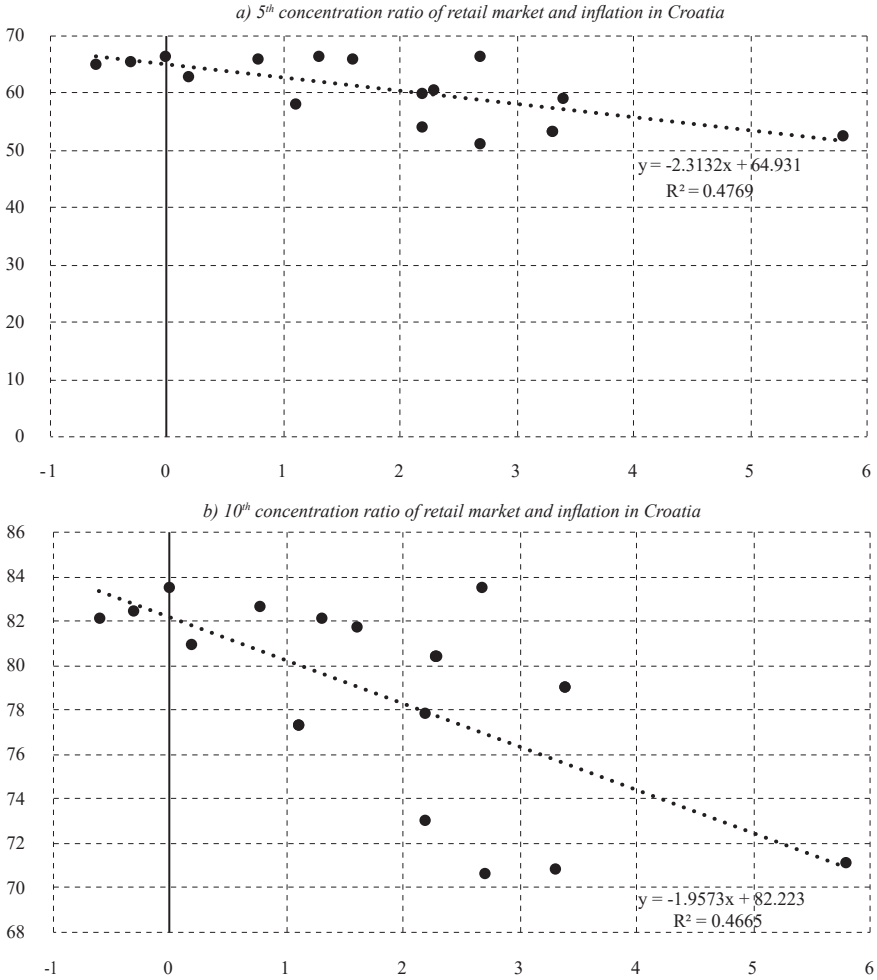
The second one is price convergence among euro area member states. For example, Sturm et al. (2009) find that the euro introduction has indeed stimulated price convergence, the effect being much larger for non-tradable goods and services than for tradables.

When it comes to the underlying drivers of price convergence, Sturm et al. (2009) do not offer unambiguous evidence. Among the rare robust results is the finding that distance negatively affects price differentials. When explaining these inferences, Sturm et al. (2009: 221) question the appropriateness of macro data for this type of analysis. As micro data on prices would be a possibly more appropriate data source for testing both price convergence and the LOP, we leave this issue to future research.

If we were to identify a potential domestic culprit for the Croatian price hike around the currency changeover, it might be market concentration. The notion itself is not new. For example, Dziuda and Mastrobuoni (2009) find both anecdotal and rigorous econometric evidence that highly concentrated retail markets experienced more intensive euro-related inflation effects in the 2002 currency changeover. As expected, competition brings considerable benefits to consumers. To empirically question this claim for the Croatian case, we did some back-of-an-envelope calculations using two different measures of market concentration.

FIGURE 4

Market concentration and inflation in Croatia



Note: y-o-y annual HICP inflation rates are depicted on the horizontal axis, and measures of market concentration are on the vertical axis. Both panels refer to the period of 2006-2021, conditioned by data availability.

Source: Author's calculation based on data from the Agency for the Protection of Market Competition.

As expected, figure 4 detects a rather strong negative correlation between market concentration and inflation. The assessed data is not restricted to the euro changeover period, and these scatter plots should not be interpreted as nothing more than correlations. Nevertheless, if we were to formulate policy implications from this analysis, they would certainly include market competition and ensuring effective antitrust regulations. In such circumstances, consumers have the opportunity to penalize price manipulations and malpractice of any kind by changing retailers without significant switching costs. Mužić and Pufnik (2022), as well as Falagiarda et al. (2023) also highlight competition as a key factor that should contribute to inflation stabilization after the euro conversion in Croatia.

5 DISCUSSION AND CONCLUSION

This paper reveals that the euro changeover has had a modest impact on the overall inflation in Croatia. A disaggregated anaylsis reveals that very few categories of products and services (only food, clothing and restaurant prices) have indeed witnessed a substantial increase in the dawn of 2023 due to unfair pricing strategies, rounding effects, and retailers' desire to generate extra profit.

Some attention should also be devoted to the political aspect of the changeover process. European Commission (2022) states that only 25% of Croatians feel that it is the right moment to adopt the common currency. The setting of already intensive inflationary pressures due to global circumstances added considerable noise to the communication channel and made it extremely difficult to monitor high-frequency price changes at all, let alone to identify euro-related price manipulations. As a consequence, the Government was not able to identify price manipulators among the retailers and could not blacklist them, as was originally planned (Government of the RC and CNB, 2020), and as was done by countries that have previously entered the euro area.

This paper does not even come close to resolving all issues related to the euro-inflation nexus. We are confident that future studies will focus on an abundance of micro data on prices, which will possibly help in an understanding of the role and magnitude of price rounding amid the changeover, and deepen the understanding of price convergence and the validity of LOP. Further research on this topic should also focus on the phenomenon of inflation perceptions and its underlying determinants (media effects, the role of *a priori* expectations, socio-demographic factors, etc.). This would surely shed some light on the observed gap between actual and perceived inflation after the Croatian euro changeover.

Disclosure statement

The author has no conflict of interest to declare.

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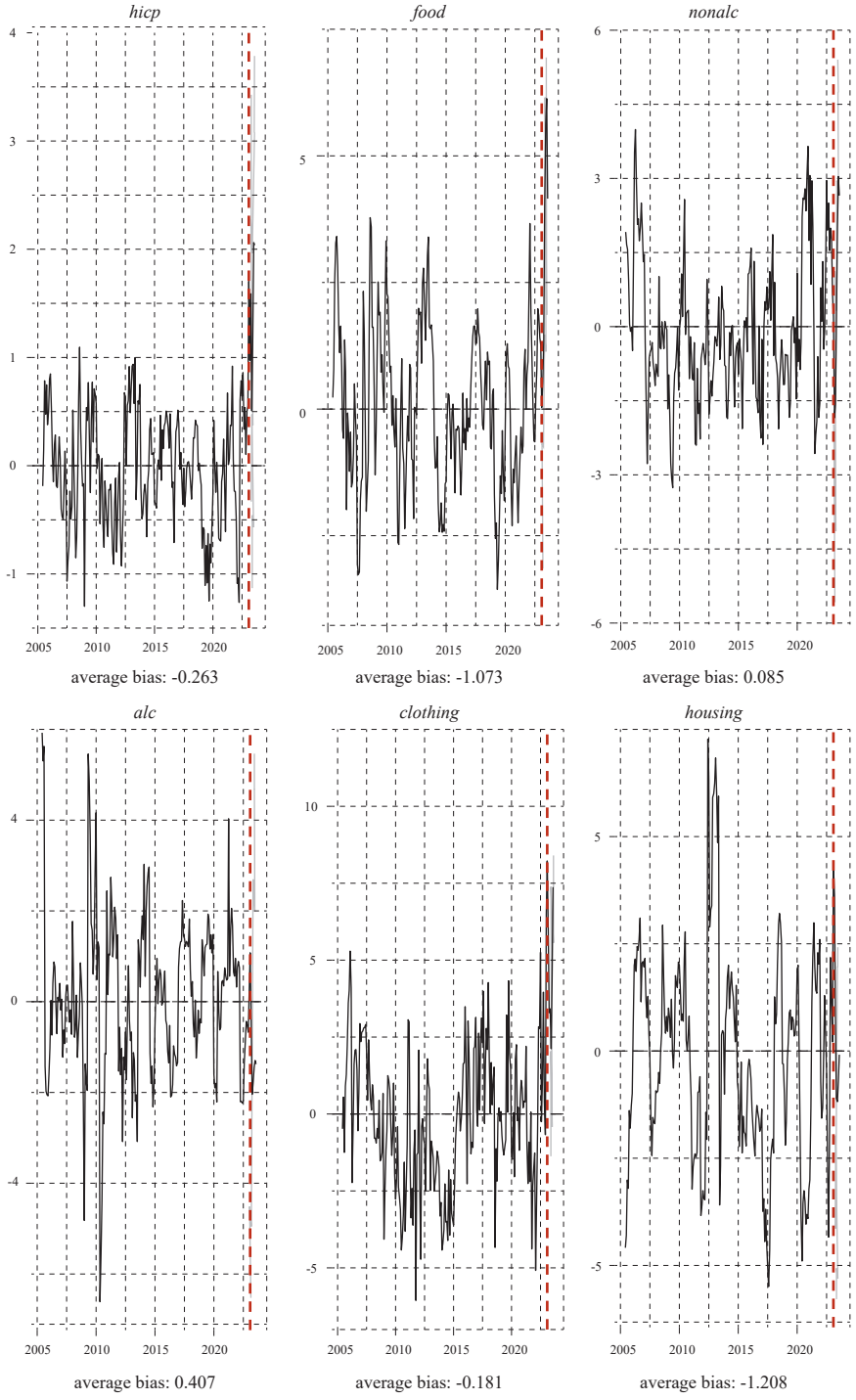
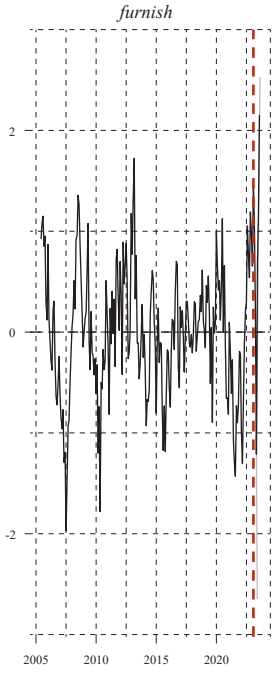
FIGURE A1

ASCM baseline estimations

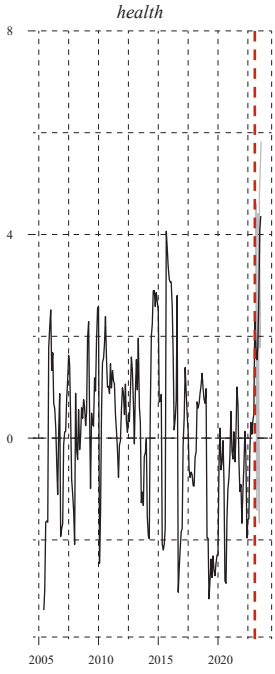


average bias: -0.263 | average bias: -1.073 | average bias: 0.085

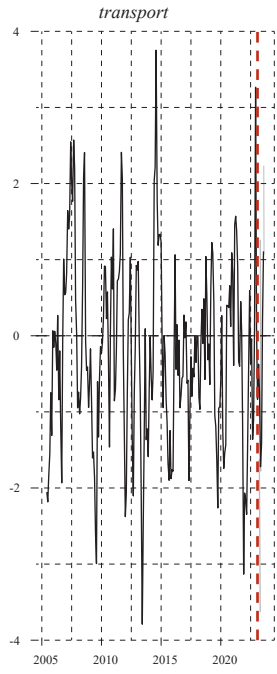
average bias: 0.407 | average bias: -0.181 | average bias: -1.208



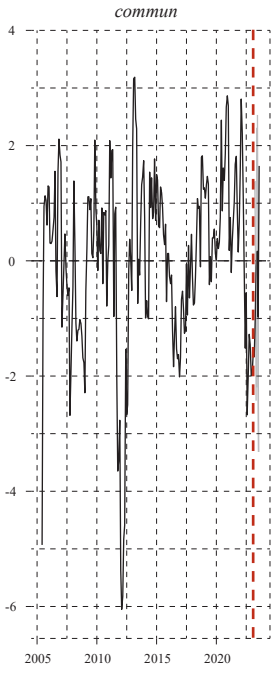
average bias: -0.138



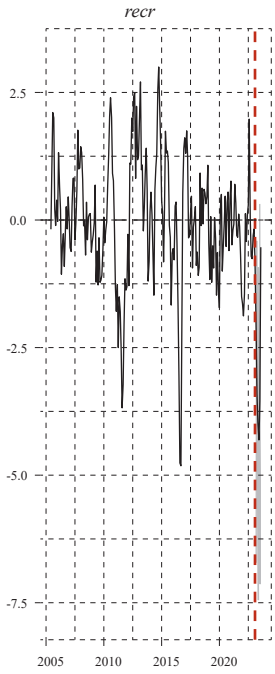
average bias: -0.889



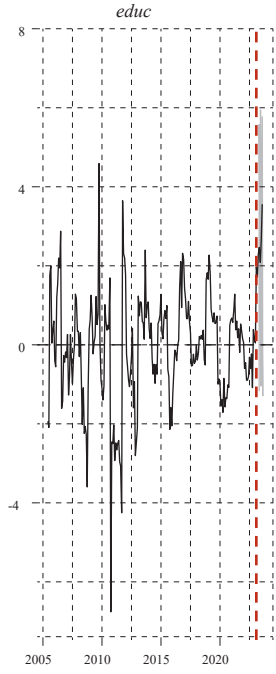
average bias: 0.490



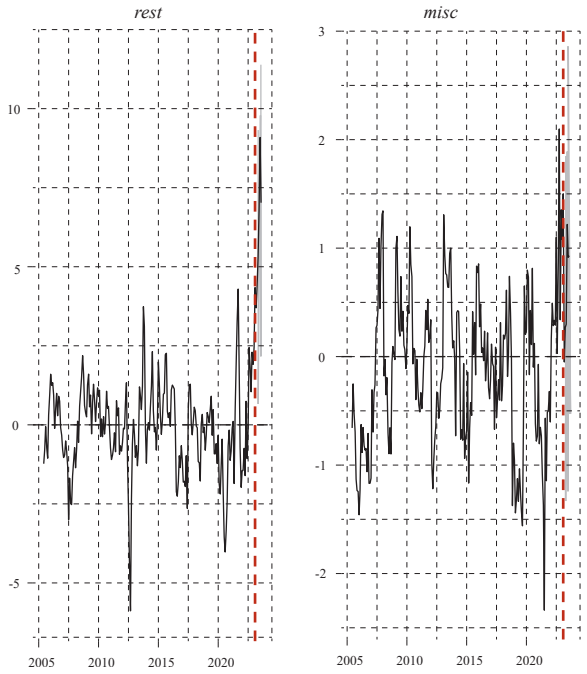
average bias: 0.026



average bias: 0.005



average bias: -2.812

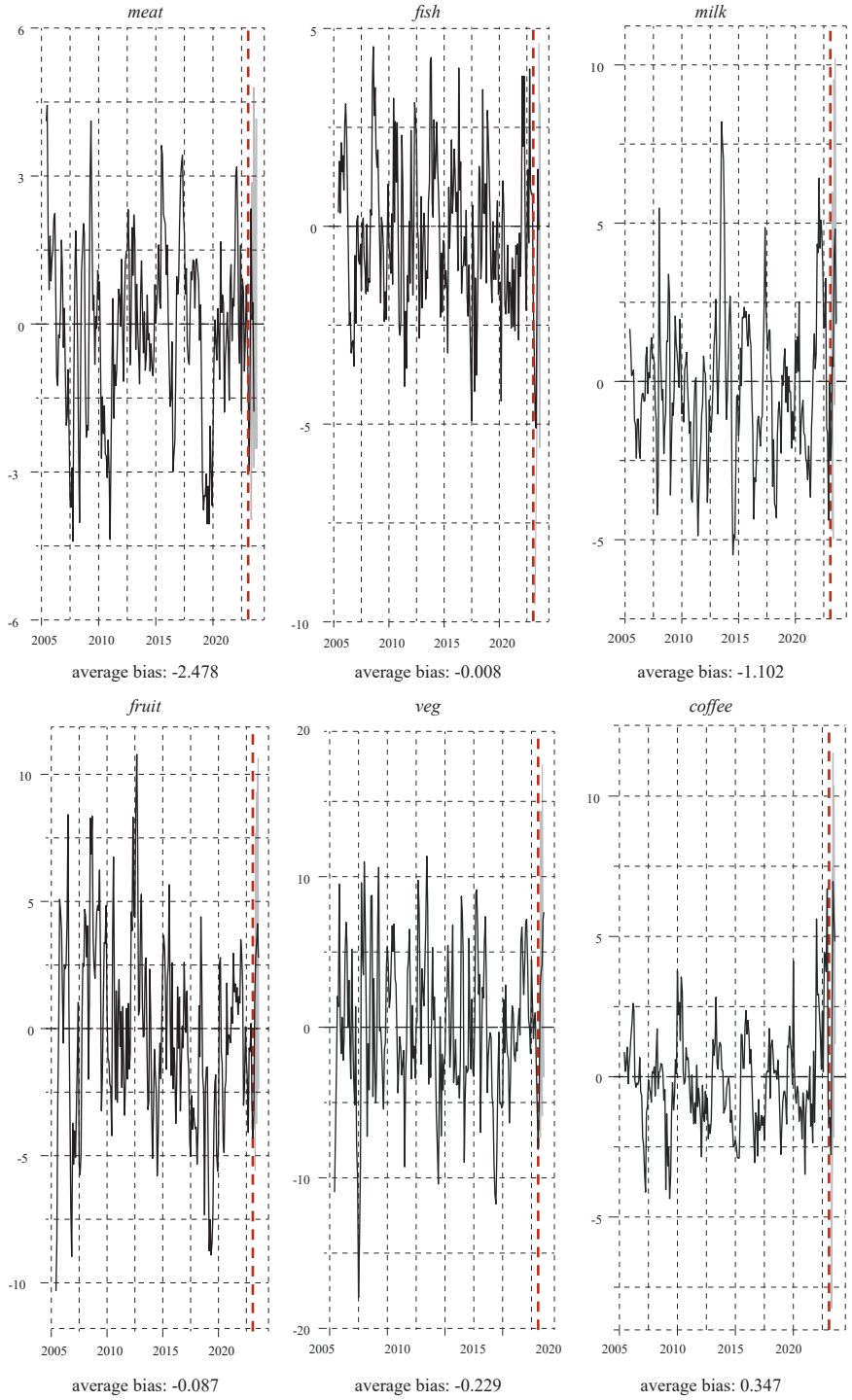


Note: Vertical axis captures the gaps between actual and synthetic values of corresponding variables (in percentage points). Positive gaps imply that actual values are greater than the synthetic ones, i.e. the currency changeover induced an inflation hike. Horizontal axis denotes time. Vertical dashed line denotes the date of currency changeover (January 2023). Grey shaded area after the currency changeover corresponds to the 95% confidence interval. Hicp and health models are estimated without auxiliary covariates. Food model is estimated with exp, gap, hicp, beer, fish, and milk as covariates. Nonalc, clothing, and housing models use exp, gap, and hicp as covariates. Furn and commun utilize fuel, exp, gap, and hicp; while recr, educ, rest, misc, and alc use fuel, exp, and gap as covariates. For the transport model we used exp and gap.

Source: Author's calculation.

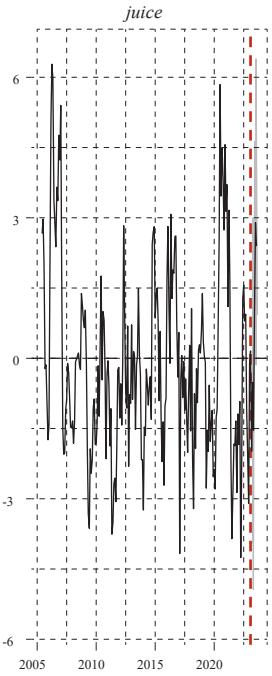
FIGURE A2

ASCM estimations for lower-level ECOICOP inflation categories

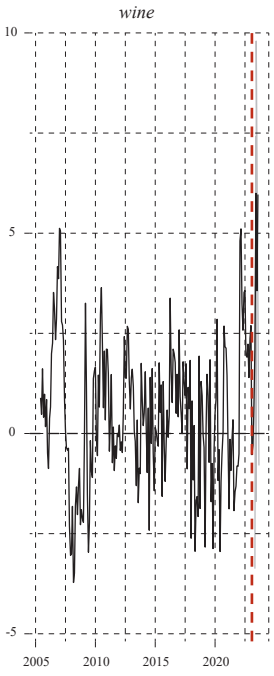


average bias: -2.478 | average bias: -0.008 | average bias: -1.102

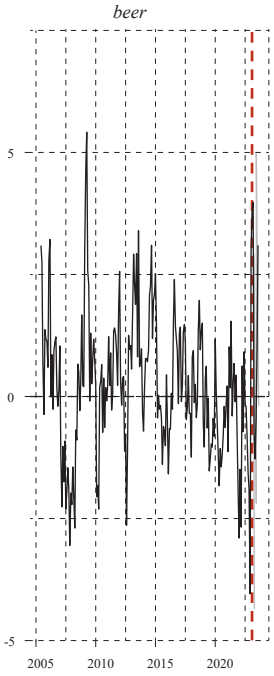
average bias: -0.087 | average bias: -0.229 | average bias: 0.347



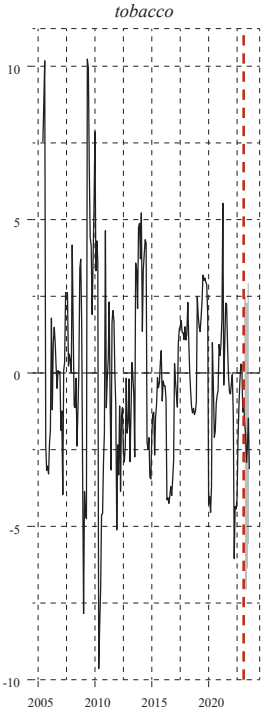
average bias: -0.571



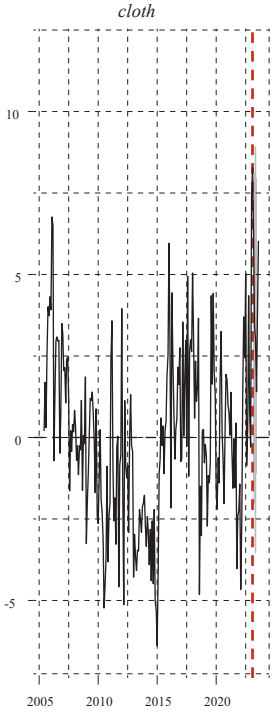
average bias: 1.924



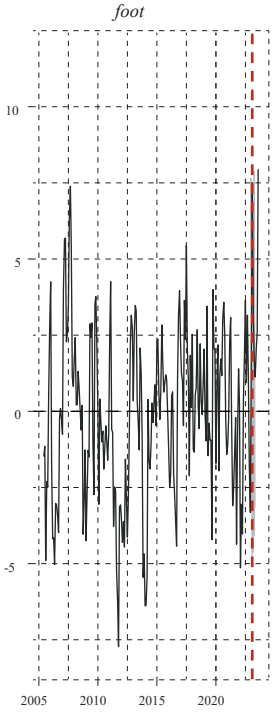
average bias: -0.968



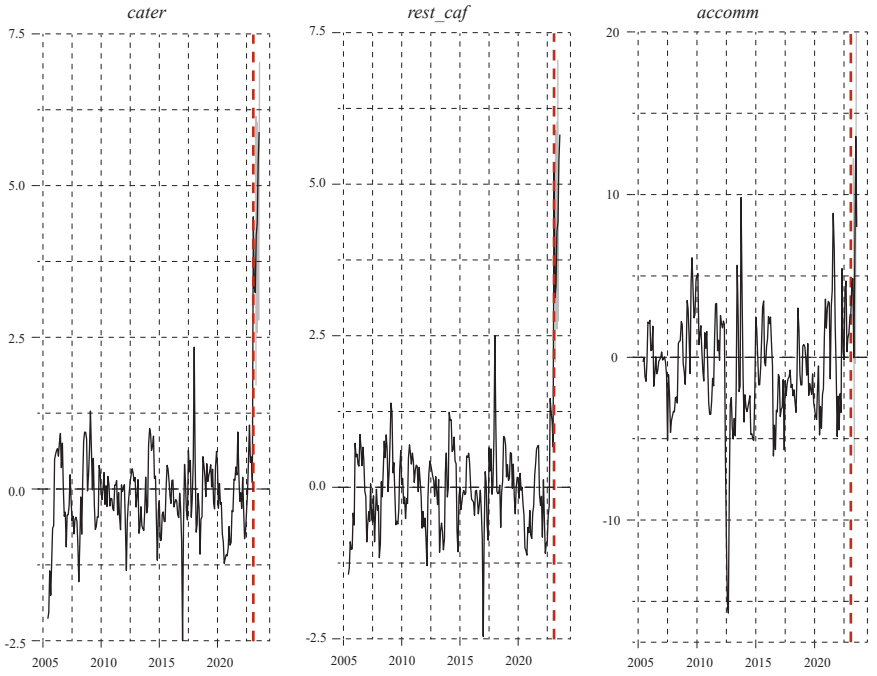
average bias: 0.196



average bias: 0.163



average bias: 0.057



Note: Vertical axis captures the gaps between actual and synthetic values of corresponding variables (in percentage points). Positive gaps imply that actual values are greater than the synthetic ones, i.e. the currency changeover induced an inflation hike. Horizontal axis denotes time. Vertical dashed line denotes the date of currency changeover (January 2023). Grey shaded area after the currency changeover corresponds to the 95% confidence interval. Meat, fish, fruit, veg, foot, rest_solo, and accomm models are estimated without auxiliary covariates. Wine and cloth models use exp, gap, and hicp as covariates. Milk, juice, beer, tobacco, and cater utilize fuel, exp, gap, and hicp as covariates. For the coffee model we used exp and gap.

Source: Author's calculation.

Table A1

ASCM robustness check via matrix completion method (January to July 2023)

	January	February	March	April	May	June	July
hicp	1.048	0.434	0.847	0.000	0.702	**1.652**	**1.823**
	(0.089)	(0.174)	(0.352)	(0.826)	(0.568)	(**0.023**)	(**0.014**)
food	-0.522	-0.716	-0.232	1.993	3.079	3.914	2.744
	(0.413)	(0.423)	(0.793)	(0.775)	(0.460)	(0.249)	(0.709)
nonalc	-0.507	-2.834	-2.613	-1.084	1.189	2.076	2.150
	(0.765)	(0.197)	(0.202)	(0.634)	(0.427)	(0.122)	(0.113)
alc	1.436	0.294	-1.040	-0.518	-0.103	0.553	0.109
	(0.432)	(0.822)	(0.305)	(0.441)	(0.577)	(0.690)	(0.690)
clothing	**6.406**	**4.039**	1.820	1.070	0.093	1.796	**4.496**
	(**0.005**)	(**0.023**)	(0.263)	(0.305)	(0.498)	(0.192)	(**0.005**)
housing	0.391	-0.587	-1.036	-5.251	-5.417	-4.636	-3.567
	(0.117)	(0.146)	(0.362)	(0.789)	(0.704)	(0.606)	(0.573)
furn	**1.784**	1.233	0.046	-1.423	0.143	0.882	**1.607**
	(**0.028**)	(0.174)	(0.521)	(0.324)	(0.615)	(0.282)	(**0.033**)
health	2.026	1.316	0.594	0.278	1.040	2.156	2.361
	(0.502)	(0.728)	(0.728)	(0.573)	(0.329)	(0.197)	(0.192)
transport	-1.009	-0.596	-0.339	-1.726	-1.209	0.655	1.183
	(0.761)	(0.488)	(0.840)	(0.596)	(0.643)	(0.488)	(0.315)
commun	0.368	-0.245	0.629	1.562	0.928	-0.252	1.924
	(0.516)	(0.526)	(0.667)	(0.887)	(0.991)	(0.526)	(0.380)
recr	0.700	-0.570	-2.035	-2.597	**-2.989**	**-2.664**	-0.735
	(0.967)	(0.338)	(0.146)	(0.056)	(**0.047**)	(**0.033**)	(0.085)
educ	0.353	-24.000	0.186	0.011	-0.190	0.395	1.052
	(0.981)	(0.873)	(0.808)	(0.704)	(0.624)	(0.761)	(0.958)
rest	**3.341**	**2.776**	**2.863**	**3.088**	**4.725**	**7.510**	**5.811**
	(**0.028**)	(**0.033**)	(**0.028**)	(**0.042**)	(**0.014**)	(**0.005**)	(**0.005**)
misc	**1.042**	-0.355	-0.237	-0.418	-0.380	**-0.318**	**0.014**
	(**0.028**)	(0.695)	(0.376)	(0.254)	(0.164)	(**0.047**)	(**0.038**)

Note: Table entries are gaps between actual and synthetic values of corresponding variables. Positive gaps imply that actual values are greater than the synthetic ones. P-values are given in parentheses. Bold entries are significant at the 5% level.

Source: Author's calculation.

Table A2

ASCM robustness check via generalized synthetic control (January to July 2023)

	January	February	March	April	May	June	July
hicp	2.130	1.686	1.660	0.683	1.086	**2.256**	**2.379**
	(0.089)	(0.174)	(0.352)	(0.826)	(0.568)	**(0.023)**	**(0.014)**
food	1.317	1.103	1.866	2.682	3.121	3.462	1.893
	(0.413)	(0.423)	(0.793)	(0.775)	(0.46)	(0.249)	(0.709)
nonalc	1.229	-1.142	2.255	-0.191	1.816	2.812	1.673
	(0.765)	(0.197)	(0.202)	(0.634)	(0.427)	(0.122)	(0.113)
alc	0.253	-1.483	-3.047	-2.157	-2.005	-1.661	-1.648
	(0.432)	(0.822)	(0.305)	(0.441)	(0.577)	(0.69)	(0.69)
clothing	**6.200**	**4.550**	0.759	1.946	0.806	3.057	**6.611**
	(0.005)	**(0.023)**	(0.263)	(0.305)	(0.498)	(0.192)	**(0.005)**
housing	6.506	5.691	2.228	0.138	0.341	0.600	-0.541
	(0.117)	(0.146)	(0.362)	(0.789)	(0.704)	(0.606)	(0.573)
furn	**-3.466**	-3.012	-3.861	-4.883	-3.060	-1.630	**-0.530**
	(0.028)	(0.174)	(0.521)	(0.324)	(0.615)	(0.282)	**(0.033)**
health	1.483	0.804	1.072	1.593	0.537	3.578	3.578
	(0.502)	(0.728)	(0.728)	(0.573)	(0.329)	(0.197)	(0.192)
transport	1.844	1.932	-0.292	-1.231	-1.572	0.027	1.589
	(0.761)	(0.488)	(0.84)	(0.596)	(0.643)	(0.488)	(0.315)
commun	-2.172	-1.698	-0.956	-0.133	-0.398	-1.550	1.175
	(0.516)	(0.526)	(0.667)	(0.887)	(0.991)	(0.526)	(0.38)
recr	-3.983	-5.523	-7.025	-7.190	**-6.930**	**-6.538**	-4.478
	(0.967)	(0.338)	(0.146)	(0.056)	**(0.047)**	**(0.033)**	(0.085)
educ	6.853	6.611	6.372	5.934	5.669	5.962	6.387
	(0.981)	(0.873)	(0.808)	(0.704)	(0.624)	(0.761)	(0.958)
rest	**2.290**	**1.822**	**2.142**	**2.303**	**4.345**	**7.273**	**5.867**
	(0.028)	**(0.033)**	**(0.028)**	**(0.042)**	**(0.014)**	**(0.005)**	**(0.005)**
misc	**-1.425**	-2.578	-2.593	-2.417	-2.143	**-1.117**	**-0.310**
	(0.028)	(0.695)	(0.376)	(0.254)	(0.164)	**(0.047)**	**(0.038)**

Note: Table entries are gaps between actual and synthetic values of corresponding variables. Positive gaps imply that actual values are greater than the synthetic ones. P-values are given in parentheses. Bold entries are significant at the 5% level.

Source: Author's calculation.

Table A3

ASCM robustness check via the Becker and Klößner (2018) method (January to July 2023)

	January	February	March	April	May	June	July
hicp	0.851	0.634	1.218	-0.527	-0.425	0.459	0.948
food	-2.481	-1.535	-0.590	0.548	1.102	1.167	0.343
nonalc	0.218	-1.857	-1.481	-0.360	1.590	1.664	2.326
alc	2.164	-0.168	-1.283	-1.377	0.283	1.941	1.028
clothing	7.069	4.907	3.035	4.122	2.867	3.736	7.044
housing	-6.476	-4.073	-3.834	-9.746	-11.619	-10.590	-8.810
furnish	4.001	2.770	2.731	0.847	1.593	1.723	2.154
health	-0.227	-0.686	-0.945	-1.839	-0.615	-0.386	-0.062
transport	-1.400	-1.975	-1.969	-2.962	-4.194	-2.425	-0.019
commun	-2.808	-3.525	-3.162	-1.544	-0.892	-1.316	0.756
recr	3.000	1.630	0.586	-1.504	-1.260	-1.679	-2.002
educ	-5.692	-6.128	-6.146	-5.223	-5.587	-5.525	-5.425
rest	4.238	3.424	2.932	0.292	3.928	6.773	4.584
misc	2.999	1.364	2.649	3.161	3.476	2.990	3.050

Note: Table entries are gaps between actual and synthetic values of corresponding variables. Positive gaps imply that actual values are greater than the synthetic ones.

Source: Author's calculation.

Forecasting medical inflation in the European Union using the ARIMA model

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Article**
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Abstract

As healthcare costs continue to pose significant challenges for governments and policymakers, accurate forecasting of medical inflation has become crucial in the European Union. This study aims to provide insights into the trajectory of medical inflation within the EU using the Autoregressive Integrated Moving Average (ARIMA) model and to check whether this model is an effective tool for predictions of medical inflation. The findings of the study have significant implications across various sectors. With accurate forecasts of medical inflation, policymakers can proactively address challenges, insurers can determine appropriate premiums and develop innovative models, and healthcare entities can allocate resources strategically to ensure financial stability and quality care.

Keywords: medical inflation, HICP, ARIMA model, time series forecasting

1 INTRODUCTION

As healthcare expenses continue to escalate globally, there is an increasing need to comprehend and predict medical inflation accurately. This has become imperative for governments, policymakers, and healthcare providers. Additionally, forecasting medical inflation presents a significant challenge due to the differences in healthcare systems across EU member states. Many EU countries rely on public healthcare systems, meaning governments have to plan medical interventions according to the costs of medical products, equipment, outpatient services, and hospital services. Consequently, having an accurate forecast of medical inflation is crucial for national budget preparation. Advanced statistical models provide valuable insights into future trends.

This article examines the efficiency and accuracy of advanced models for the forecasting of medical inflation in order to provide insights into the potential trajectory of medical inflation in the EU. Accurate predictions of medical inflation have significant implications across various sectors. Policymakers can proactively address challenges, insurers can determine appropriate premiums and develop innovative models, and healthcare entities can allocate resources strategically for financial stability and quality care. This article aims to make an accurate forecast of medical inflation for members of the European Union. Hence, the research question is *whether the ARIMA model is effective for forecasting medical HICP for European Union members.*

In order to establish a conceptual framework for understanding the matter discussed, it is essential to outline some fundamental concepts. Medical inflation is the general level of price growth in healthcare procedures, including diagnostic tools, treatment methods, and pharmaceuticals. Typically, more developed healthcare systems experience higher levels of medical inflation. Given the rapid development of EU countries in recent years, we have witnessed a significant increase in medical inflation in the European Union. Key drivers of rising medical inflation include technological advances and structural changes in healthcare systems (Dular, 2010).

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It is important to recognise that technological advances in healthcare do not reduce the required amount of labour, meaning that productivity does not increase. This differs from other sectors where productivity consistently improves. As a result, there is an increase in the relative price of healthcare services, which means that for one unit of healthcare services, an individual can purchase more units of products from other sectors. Labour productivity in healthcare thus lags behind labour productivity in other sectors. General inflationary pressures have a greater impact on prices in healthcare than in other sectors. This relative cost increase is referred to as the Baumol effect. The first reason for low labour productivity in healthcare is the inability to standardise processes due to the nature of working with diverse individuals. The second reason is that the quality of healthcare services is contingent upon the quantity of medical staff. Increasing the productivity of healthcare personnel can only be achieved by reducing patient treatment time or extending the working hours of medical staff. Unfortunately, both approaches result in declining service quality (Culyer and Newhouse, 2003).

Medical inflation can be considered a healthcare component within the Harmonized Index of Consumer Prices (HICP), which is calculated monthly by the Statistical Office of the European Communities (Eurostat). It is measured by the prices of consumer goods covering 700 products and services on average. HICP reflects the average household expenditure on a basket of goods in the euro area. As it is a harmonised index, all EU member states use the same methodology to calculate it, making values comparable. The calculation of the HICP is based on data collection of prices in physical and online stores in the euro area, aggregated into 295 categories. The next step involves determining and regularly adjusting the weights of individual groups of commodities or services. The weights are determined based on the results of surveys in which households report their expenditure patterns. They represent national averages that reflect the expenditures of all types of consumers. The final step in calculating the HICP is assigning the weights to individual countries, which are weighted according to their share of total consumption expenditures in the euro area. The HICP for individual countries is then calculated by national statistical offices, and the data is provided to Eurostat, which then calculates the HICP for the euro area as a whole (ECB, 2023).

The statistical approach of measuring medical inflation is somewhat more specific than the conventional measurement of inflation described above. Economic theory assumes the consumer is perfectly informed, rational, and financially responsible. Higher costs for medications would therefore imply better treatment outcomes for the consumer. However, a problem arises because medications cannot be equated with normal goods. It would be necessary to consider information asymmetry, decision-making imperfections regarding treatment, non-standard payment methods, and other factors (Morgan, 2002).

Moreover, another challenge in measuring medical inflation is due to the problematic determination of the healthcare component within the consumer price index.

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The first difficulty lies in measuring effectiveness, which can be assessed in various ways. It could be measured in terms of reducing mortality rates or increasing quality of life. However, if we opt for the former measurement approach, the obtained statistics would not provide much information about the treatment of acute health issues that do not endanger life. The second challenge stems from the unequal relationship between the consumer and the intermediary, as patients are subordinate. Another aspect is the continuous advancement of medical technology, which prompts ongoing organisational changes in the healthcare sector. Therefore, most studies investigating medical inflation utilise a narrowed-down version of the harmonised consumer price index specifically focused on the healthcare sector, which is also the case in this study (Culyer and Newhouse, 2003).

2 LITERATURE REVIEW ON INFLATION FORECASTING METHODS

The first known analysis of inflation expectations in history was conducted by the American company Blue Chip Economic Indicators, established in 1976. In 1979, they conducted a survey in which respondents were asked to predict the average level of inflation for the next ten years. The survey included the top economists of that time in the United States. Before 1979, there had been no data regarding surveys on inflation expectations, so in the past, exponential smoothing of actual inflation values and the inflation gap were commonly used for the period before that year (Faust and Wright, 2012).

With the development of statistics, the first predictive methods also emerged. One of the first and simplest methods is direct forecasting. For each time step h, the prediction of the inflation value at time $t + h$ is obtained using classical regression. The inflation values at times $t + h$ are then used to forecast the inflation at time $T + h$. The index t represents the time point within the selected time interval, while T represents the upper limit of the selected time interval (Faust and Wright, 2012). A relatively simple method for predicting inflation is recursive autoregression (RAR). If the AR model is properly specified, the prediction asymptotically outperforms the selected benchmark. Marcellino, Stock, and Watson have demonstrated that, in general, forecasting with recursive autoregression is more accurate than direct forecasting. However, in the case of model misspecification, direct forecasting is more robust (Marcellino, Stock and Watson, 2006).

In addition to mathematical forecasting methods, there are more economically-oriented methods, one of which is forecasting based on the Phillips curve (PC). One of the early studies in which this method was employed is the study by Stock and Watson. They predicted inflation in the United States for 12 months. The inflation forecasts generated using the Phillips curve proved to be more accurate than forecasts made based on other macroeconomic variables such as interest rates, money supply, commodity prices, and others (Stock and Watson, 1999). Groen, Paap, and Ravazzolo (2013) also used the Phillips curve for inflation forecasting. They constructed a model based on various regression specifications selected from a group of potential predictors. These potential predictors include lagged inflation values, actual inflation values, characteristics of individual periods, and

other statistically significant features for inflation prediction. The model also incorporates random shocks. This model specification type provides relatively accurate quarterly inflation predictions (Groen, Paap and Ravazzolo, 2013). Among the well-known models for inflation forecasting is the use of the classical random walk, which relies solely on past realisations of the random walk. We have the pure random walk model (RW) and the advanced random walk model (RW-AO) developed by Atkeson and Ohanian. The advanced random walk model often proves to be superior to models based on the Phillips curve. The Phillips curve is more successful in predicting inflation in industrialised economies than at the global level (Atkeson and Ohanian, 2001).

Univariate and multivariate factor-augmented models are also commonly used in inflation forecasting. However, these models are more suitable for analyses in which explanatory variables such as exchange rates, commodity prices, and similar factors can be incorporated. One of the early analyses or inflation forecasts in the European Union using these models was conducted by Bikker. The study argues that the best forecasts for the entire European region are constructed from different models for individual countries. The author focused on using nested models based on simple AR models (Bikker, 1998). Among other methods, the univariate stochastic volatility of unobserved components (UCSV) model is also used for inflation forecasting. Stock and Watson applied this model to inflation forecasting in the United States. They proposed a model with precisely determined parameters in which the deviation of inflation from long-term expected inflation is stable (Stock and Watson, 2010).

In recent years, predictive methods based on neural networks have been developing. Nakamura found that the accuracy of neural network predictions is higher than that of predictions obtained using univariate regression, but only for quarterly and semi-annual forecasts. Unfortunately, in the study published then, neural networks were not the most accurate for twelve-month forecasts (Nakamura, 2005). Eight years later, a study by Choudhary and Haider was published on the use of neural networks for inflation forecasting. They compared the use of neural networks with a first-order autoregressive model for predicting inflation in different countries. Neural networks provided more accurate inflation predictions for only 45% of the countries (Choudhary and Haider, 2012). In the last year, an article by Karadžić and Pejović was published, comparing the autoregressive integrated moving average model (ARIMA), the Holt-Winters model, and the neural network autoregression model (NNAR) for inflation forecasting in the Balkan countries and the European Union. The authors also found that the most accurate prediction of twelve-month inflation in EU countries can be achieved using the ARIMA model rather than the neural network. Most studies published in recent years that forecast inflation utilise the ARIMA model (Karadžić and Pejović, 2021).

There are also other models for inflation forecasting, but they are relatively unexplored. They include autoregressive forecasting in output gap form (AR-GAP),

fixed λ-based forecasting, Phillips curve-based forecasting in output gap form (PC-GAP), Phillips curve-based forecasting in output gap form with time-varying NAIRU (PCTVN-GAP), time-conditioned forecasting based on VAR (Term Structure VAR), time-varying parameter VAR forecasting (TVP-VAR), exponentially weighted averages forecasting (EWA), Bayesian model averaging forecasting (BMA), factor-augmented vector autoregressive forecasting (FAV), dynamic stochastic general equilibrium forecasting (DSGE), dynamic stochastic general equilibrium with time-varying mean forecasting, and others (Faust and Wright, 2012).

As presented, methods for predicting inflation are well-researched. However, the situation is different in the field of predicting medical inflation. The first comprehensive study on this topic was published by DePamphilis in 1976. He presented a model for predicting quarterly healthcare costs using selected macroeconomic variables using multivariate regression (DePamphilis, 1976). In the following years, more studies predicting healthcare costs were published, and even the prediction of medical net discount rates emerged. Ewing, Piette, and Payne demonstrated that it is possible to improve predictions of medical net discount rates using an ARMA model by modelling time-varying characteristics of net discount rate volatility (Ewing, Piette and Payne, 2003).

American economists have also predicted long-term growth in healthcare expenditures using a dynamic general equilibrium model. They assumed that the introduction of new medical treatments is endogenous, and the demand for healthcare services depends on the state of technology. These projections covered 75 years (Borger, Rutherford and Won, 2008). Additionally, economists have often used linear autoregressive moving average models (ARMA) to predict medical inflation in recent studies. Cao, Ewing and Thompson conducted a comparative study where they compared this method with nonlinear neural networks. The research findings are similar to the previous conclusions of Karadžić, Pejović, and Nakamura. Neural network predictions are also slightly more accurate in this case, but primarily for shorter periods (Cao, Ewing and Thompson, 2012).

3 METHODOLOGY

In this article, I decided to use the time series theory, precisely the ARIMA model, to analyse and predict medical inflation in the European Union. The first part of this chapter provides a brief overview of fundamental definitions and characteristics of time series, which are essential for understanding the analysis and forecasting of medical inflation. While the second part presents the methodology used for the analysis and forecasting.

It is known that a stochastic process is a family of random variables defined on the same probability space. A stochastic process X_t, $t \in T$, where $T \subseteq \mathbb{R}$, is then called a time series. A time series is stationary if its properties do not depend on the time at which the time series is observed. A weakly stationary time series X_t is an ARMA(p,q) process, an autoregressive moving average process of order (p,q), for

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$p,q \in \mathbb{N} \cup \{0\}$, if there exists a sequence $Z_t \sim WN\ (0, \sigma^2)$ and real parameters $\rho_1, \rho_2, \ldots \rho_p$ and $\theta_1, \theta_2, \ldots \theta_q$ such that for all $t \in \mathbb{Z}$, the following holds (Basrak, 2022)

$$X_t - \rho_1 X_{t-1} - \cdots - \rho_p X_{t-p} = Z_t - \theta Z_{t-1} - \cdots - \theta_q Z_{t-q} \quad (1)$$

Process X_t is an ARIMA(p,d,q) process, an autoregressive integrated moving average process of order (p,d,q), where $d \in \mathbb{N} \cup \{0\}$, if $(1-B)^d X_t$ is a causal ARMA(p,q) process, where B is a linear filter. In this case, X_t satisfies the equations

$$\rho(B)(1-B)^d X_t = \theta(b) Z_t, t \in \mathbb{Z} \quad (2)$$

Moreover, $Z_t \sim WN\ (0, \sigma^2)$ and ρ and θ are polynomials such that $\rho(z) \neq 0$ for $|z| \leq 1$. A time series X_t can be decomposed into three components. A decomposition is (Basrak, 2022)

$$X_t = m_t + s_t + Y_t, t \in \mathbb{Z} \quad (3)$$

The first component m_t is called the trend, which represents the long-term movement or direction of the average of the time series. The second component s_t is called the seasonal component; it includes the influences of seasons and calendars and has a specific period. The third component Y_t is called the irregular component, consisting of fluctuations that do not belong to either of the first two components and can be weakly or strongly stationary. In practice, determining these three components of a time series is often difficult. Therefore, when choosing a model, it is important to strive for simplicity and adhere to the principle of Occam's razor (Basrak, 2022).

Usually, exploratory analysis of a time series is based on the following steps:
- plotting the observed values and identifying deviations from stationarity,
- removing trend and seasonality,
- selecting an appropriate model for modelling the residuals.

Deviations from stationarity can be tested using statistical tests, with the modified Dickey-Fuller test (ADF test) and the Kwiatkowski-Phillips-Schmidt-Shin test (KPSS test) being the more well-known. In practice, time series are often non-stationary, so it is necessary to remove trend and seasonality. Moreover, the removal of trend using estimation can be done using various methods, such as linear filer, exponential smoothing and polynomial approximation. Furthermore, the removal of seasonality is usually done by differencing (Hamilton, 1994).

When examining a time series, it is typical to complement the exploratory analysis with a spectral analysis, which entails decomposing the time series into periodic components of sinusoidal functions. The purpose of spectral analysis is to identify prominent or significant frequencies in the given time series. The visual representation of the spectral analysis is a periodogram, which quantifies the contributions of individual frequencies to the regression of the time series. The periodogram values can be interpreted in terms of data variance with respect to frequency or period.

Furthermore, usually, the Fourier linear spectrum is used. This is a graph of the periodogram against the corresponding frequencies. In practice, the Fast Fourier Transformation (FFT) is commonly used for calculating the periodogram efficiently, which is also used in R for generating periodograms and spectral analysis (Wearing, 2010).

4 ANALYSIS OF MEDICAL INFLATION IN EU COUNTRIES

The data on medical inflation or the Harmonized Index of Consumer Prices (HICP) in the healthcare sector in EU countries was obtained from Eurostat, where monthly data on inflation growth rate changes are available. The data was collected for all EU member states, including Austria, Belgium, Bulgaria, Czech Republic, Cyprus, Denmark, Estonia, Finland, France, Greece, Croatia, Ireland, Italy, Latvia, Lithuania, Luxembourg, Hungary, Malta, Germany, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, and Sweden. The categories within the healthcare sector of HICP include medical products, appliances and equipment, outpatient services, and hospital services (Eurostat, 2023). The time frame covers the period from 2000 to 2022. The R programming language was used for the practical part of the task. The data was imported and cleaned using the *readxl* and *tidyverse* packages. Subsequently, a time series object was constructed for each country. For the analysis and forecasting presented below, the *tseries*, *forecast*, and *TSA* packages were used.

The first step in the analysis is to identify any deviations from stationarity, which was done by graphical analysis of the time series for all countries. On the one hand, medical inflation of some member states appeared stationary, since graphical analysis suggests a constant variance, with no evident seasonal components or trend. On the other hand, the majority of them appear non-stationary, as there is a noticeable downward or upward trend. For a more comprehensive analysis, the time series for each country was decomposed, meaning that their trend, seasonal component, and irregular component were plotted. Based on the graphical decomposition, it is challenging to determine the trend as there is no clear upward or downward trend in any of the counties. Nevertheless, the seasonal component is visible in the graphical decomposition of all countries, and a recurring pattern is noticed. Despite the indications of a seasonal component in the decompositions, it is difficult to observe it clearly in the curve plots by years. To facilitate the identification of any exceptional months, polar coordinates were used, yet the plots did not suggest any exceptional months.

For a more precise stationarity analysis, two statistical tests were conducted: the Dickey-Fuller test and the Kwiatkowski-Phillips-Schmidt-Shin test (Vijay Kumar, 2023). If both tests confirmed stationarity, one can conclude that the time series is stationary at a significance level of 0.05. The results of the tests, shown in table 1, indicate that 12 out of 27-time series are stationary. Based on the comprehensive analysis the time series were deseasonalised and differenced, which effectively removes the seasonality and trend. The transformed time series are now stationary and suitable for further analysis.

Table 1

Results of ADF and KPSS tests

Member state	ADF test	KPSS test	Stationarity
Austria	0.02*	0.10	Stationary
Belgium	0.49	0.10	Non-stationary
Bulgaria	0.41	0.07	Non-stationary
Croatia	0.01*	0.10	Stationary
Cyprus	0.08	0.10	Non-stationary
Czechia	0.01*	0.10	Stationary
Denmark	0.01*	0.10	Stationary
Estonia	0.23	0.10	Non-stationary
Finland	0.08	0.10	Non-stationary
France	0.05	0.10	Stationary
Germany	0.01*	0.10	Stationary
Greece	0.28	0.80	Non-stationary
Hungary	0.01*	0.10	Stationary
Ireland	0.13	0.03*	Non-stationary
Italia	0.01*	0.10	Stationary
Latvia	0.28	0.10	Non-stationary
Lithuania	0.21	0.08	Non-stationary
Luxembourg	0.01*	0.10	Stationary
Malta	0.28	0.10	Non-stationary
Netherlands	0.08	0.10	Non-stationary
Poland	0.65	0.04*	Non-stationary
Portugal	0.01*	0.10	Stationary
Romania	0.01*	0.02*	Non-stationary
Slovakia	0.04*	0.10	Stationary
Slovenia	0.51	0.03*	Non-stationary
Spain	0.01*	0.10	Stationary
Sweden	0.07	0.10	Non-stationary

Note: $^{*}p < 0.05$, $^{**}p < 0.01$ *and* $^{***}p < 0.001$.

After that, a spectral analysis was conducted in order to identify periodicities. For each country a smoothed periodogram was plotted according to which it was possible to identify the values of the medical HICP with the highest frequencies and calculate the corresponding periods of occurrence. For most countries, the period was 3 months or one quarter of a year. After exploratory and spectral analysis, the ARIMA model was determined. The traditional way to determine the model and the values of its parameters is by plotting the autocorrelation function (ACF) and partial autocorrelation function (PACF). The optimal parameters can be selected according to the graphs and with the use of the Akaike information criterion (AIC). However, in R, there is a function called *auto.arima* that uses the Hyndman-Khandakar algorithm. This algorithm minimises both the AIC value and the maximum likelihood value to better fit the model to the data. Thus, because of the algorithm's ability to fit models effectively, the *auto.arima* function was used.

5 RESULTS

Firstly, for each country test forecasts were created using only the data from 2000 to 2022. A 12-month forecast for the medical HICP was generated and then compared with the actual measurements. For example, figures 1 and 2 are the test forecasts for Italy and Ireland with 95% CI. Measured values are determined by a black line, while a red line determines forecasted and actual values.

FIGURE 1

Test forecast – Italy

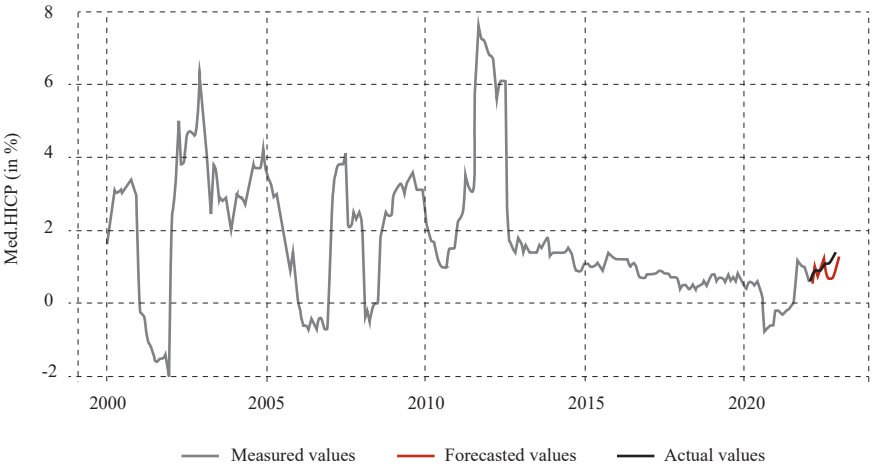
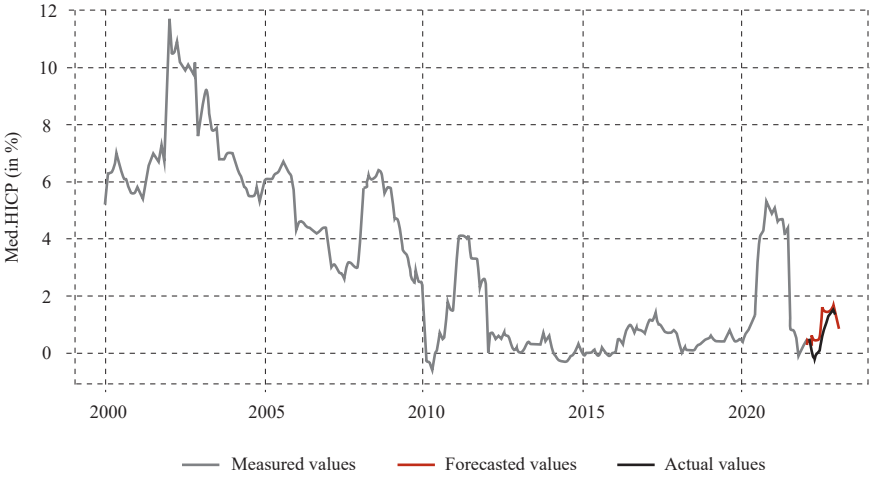


FIGURE 2

Test forecast – Ireland



Secondly, actual forecasts for the next 12 months were generated. For example, figures 3 and 4 are the forecasts for the medical HICP for the Netherlands and Cyprus with 95% CI. Measured values are determined by a black line, while a red line determines forecasted values.

FIGURE 3

Forecast – Netherlands

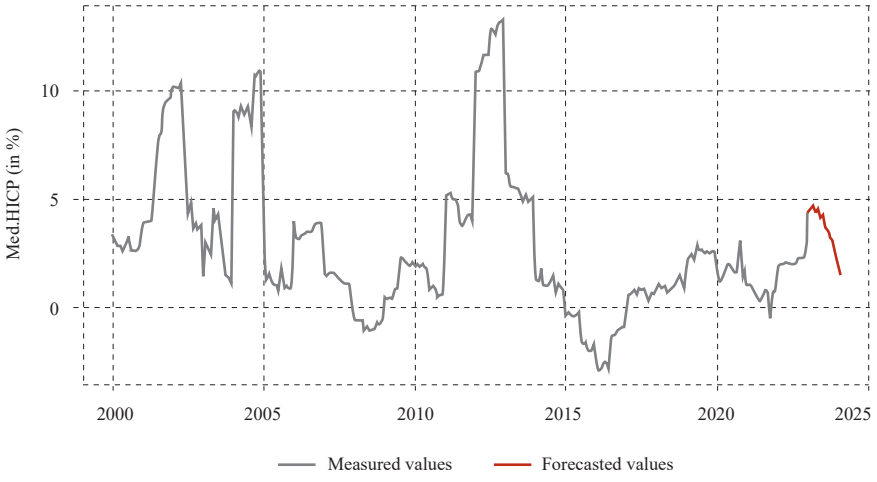


FIGURE 4

Forecast – Cyprus

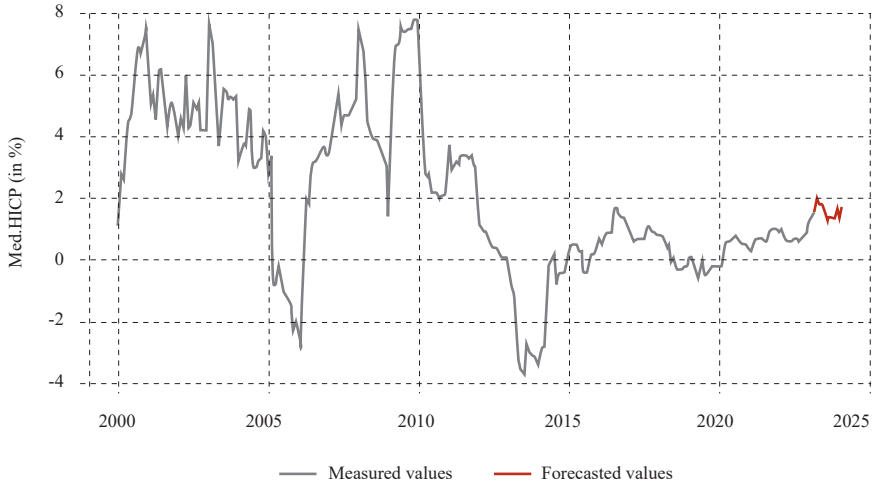


Table 2
Absolute differences between forecasted and actual values of medical HICP in pp

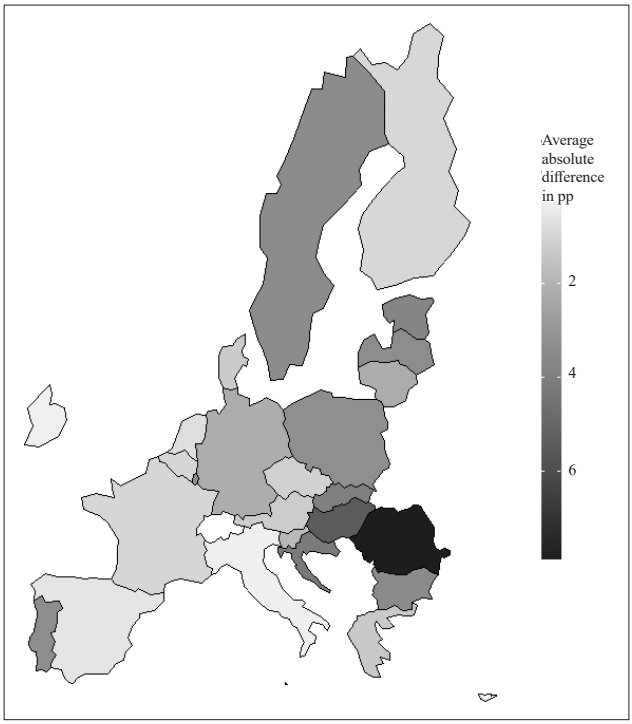
Member state	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Average
Austria	0.68	1.02	0.12	0.91	0.69	0.77	0.43	0.89	2.00	1.86	2.12	3.34	1.23
Belgium	0.06	0.25	0.25	0.30	0.33	0.63	0.82	1.07	1.16	1.30	1.48	4.07	0.98
Bulgaria	0.17	0.45	0.92	1.37	1.86	2.02	1.64	1.89	4.22	6.70	9.59	11.02	3.49
Croatia	0.28	1.38	2.14	2.27	2.48	3.66	5.06	5.67	6.12	6.28	6.59	8.17	4.18
Cyprus	0.09	0.14	0.66	0.41	0.46	0.33	0.02	0.11	0.06	0.08	0.47	0.12	0.25
Czechia	0.69	0.87	0.11	0.38	0.64	0.98	0.83	1.49	0.51	1.56	2.19	2.86	1.09
Denmark	0.72	0.69	0.43	0.12	1.35	1.03	1.02	0.69	1.71	1.92	2.67	2.71	1.25
Estonia	0.67	1.31	1.15	2.03	2.57	3.05	3.21	4.93	6.18	5.65	6.83	7.22	3.73
Finland	1.30	1.22	1.52	2.00	0.40	0.68	0.60	0.92	0.76	0.77	0.84	0.29	0.94
France	0.42	0.82	1.19	0.95	1.14	0.66	0.17	1.06	1.58	1.01	1.15	1.58	0.98
Germany	0.01	0.18	0.06	0.03	0.45	0.45	1.99	2.41	2.60	2.64	2.71	2.73	1.35
Greece	0.38	0.59	0.15	0.87	1.59	2.00	2.17	3.01	3.51	3.33	4.07	4.88	2.21
Hungary	0.20	0.00	0.51	1.26	2.17	3.48	5.25	6.95	9.34	11.16	12.75	12.64	5.48
Ireland	0.11	0.59	0.64	0.38	0.38	0.73	0.34	0.01	0.06	0.14	0.13	0.01	0.29
Italia	0.04	0.16	0.08	0.15	0.03	0.18	0.26	0.43	0.52	0.63	0.37	0.81	0.30
Latvia	0.08	1.29	1.72	2.55	2.88	3.23	3.19	3.94	4.76	4.66	5.91	6.29	3.38
Lithuania	0.11	0.04	0.72	1.40	1.76	2.23	2.75	2.59	3.70	3.39	4.58	3.62	2.24
Luxembourg	0.83	0.64	2.47	3.04	3.27	3.27	3.57	4.58	4.22	4.59	5.21	5.65	3.45
Malta	0.46	0.07	0.32	0.70	0.25	0.45	0.93	1.49	1.93	1.93	2.39	2.11	1.09
Netherlands	0.40	0.04	0.37	0.32	0.14	0.18	0.61	0.40	0.91	0.47	1.10	3.66	0.72
Poland	0.51	1.34	1.97	2.72	2.89	3.06	3.09	3.40	4.21	5.01	5.06	6.67	3.33
Portugal	0.37	0.12	0.04	0.17	5.05	5.45	5.34	5.18	5.46	4.47	4.39	4.23	3.36
Romania	0.51	1.45	2.97	4.30	6.11	7.25	8.33	9.55	11.11	12.84	14.37	15.64	7.87

Member state	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Average
Slovakia	0.48	0.92	1.56	2.89	2.60	3.25	4.20	5.20	5.03	6.22	7.28	7.68	3.94
Slovenia	0.95	0.67	0.28	0.52	0.48	0.09	1.97	2.00	1.44	3.95	5.50	3.75	1.80
Spain	0.32	0.20	0.11	0.07	0.50	0.41	0.57	0.80	0.81	1.18	1.05	1.05	0.59
Sweden	0.45	1.54	2.23	2.92	3.16	2.52	4.01	4.36	3.95	4.24	5.33	6.08	3.40
Average	0.42	0.66	0.91	1.30	1.70	1.93	2.31	2.78	3.25	3.63	4.30	4.77	2.33

For each EU member state, the absolute difference between the test forecasted values and actual values for each month from March 2022 to February 2023 was calculated. The results are shown in table 2. As the forecast horizon increases, the absolute differences between the forecasted and actual values also increase. The most accurate forecasts are observed within a 3-month horizon, where the differences are less than 1 pp. On average, the forecasted and actual values differ by 2.33 pp. Notably, the countries with an average absolute difference of less than 1 pp are Belgium, Cyprus, Finland, France, Ireland, Italy, the Netherlands, and Spain. On the other hand, the countries with the highest average absolute differences, exceeding 4 pp, are Croatia, Hungary, and Romania.

FIGURE 5

Average absolute difference between forecasted and actual values of medical HICP



One of the key reasons for the large differences between forecasted and actual values in the latter group of countries is the fluctuation of domestic currencies since these countries are not part of the euro area but have their own currencies. On the other hand, the remaining countries are part of the euro area and follow the common European monetary policy, which ensures price stability. Price stability is achieved with the use of various instruments such as open market operations, open offers, and maintenance of required reserves (Rakić, 2023). The mentioned differences between the two groups of countries are visible in figure 5.

6 DISCUSSION

The analysis findings reveal the ARIMA model's effectiveness for the euro area countries in capturing the temporal patterns and dynamics of medical inflation. The model demonstrates its ability to consider both short-term fluctuations and long-term trends. However, considering multiple time series, the opportunity arises to extend the analysis by checking possible dependencies among them; specifically, one could explore the application of methods specialised for panel data analysis. Furthermore, extending the forecasting horizon and adjusting the length of the primary time series of medical inflation would be a significant enhancement as well. Furthermore, future researches on this topic could explore the inclusion of exogenous variables such as demographic trends, technological advances and policy changes. Moreover, other forecasting techniques such as machine learning algorithms can be used to predict medical inflation. All these improvements would enable the model to capture complex time series patterns, consequently resulting in more accurate forecasts and valuable insights into the dynamics of medical inflation.

Given that the ARIMA model has not been previously used for forecasting medical inflation, it is challenging to validate the congruence of the obtained results with existing conclusions. Nevertheless, the findings do partially align with the latest findings in the field of inflation forecasting using various methods, as presented in section 2, particulary in studies conducted by Ewing, Piette, Payne, Karadžić and Pejović. Additionaly, the obtained results align with articles exploring the ARMA model's capability to forecast medical inflation, considering that the ARIMA model is essentially an enhancement of the ARMA model. However, there are some limitations and disadvantages of using the ARIMA model for forecasting medical inflation in the EU. Firstly, since ARIMA models are inherently linear, they may not fully capture the complex non-linear relationships that could exist in healthcare economics, and factors such as sudden policy changes or technological breakthroughs may not be appropriately modelled using ARIMA model alone. Secondly, ARIMA models provide accurate predictions only for short or medium term forecasting, while for long-term projections alternative approaches should be used.

The predictions provide an insight into the anticipated trajectory of medical inflation, allowing policymakers of euro area countries to proactively address potential challenges and make appropriate policy responses, especially regarding the issues of an ageing European population and the rapid progress in medical technology and practices. Moreover, reliable predictions of medical HICP provide guidance specifically for policymakers in the ministries of health for enhancing the efficiency of public spending in the healthcare sector. The situation is even more delicate for EU countries, as many rely on a public healthcare system. These systems usually operate on a national level, with the government covering the majority of medical expenses. At the same time, residents are only required to pay small fees in the form of compulsory health insurance.

Furthermore, by anticipating future healthcare costs, health insurance companies can benefit in several ways. By analysing and predicting healthcare costs, insurers can gain insight into the expected expenditure in different areas of healthcare services, which would enable them to determine appropriate premiums to charge and develop innovative health insurance models. Besides, accurate projections allow insurers to engage in informed discussions with hospitals and other healthcare entities and thus negotiate payment agreements which align with the projected costs. This would ensure a fair and sustainable partnership between insurers and healthcare providers.

Besides, projections of medical inflation play a vital role in the administrative aspects of hospitals and other healthcare entities. Considering such forecasts, they can gain valuable insights into the expected cost increases. Such predictions would enable them to make informed decisions and allocate their resources to areas that are likely to experience the highest inflationary pressures. This proactive approach would help to ensure the financial stability of healthcare organisations, enabling them to continue providing quality care to their patients without compromising their financial integrity.

7 CONCLUSION

Since the European Union continues to grapple with the complexities of healthcare financing and accessibility, forecasting medical inflation is becoming essential. Accurate forecasts of medical HICP enable policymakers to address challenges proactively, insurers to set appropriate premiums and develop innovative models, and healthcare entities to strategically allocate resources to ensure financial stability and quality care. Thus, forecasting medical inflation using the ARIMA model holds substantial significance for public sector economics in the European Union.

In this article, I have explored the application of the ARIMA model to forecast medical inflation within the European Union. Through rigorous analysis of historical data and advanced time series techniques, the study provides valuable insight into the future trajectory of medical inflation, especially for euro-area countries. The findings of the analysis show the effectiveness of the ARIMA model, which has the potential to capture complex temporal patterns and dynamics of medical inflation.

Disclosure statement

The author has no conflict of interest to declare.

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Potential investments of pension funds in long-term care for the elderly: the case of Croatia

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Abstract

Contributions to pension funds are placed on the capital market. To invest in a better old age for those who set aside those funds, it is necessary to adjust the system. The paper analyzes the problem in the long-term care system faced by private care homes, the outlook for the building of additional homes, and the interest of pension funds in investing in the long-term care system. The problem is becoming more and more significant as the population is growing older. The authors interviewed sixteen respodents. The aim was to collect views on the current possibilities and perspectives for the development of the long-term care system in Croatia. The results indicate that pension funds do have an interest in investing, but before that, the system of homes for the elderly needs to be reorganized.

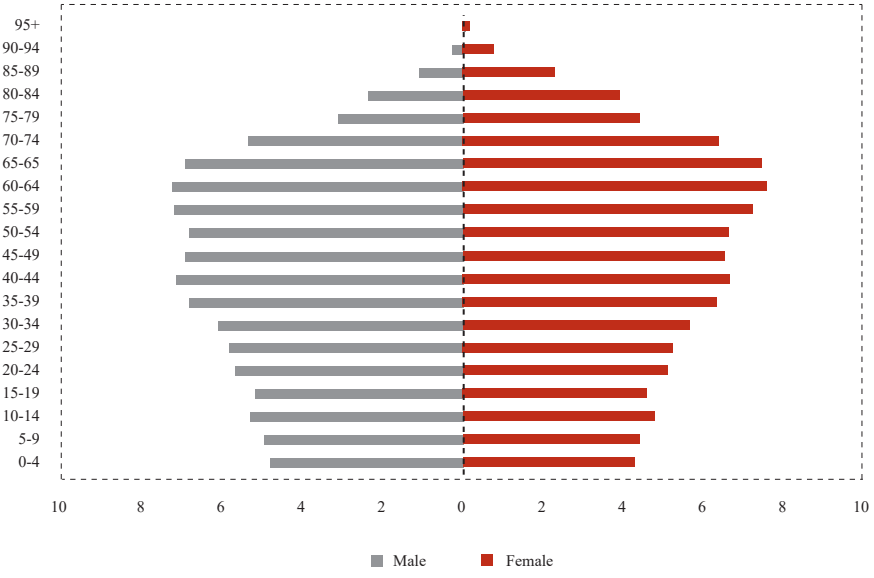
Keywords: homes for the elderly and infirm, long-term care, investment, pension funds, restrictions, Croatia

1 INTRODUCTION

Long-term care for the elderly is a topical subject worldwide and in Croatia, primarily due to the trend of population aging. According to the results of the population census, Croatia had a population of 3.87 million in 2021 (CBS, 2023).

Chart 1

Age-sex pyramid according to the 2021 census



Source: Authors (CBS, 2023).

The current age-sex pyramid shown in chart 1 is of the constrictive type. This type is generally characterized by low fertility, low mortality, long life expectancy and an overall aging population (Saroha, 2018). In the current pyramid, these features can be observed, with special emphasis on the significant number of the mature population.

Table 1

Average age of population in Croatia, 1971-2021

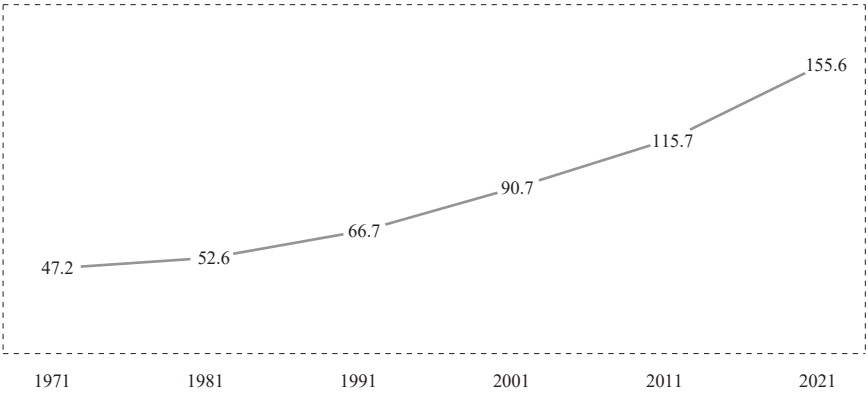
	1971	1981	1991	2001	2011	2021
Women	35.5	37.1	38.7	41.0	43.5	45.9
Men	32.4	33.8	35.4	37.5	40.0	42.5
Total	34.0	35.4	37.1	39.3	41.8	44.3

Source: Authors (CBS, 2022).

The average age of the population of Croatia shown in table 1 is increasing. From 1971 to 2021, the average age of men increased by 10.1, for women by 10.4, and the total by 10.3 years. In 2021, it was 42.5 years for men, 45.9 years for women, with a total average age of 44.3 years (CBS, 2022).

Chart 2

Aging index 1971-2021 (in %)



Source: Created by the authors (CBS, 2022).

One of the best indicators of the age of the population is the aging index shown in graph 2, which shows the ratio of the numbers of inhabitants over 60 and under 20. The critical limit of the ratio is 40 and therefore Croatia has been classified as a country with an old population since 1971 (Obadić et al., 2017). Croatia already achieved the value of 47% of old people in 1971, which grew to 156% in 2021 (CBS, 2022). Because of the trend of population aging, the need for long-term care grows every single day.

Traditionally, older members of the household were taken care of by younger members of the family. The modernization of society led to changes in family habits and roles, which led to an increase in the popularity of homes for the elderly and infirm (below referred to as homes) where they are provided with medical care, all-day supervision, and the possibility of socialization with peers, on condition of payment of fees. There are currently three groups of homes in Croatia: owned by the state, decentralized and homes owned and run by other founders, legal or natural persons, religious communities, and commercial companies (Bađun, 2017).

According to MROSP (2022), Croatia is currently the founder and owner of three institutions for long-term care: the Majka Marija Petković Home for elderly and gravely ill adults in Blato on Korčula; the Home for adults and rehabilitation in Metković and the Home for the elderly in Oklaj. Decentralized homes (45 of them) are those owned by units of regional self-government, i.e. counties, including the City of Zagreb. The third group consists of privately owned homes (121 of them) whose owners are natural or legal persons, religious societies, organizations, etc.

Table 2

Type, number, and total accommodation capacity of homes in 2022

Type	Number	Total accommodation capacity
State	3	171
Decentralized	45	10,869
Private	121	8,421
In total	169	19,461

Source: Authors (MROSP, 2022).

Currently, there are large disparities among the needs and capacities of long-term care facilities. The pressure is especially felt in homes owned by the state, regional self-government units and the City of Zagreb. The charges of private and state-owned homes differ significantly, so in the private sector, due to higher prices, the disparity between supply and demand is significantly lower. Prices in state and decentralized homes range between 266 and 796 euros per month, and in private homes between 995 and 1,593 (Gelo, Matanić and Matanić Vautmans, 2021). It is important to point out that the prices partly depend on the level of service, type of diet, number of beds per room, etc. Primarily because of the difference in prices, accommodation in government owned homes tends to be preferred.

Long-term care can be financed from public and private sources. The state finances the accommodation of clients partly from the state budget, while the client or family finances the rest. According to the Social Welfare Act (Zakon o socijalnoj skrbi), a person who uses social services must contribute with income and assets that are not necessary for their life or the lives of the other members of the household (Art. 121, paragraph 1). Croatia allocates a certain amount every year to finance the social welfare system and exposes itself to certain losses that represent a burden on the working population and raises doubts concerning the long-term sustainability of such a system. The share of state expenditures for social protection and expenditures for social protection benefits in GDP in 2021 is 22.3%, most of which is allocated to expenditures for old age (7.5%) and sickness/health care (7.8%) (CBS, 2023).

The mandatory pension fund collects the contributions of pension fund members and then invests them to increase the value of the pension fund's assets. A pension fund is an asset without legal personality, owned by its members whose individual ownership rights are determined as a proportion of the funds in the individual's personal account, while investment options are prescribed in accordance with the

accompanying legislation, the Act on Mandatory Pension Funds (Zakon o obveznim mirovinskim fondovima) and the Regulations on Permitted Investments and additional restrictions on investments of the mandatory pension fund (Pravilnik o dozvoljenim ulaganjima i dodatnim ograničenjima ulaganja obveznog mirovinskog fonda). Pension funds invest on the capital market in financial instruments that must be listed on the official market. Regarding the riskiness and profitability of investments, pension fund investments are classified according to categories A, B or C. The most risky, but also the most profitable investments, are part of the category A fund, the less risky and profitable is fund B, and the least risky and least profitable is fund C. Asset investments of mandatory pension funds of different categories are legally limited by the definition of the permitted forms and instruments of investment/property; investments with regard to the type of investment/asset; with regard to the net value of the pension fund's assets, and the currency and maturity compatibility of the assets. Investing in the system of long-term care for the elderly from the perspective of pension funds is currently not possible, because the property values of the homes are too low and are not listed on the stock market.

The primary goal of this research is to examine the current problems of the long-term care system for the elderly and the possibilites of its more appropriate financing. The point of this paper is to draw attention to the current demographic trends and propose a more adequate and long-term sustainable organization for that system. The hypotheses were defined according to the current problems of the business model of existing homes, the challenges, and the perspectives in the construction of privately owned homes through the wilingness of pension funds to invest. The research showed that there is a lack of capacity in the homes, with long waiting lists and a lack of educated personnel. Stress, low wages, and high workloads contribute to the long-term care system not being considered an attractive workplace. When building a home in private ownership, one encounters several problems such as strict legal regulations, insufficient interest of the state in cooperation through a public-private partnership (PPP) and the constant growth in real estate prices. For investment by pension funds to be profitable and sustainable in the long term, it is necessary to consolidate existing or build new multi-site operator homes the overall possible profit of which could be acceptable to pension funds. Sixteen people were interviewed in the research (seven directors of all threee types of homes, three academics, three representatives from two pension fund management companies, one person from the Ministry of Labour, Pension System, Family and Social Policy (referred to as the Ministry) and one from a private investment company). The triangulation process used in the research was chosen so that the opinions of different experts would indicate the current problems in the long-term care system, the perspectives, and potentials for improvement that the system has, and the prerequisites that the reorganization of the system must meet for pension funds to be able to invest in it. The first part of the paper offers an introduction in which the demographic trends and demographic characteristics of Croatia are explained, and the specifics of the homes in Croatia and the characteristics of mandatory pension funds (method of business, problems in business, ownership) are described. The second part contains an overview of the existing literature, and the third part presents and describes

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methodological framework in more detail. The fourth part offers the results and is divided into several areas in which the current problems of the business model of existing homes, challenges in building privately owned homes, perspectives in building homes and the willingness of pension funds to invest in long-term care for the elderly are presented. At the end, there is a conclusion and a proposal for reorganization of the system of homes, which would open the possibility for pension funds to invest.

2 LITERATURE REVIEW

Pension funds are investors in the capital market. According to Olgić Draženović and Kusanović (2016) the capital market is an important source of financing for sustainable investment projects and further economic development. The growth of institutional investors through the accumulation of individual savings is particularly important for the development of the capital market in the transitional countries of Central and Eastern Europe, including Croatia. Accumulating citizens savings by investing in institutional investors is considered a safe investment because citizens are an inexhaustible source of savings that is renewed again and again. According to Krišto, Stojanović and Pavković (2014) institutional investors encourage liquidity and activities. They point out that institutional investors, especially pension funds – due to their long-term investment strategy – have a positive impact on financial stability, thus contributing to economic growth and competitiveness. Novaković (2015) expands the possibilities of measuring performance in active portfolio management. The mentioned economic growth is possible with appropriate regulation, which determines the way in which pension funds as investors achieve returns. Stewart, Despalins and Remizova (2017) consider regulatory barriers to long-term investment, suggesting the expansion of investment into foreign markets. Peksevim (2021) points out that it helps portfolio diversification and improves the delivery of safe, adequate pensions in certain countries of Central and Eastern Europe. The capital market is expanding and the liquidity of invested financial instruments is encouraged, which makes for more adequate investment. In addition, South Africa's largest pension fund, GEPF, is described; it allocates 5% of its asset to social investment and "SelFIES" are mentioned as a pension bond that offers periodic coupon payments to its participants as pension payments. By adjusting investments, it is possible to access the market of health care arrangements that have a positive effect on the development of the economy. Bali and Asher (2012) through the positive connection of health and pension arrangements in costs, exposure to risks and influence on political decisions suggest better coordination for simpler management of the cost of aging. Health care is broadening the horizons of investment and the usefulness of saving for old age.

Allocating resources to pension funds will meet the goal of more adequate care in old age with additional sources of funds, which Yessentay et al. (2020) want to achieve through financial support for the modernization of health institutions using the resources of pension funds. On the other hand, Tanaka (2016) advocates replacing the system of automatic adjustment of pension benefits with a system that predicts the specific levels of care required. In this way, the financial adjustment of

long-term care insurance and public pensions would be ensured so that if a long-term beneficiary reaches a certain level, his required care benefit will have to be expanded, which increases the individual cost. A similar approach is proposed by private sector products such as "qualified longevity contract" in the US and "living pensions" in the UK. Bađun (2017) predicts that the future financing of elderly care will be achieved through a combination of private and public sources of funds, because the prices of homes will rise in order not to operate at a loss. Currently, beneficiaries' families are also largely involved in the financing of living in the homes. Hlebec and Filipovič (2018) thus emphasize that future policies must consider that the financing of life for the elderly should also take cognizance of the financial difficulties of the family. Currently, there are no papers that present investment models of pension funds in long-term care for the elderly, either in Croatia or worldwide.

3 METHODOLOGY

The research was conducted in the form of semi-structured interviews during May and June 2022. It was approved by the Ethics Committee of the Faculty of Medicine of the University of Zagreb. The interviews were transcribed and analyzed using a qualitative method. The research uses a triangulation process. A complex and connected group of similar concepts, assumptions and notions is united by qualitative research (Halmi, 2013). Good research practice obliges the researcher to triangulate, that is, the use of multiple methods, data sources, and researchers' findings (Flick, 2018). It often features a combination of several qualitive data. At the same time, it is more broadly focused on what is being combined – several theoretical approaches or several types of date (Mathison, 1988). The concept of triangulation is used in the measurement process of assessing the veracity of research results. There are alternative perspectives on the use of triangulation whose goals seek a deeper understanding of different results by placing them in a mutual relationship (Mertens and HesseBieber, 2012).

Sixteen respondents participated in the research. Directors from two state owned homes, two private homes, two county homes, including the City of Zagreb, and one over which the City of Zagreb has founding rights. As for academics, a professor from the Faculty of Ecnomics of the University of Zagreb, a professor from the Faculty of Medicine of the University of Zagreb from the Andrija Štampar School of Public Health and a senior research associate from the Croatian Institute of Public Finance were included. In order to represent the regulators, an interview was conducted with a person from the Croatian Financial Services Supervision Agency. From the perspective of investors, three high-ranking representatives from the Pension Fund Management Company participated, as well as a representative of a private investment company that has the practice of investing in homes in the territory of Croatia, and a representative of the Ministry. All participants were contacted by e-mail with an invitation letter explaining the aim and purpose of the study and a list of questions. Homes from various parts of the country were contacted to determine possible regional differences in their operations. The interviews with the homes were conducted by telephone, with the presence of both authors, with parallel

writing and recording of the telephone conversation after obtaining verbal consent, except for two respondents who answered the questions in writing, via e-mail. The interview with the representatives of one pension fund was conducted via an online video platform, while the representative of the other answered in writing, via e-mail. The meeting with the representative of the private investors was also organized via an online video platform. Other interviews with experts were conducted in their institutions, also with the presence of both authors. The interview consisted of 5 questions. The first question was intended for all participants – about the main problems of the existing business model of homes and, in general, the adequacy of the functioning of the system. The second question was intended primarly for directors of privately owned homes and representatives of private investors – to point out the existing problems of establishing a long-term care institution in Croatia. The third question was intended to find out the participant's opinions about the need to build new homes and their market potential. The fourth and fifth are intended to examine the views of investors, that is, pension funds, on how possible it was for them currently to invest in the long-term care system, and how willing they might be. The respondents were asked to express their views and opinions on the questions posed, and were free to follow up on topics that seemed to them related to the topic in question, and the authors of this text, in accordance with the natural flow of the conversation, asked additional sub-questions to better clarify the mentioned topic.

TABLE 3

Questions to respondents

1. What do you think are the potentials/problems of the business model of existing homes for the elderly (systems for the elderly)? a. Who or what influences these potentials or problems?
2. Can you list the challenges in building long-term care facilities for the elderly in private ownership? a. Do these challenges change over time? b. Do they become more or less intense in response to the environment in which they are located?
3. Do you think there are prospects in the construction of homes fot the elderly and what are their market potentials, looking a. from the perspective of private homes for the elderly as an export product b. from the perspective of investment in infrastructure c. from the perspective of potential arrivals of large intenational companies dealing with homes for the elderly?
4. What are the advantages/disadvantages for, and is there a willingness on the part of, pension funds to invest in homes for the elderly? a. Why don't they invest right now? b. What are the preconditions for them to invest more significantly (the development phase of the market for homes for the elderly)? c. Do you think there should be a regulatory change in pension fund investments? d. What are the risks and gains from the perspective of pension investments?
5. Are you planning or considering investing in homes/are you planning to invest in a home from a finance institution side? a. Do you have any indiacation of significant new investments in homes for the elderly?

Source: Authors.

4 RESULTS AND DISCUSSION

In table 4, the research results are grouped according to key categories.

TABLE 4

Research results

Key categories	Topics	Quotation
The current business model problem of existing homes	Capacity	"The problems are insufficient space, or lack of capacity."
	Waiting list	"We currently have 270 people on the wating list and many people who applied while they were still mobile…"
	Personnel – shortages and the disconnection of different professions	"And this fragmentation and lack of coordination worsens the shortage and lack of human resources in the institution."
Challenges in the construction of privately owned homes	Strict legal regulations and non-transparent criteria for obtaining accommodation in a state/county home	"It is a long-term battle and struggle because you have to meet all technical standards, conditions, so there are special regulations for the construction of such facilities."
	Real estate market and problems in construction	"The construction industry is affected by the lack of labor, as well as by rising costs."
	Cooperation in the form of PPP	"So, if one user has thousands of kuna, and our private home is the only home in the area to accommodate this type of user, the public sector should compensate him for the difference."
Perspective in building homes	Demographic need	"It is simply a need that will develop more and more, we have more and more old population and we are increasingly becoming an older nation."
	Export product	"If we look at Croatia as some kind of tourist destination, a country that bases its economy on the industry, then it could be our export product."
Investment of pension funds in homes	Current investments	"Given that there is currently no company that is listed on the regulated market, whose primary branch of activity is the management of homes in the territory of the Republic of Croatia, we are not able to invest in it."
	Prerequisites	"When investing, ensure that such investment is in accordance with the nature and size of the pension fund's obligations. Take into account the specific risk and return characteristics of such investment on the overall risk profile of pension funds and impact of that investment on the liquidity of the pension fund."
	Legislation	"Although in principle we welcome changes in the regulations that result in an easier flow of capital between investors and recipients of funds, we believe that the current regulations do not prevent investments by pension funds…"
	Risk, profitability and readiness	"We are ready to enter the project if sit is concluded that it meets all the criteria. In this particular case, we believe that a relatively higher risk in the mentioned type of investment would also imply a relatively higher level of yield."

Source: Authors.

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4.1 CURRENT PROBLEMS OF THE BUSINESS MODEL OF EXISTING HOMES

After the analysis of the data obtained from the respondents, it can be concluded that the existing system of long-term care for the elderly faces many problems.

Primarily, there is a lack of capacity aligned with real needs in Croatia, which entails substantial waiting lists. On 31 December 2021, the total number of requests for accommodation in state homes that were turned down was 130, and in decentralized ones as many as 6,148 (MROSP, 2022). It should be considered that these figures only show currently interested users, that is, those who are immediately ready to be placed in a home, and not the total number of applicants, which is assumed to be many times higher. Therefore, the question arises as to what extent waiting lists reflect the real demand for long-term care. Four interviewees point out that the current number of people on waiting lists also depends on the perception of senior citizens about the homes. Namely, in Croatian society, there is still the idea of families taking care of the elderly members and refusing to place them in a home until they "fall off their feet", that is, when the family can no longer adequately care for the needs of their elderly members. "We currently have 270 people on the waiting list, and large part of those who applied while they were still mobile…" points out the director of a county home. Potential users pre-register on the list even if they don't really want accommodation yet, and if a place appears users reject it, thus adding to the burden on the lists. Owners of private homes do not highlight this as the main disadvantage, stating that people prefer state and decentralized homes because of the lower costs of accommodation. One home founded by the county states that they have lists of about 270 interested parties, while in a private home there are only about twenty of them.

Both private and state homes, as well as experts point out the lack of educated staff, primarily nurses and caregivers. The director of a private home states that "It is impossible to find staff (especially high quality staff) on the Croatian labor market, and there are no indications that the education system will adapt..." The director of a county home points out that already in high school there is a kind of recruitment of the future workforce. Everyone agrees that the labor shortage is further aggravated by the emigration of health workers. From the year Croatia joined the EU until 2020, 926 nurses left Croatia, and another 1,829 have sought confirmation of their work license (Stašević, Škalec and Ropac, 2020). When retaining workers, the limiting conditions are low pay, stressful working conditions, while staff often do not have a sufficient level of education for the work they are expected to perform (OECD, 2020). Due to the positive economic growth in the last few years, the long-term care sector in Croatia is improving, but is still significantly below the standards in developed EU countries (European Commission, 2021). There is also no proper connection between doctors and carers. An expert in public health points out that "Long-term care is a 24-7-365 concept of care. It must cover everything: activities of daily life, housing and interventions some of which are therapeutic, rehabilitative and even a social life. But right now everything is torn apart in its little houses. Chaos reigns." "Croatia has a lot of

services, defined procedures that you do for someone: you bathe them, wash them, change their diapers, give them medicine. These are services and you have everything in Croatia, but services cannot replace care." He concludes: "And this fragmentation and lack of coordination worsens the shortage and lack of human resources in the institution. And the work in the institution is difficult, it cannot be paid adequately, it is not organized..."

4.2 CHALLENGES IN BUILDING PRIVATELY OWNED HOMES

In Croatia, there is an interest of individuals and private investment companies in investing in long-term care, but some of the rules and laws are relatively difficult to implement, and with the slow and extensive bureaucracy, a certain number of investors find themselves in stalemate. Directors of both private homes interviewed agree with the above. "Construction of a facility for the care of the elderly and infirm has many challenges when it is done according to the law within the Ministry's system. There are many parameters that must be taken into account and that require a certain definition of the business process flow before anything is built." The academic states, "It is a long-term battle and struggle because you have to meet all the technical standards, conditions, special regulations for constructing such a building". About the problematic bureaucracy and specific legislation, the representative of private investors says, "The investor spends so much time from one step to the next, and then the investor is in the status quo. He cannot do anything else because he is waiting for the decision of the previous step."

According to the Ordinance on criteria for classifying homes (Pravilnik o mjerilima za razvrstavanje domova za starije i nemoćne osobe), for a category I home, it is prescribed that the door at the exit from the premises must be at least one hundred centimeters wide (Art. 16, paragraph 2), corridors must be at least one hundred and eighty centimeters wide (Art. 16, paragraph 22), and the dining room must have an area of at least two square meters per mobile user (Art. 16, paragraph 2). The Ordinance also defines how many and which professions must be employed with regard to the number of users, the type and equipment of auxiliary premises, and the scope and quality of services provided to individual users. The academic points out that the state sets the regulatory framework, while at the same time it neglects the long-term care system and the existence of the problem of unclear criteria on the basis of which the possibility of placing a person in a state/county home is determined. "...the state subsidizes accommodation in state and county homes, covering losses caused by the price of accommodation, which was not economically determined." It follows from this that the state makes it much more difficult to operate and establish private homes, but also tries to protect the oldest and most vulnerable members of the community through strict regulations and provide them with a dignified remainder-of-life.

In EU countries, the model of financing public sector services through PPP is increasingly common (Marenjak et al., 2007), which is mentioned here because of the possibility of reducing the prices of private homes. PPP is a form of

cooperation between local or central government and the private sector for the purpose of fulfilling public needs (Persoli, 2007). The academic notes that there are various models based on which the state could participate more actively and adequately in the social welfare system. "The state will have to do something, it will probably encourage private entrepreneurs, co-finance, to increase capacity, for example through PPP." The representative of private investors denies that there is any current interest of the state and any financial institutions in PPP, which would make private homes available to a larger number of citizens. "The problem with institutions is that the institution as such should actually receive help from the public sector in such a way that, not to us, but to them, those who are in need, they provide compensation for the difference in price. So if one user has three thousand kuna, and our home is the only one in the area to accommodate this type of user, the public sector should compensate him for the difference." Not a single form of PPP in the field of institutional care for the elderly has yet been applied in Croatia (Gelo, Matanić and Matanić Vautmans, 2021).

In Croatia, the market prices of real estate imposed by the construction sector are also increasing, which is directly reflected in the increase in the price of accommodation in private homes, thereby further reducing the interest of citizens in private homes. Private investors note that "At the moment, we are faced with the fact that one offer is valid for maybe only a week due to constant maneuvers on the European, but also on the world market." Some of the reasons for the increase in the price of real estate are the low supply of real estate in the desired location, the assumed further increase in the market price that leads to a real increase and credit expansion (Mustać, 2019). The academic's comment "The construction industry is affected by the lack of labor, but also by rising costs. So, in general, all the costs of some kind of investment have increased, and now, in anticipation of the rise in interest rates, this disincentivizes the market even more and will surely create pressure on public housing..."

4.3 HOME BUILDING PERSPECTIVES

Perspectives in the construction of homes do exist, respondents agree, primarily due to the trend of population aging. "It is simply a need that will develop more and more, we have more and more of an elderly population and we are increasingly becoming an older nation", says the director of a county home. According to the definition of the Croatian encyclopedia (b.d.), aging is "a process of gradual and spontaneous changes in the organism, which is characterized by the progressive weakening of physiological functions, the deterioration of tissues and organs, and thus the organism as a whole; it leads to the cessation of vital functions." Biological changes in the organism, together with the cognitive and psychological changes that aging entails, lead to an increased need for its adequate, increased socialization and design of an environment satisfactory for older people, respecting their biological and psychological needs. In the last ten years alone, the number of residents over the age of 65 has increased by more than one hundred thousand. The total life expectancy in Croatia in 2021 was 76.7 years (Eurostat, 2023). The assumption is that by

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2050, the share of residents over the age of 65 in the total population of Croatia will grow to 31% (Akrap, 2015). In addition to the above, there is a higher incidence of various diseases in old age. In terms of long-term care, the greatest emphasis is placed on dementia, that is, the syndrome of progressive weakening of cognitive functions due to which the patient becomes dependent on others when performing usual daily activities (Bansal and Parle, 2014). The most common and well-known form is Alzheimer's disease, and it is estimated that by 2040, more than eighty million people in the world will suffer from it (Ferri et al., 2005). Respondents put special emphasis on increasing the capacity of specialized accommodation for seriously ill users. The academic says "If someone is demented a little now, I'm speaking roughly, it will be a lot in three years. If someone lives alone in a house with help, they will be dependent on someone else in fifteen years." The Ministry says on this topic, "There is demand, but mostly for one person who is severely disabled, unable to take care of himself." The director of a private home agrees with this and describes an institution that would be ideal "A home that is structurally adapted to people suffering from the consequences of certain diseases, whether heart attack or stroke or any other cause of severe immobility. This dementia is the disease of the future." Also, Croatia is known for numerous natural beauties, including the sea, which cannot be boasted of by a certain number of highly developed countries in the neighborhood. "Health tourism expertly and under supervision uses natural medicinal agents and/or procedures of physical and rehabilitation medicine in order to preserve and improve health and/or improve the quality of life." (Ivanišević, 2016). The scientist points out that the Croatian economy is largely oriented towards tourism. "If Croatia is viewed as some kind of tourist destination, a country that bases its economy on the tourism industry, then it could be our export product, that is, the export of services for foreign citizens, primarily residents of other EU members, whether it is permanent accommodation or temporary accommodation ..." By building homes on the coast, thanks to the beauty of nature and the health benefits of seawater, Croatia can offer an extremely attractive export product. Aging Europeans could be offered lower prices for long-term care services in Croatia than in their countries, favorable climatic conditions and tourist infrastructure (Bađun and Krišto, 2021). The academic says, "If someone manages to find an adequate workforce and a business model to build a home above Primošten with a view of the Adriatic Sea and pay care workers there, then it is likely that people with serious mobiliy problems will come and be there." The representative of private investors also points out that many foreigners have a higher purchasing power, so he proposes the formation of a working group that would examine the desire of foreigners to grow old in Croatia, with a special emphasis on returnees to Croatia. "The Office for Croats outside Croatia can also help us with this. They could collect information about who would like to grow old here, and accordingly, private investors could build homes of this nature and then ensure that Croatia is recognizable in that sense as well."

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4.4 PENSION FUNDS – WILLINGNESS TO INVEST

Pension funds are showing interest in investing in long-term care for the elderly. There is an investment option where they would invest in venture capital funds, so those funds would invest in long-term care. Before that, the long-term care system needs to be reorganized so as to form networks of multiple homes in order to optimize operations.

According to the knowledge of the interviewed representatives of pension fund management companies, no one in Croatia has yet dealt with this idea in depth and presented a proposal for their investment in long-term care. By law, this is not possible for them because pension funds can only be invested in instruments that are listed on the regulated market. “Given that there is currently no company that is listed on the regulated market, which is the primary branch of home management in the territory of the Republic of Croatia, we are not able to invest in it.” According to Art. 3, St. 24 of the Capital Market Act (Zakon o tržištu kapitala), financial instruments are transferable securities, money market instruments, shares in entities for joint investments and derivatives. Therefore, it is concluded that care institutions do not fall into any of these categories. The representative of the regulatory bodies explains in detail the method of investing pension funds in infrastructure projects, along with a written explanation of the procedure, which was additionally explained to us orally at the meeting. Regarding the conditions for investment, they say, “It is an investment in transferable equity and/or debt securities that are used for financing or securitization of infrastructure projects in the territory of the Republic of Croatia” and “These securities have long-term, stable and predictable cash flows, so that they correspond to the maturity of obligation of the pension fund while respecting the principles of security, prudence and caution.” So, pension funds cannot invest in real estate, i.e. in homes. Citizens are obliged to pay part of their income into pension funds, which ensures the payment of their pension. The obligation of citizen participation involves two key items. First, there is strict legislation that controls pension fund investments. Apart from the already mentioned legally regulated possibility of investing only in financial instruments, any investments on their part must not be so risky as to threaten the function and activity of the fund itself. There are also obligations that must be fulfilled,“When making an investment, we have to ensure that such investment is in accordance with the nature and size of the pension fund’s obligation. Also, we need to take into account the specific risk and return characteristics of such investments, the impact of the investment on the overall risk profile of pension funds and the impact of that investment on the liquidity of the pension fund.” Thus, pension funds must not, when making new investments, call into question the sustainability of their obligations to other existing projects.

The representatives of the company for the management of pension funds point out that “The prerequisite is the economic profitability of such an investment, which has the ultimate goal of increasing the value of our members’ investments.” They also note that “The goal is also to minimize the risks when investing in such

a class of assets, as well as the risks during construction, that is why we are interested only for those projects that are fully built or are in a very high stage of construction, while we tend not to enter into projects that are in the beginning of construction or where construction has not yet started." The real estate and capital that pension funds have at their disposal are extremely big. Thus, for example, according to publicly available information on the respective websites, one of the four pension funds in Croatia has a net asset value of almost EUR 183 billion in the least risky category – C (Erste plavi pension fund, 2023).

For investment in long-term care to be acceptable, revenues must be much higher than those that just one institution can generate. With this goal in mind, they propose that institutions for long-term care be merged, that is, consolidated and unified, with the optimization of management, which will be led by "one manager, not fifty of them". From their viewpoint, this kind of reorganization is a feasible managerial task. They presented the idea of establishing a company of the type that would interest venture capital funds, and then the pension funds would indirectly invest in that company through the venture capital funds. Private equity funds or venture capital funds belong to the group of alternative investment funds for which the investment instrument does not need to be listed on a regulated market, and the regulations do not determine permitted investments, but the choice and method of investment itself remains with the company that manages the fund. Institutional investors such as pension funds or insurance companies invest in venture capital funds (Derenčinović Ruk, 2020). They give an example of a similar investment they made by investing in venture capital funds, which in turn invested in unified small polyclinics that provide medical and dental services. They also mention that the Croatian home market is small and underdeveloped, and that consolidation at the regional level, which would include homes from neighboring countries, would also be of particular interest to them.

Due to the further elaboration of this reorganization, the director of a private investment company that has a practice of investing in old homes was also included in the research, who expressed great satisfaction with the mentioned reorganization, because "this is the way our company works in all other countries." From the point of view of long-term sustainability and profitability this person points out that "Long-term profitability would be the level of quality that people seek and deserve. The elderly would know where that money from the pension insurance was invested." and "...when a home for eldery is opened, for example, in Belgium, it is automatically known that it will be included in the group of homes that will eventually be bought by the pension fund and ultimately be managed by the pension fund. Because a pension fund itself provides greater security to users than a private owner." Consolidating and connecting several private homes into a network would certainly be profitable and sustainable in the long term, because there would be pension funds as investors, private investment companies as executors, and the elderly population will grow as beneficiaries. The representative of private investors says, "I think that such homes would be full from the start. They would not deal with the

problem of empty places, because it is known that a strong player is involved. So, I think that would be the best solution for Croatia." The Ministry points out that "Any investment in state homes is quite difficult because they are currently still not profitable." And here arises the issue of the sustainability and feasibility of reorganisation if state homes were to be consolidated. In the same way, merging state and private homes does not make sense, because users of state homes do not pay the full economic price of accommodation, and in this way, there could not be a single price for identical services. But even they point out that in the future, due to the increase in demand, some unification might be possible.

During their working life, citizens would set aside part of their income for pension funds whose funds, in addition to pensions, would also be invested in their old age in the form of better services and more adequate care. By allocating funds to the pension system, policyholders would feel more secure because they know what their funds have been invested in. In this way, the funds would be invested in better services, and private institutions would not be forced to raise accommodation prices to ensure a higher level of service quality. This would potentially indirectly reduce the costs to private investors for providing the same level of services, which could be reflected in the price of homes. Owners of homes could provide more adequate services, which would make private homes far more interesting to their future users. By consolidating a large number of homes, there would be a greater number of users who would pay for these services, and in this way, the existing single investment of pension funds would be accompanied by a long-term inflow of money.

Representatives of the pension fund management company do not think there need to be regulatory changes, for even if the law did not restrict them in their investments there are still the preconditions mentioned that they have to meet, irrespective of the law, for the fund to have a long-term benefit from a potential investment. "We are ready to enter the project if the project meets all the required criteria. In this particular case, we believe that relatively higher risk in the mentioned type of investment would imply relatively higher levels of yield."

They also welcome this reorganization model. Respondents from one fund note that such a home market would be extremely attractive from the perspective of risk and profitability, because homes are a "stable business without volatility" as well as low-srisk, but potentially very profitable because the population is aging, so the need for this type of care is growing. Both funds are interested in investing. "In principle, we support this type of investment, and if a good opportunity appears on the market for which our in-depth analysis would show the profitability of such an investment, we would be ready to consider entering into such an investment."

5 CONCLUSION

Pension funds have a large amount of funds at their disposal because citizens are obliged to pay part of their income; by careful and safe investment the funds increase their assets. However, their investments are strictly regulated by law, and they cannot invest in real estate, only in instruments that are listed on a regulated market. In principle, the conceptual solution for the undercapacity of nursing homes is the construction of new institutions. For pension fund investments to be profitable and sustainable in the long term, the idea of consolidating existing or building new homes in a multiple site operation whose overall profit would be acceptable is suggested. The consolidation process itself is a job for management. The establishment of a company that would bring together several institutions would open the possibility of investment by venture capital funds, whose investments are not as strictly regulated as those of pension funds but depend on the assessment of the companies that manage them. Pension funds, on the other hand, as institutional investors would invest in venture capital funds and thus indirectly invest in the long-term care system.

State-owned homes are not economically profitable, and the state incurs a financial loss with them, so the construction of new homes, state-owned or decentralized, does not appear to be an ideal solution for the implementation of this type of reorganization of the long-term care system. So, when the construction of homes in which pension funds would invest is considered, it is primarily a matter of a network of homes in private ownership. Private investors are interested, they believe that it would be an ideal solution primarily because homes would not be forced to raise prices, and they would achieve a higher level of quality. The representatives of the company for the management of pension funds are also interested; they emphasize the stability of such investments due to the disproportion between supply and demand.

By building one such network of institutions, the circle would be closed. Private investors use initial capital to build a network of homes. During their working life, future users of homes allocate part of their income to pension funds, which invest in the network of homes. By investing in pension funds, owners of retirement homes can provide better and more adequate services, which makes them more interesting to future users. By allocating funds to the pension system, insured persons would feel more secure because they know that their funds have been invested not only into pensions but also into the provision of better care in old age. In the long term, due to the increasing number of users, pension funds would profit.

Of course, this paper also has its limitations. Papers regarding the investment of pension funds in long-term care for the elderly do not exist in Croatia, and they are also rare globally. The conclusions of this research are a logical consequence of the conducted qualitative methodology, that is, interviews conducted with a sufficient sample of experts who deal with various types of long-term care for the elderly. In further research, one could focus on the possibilities offered by pension

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funds and their preferences in the placement of funds, because their interest in this form of investment would encourage additional returns on the capital market, and thus the strengthening of the financial system. However, a more detailed elaboration of the possibilies and methods of unifying the system and the potential profitability of investing pension funds in long-term care is recommended.

Disclosure statement

The participants in the research, as well as the authors, are not connected in any way, and there was no promotion of their own thoughts or conflicts of interest during the creating of the article.

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Does governance contribute to the public spending – CO_2 emissions nexus in developing economies? Policy lessons for sustainable development

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Abstract

Global climate change due to increasing CO_2 emissions threatens the development and survival of many countries, especially those on the coast. Intentional government spending by sectors can lower CO_2 emissions to help these countries in sustainable development. Meanwhile, governance has some importance in enabling governments to achieve their economic development goals. Does governance affect the public spending – CO_2 emissions nexus in developing economies? The paper seeks answers by employing the system GMM Arellano-Bond estimators to assess the impact of public spending, governance/institutional quality, and their interaction on CO_2 emissions for a sample of 109 developing economies between 2002 and 2021. The results seem counter-intuitive that public spending reduces and governance increases CO_2 emissions, while their interaction lowers them. Furthermore, private investment and economic growth promote CO_2 emissions, while trade openness decreases them. The findings in this paper provide some policy lessons for governments of developing economies to protect environment.

Keywords: public spending, CO_2 emissions, governance, developing economies

1 INTRODUCTION

Global climate change and global warming have emerged as hotly debated topics worldwide, driven by the excessive discharge of emissions harmful to the Earth such as CO_2 and SO_2. These gases come from unsustainable production and consumption, and the over-exploitation of natural resources. According to United Nations (2022), generating power, manufacturing goods, cutting down forests, using transportation, producing food, powering buildings, and consuming too much are the causes of global climate change. Notably, generating electricity and heat by burning fossil fuels (gas, oil, and coal) has the largest contribution to climate change, making up 90% of all CO_2 emissions and nearly 75% of greenhouse gas emissions. The most obvious consequence is that more than 70% of the population living in developing and coastal countries (Bangladesh, India, Indonesia, Philippines, Japan, Thailand, China, and Vietnam) will be severely affected due to sea level rise (Climate Central, 2019). Therefore, the United Nations suggests that countries need to work together to overcome the climate challenges facing mankind. Governments must act immediately with the instruments at hand (fiscal policy, with government spending playing a key role) to address climate change, and move toward sustainable development (Fernández, López and Blanco, 2018). Some fiscal instruments in environmental protection are public spending, direct taxes, and indirect taxes (Postula and Radecka-Moroz, 2020). "Taxes and charges are often labelled pricing instruments, as they impose a price on the environmentally harmful aspects of production or consumption and thus aim at influencing consumer behaviour by increasing prices." (Kosonen and Nicodème, 2009). Meanwhile, public spending on environmental protection includes protection of biodiversity landscapes, pollution abatement, and wastewater and waste management. In particular, governments in developing economies should reform and improve governance/institutional quality to make sure that public spending on environmental protection is effectively allocated and used.

Regarding the academic aspect, studies on the role of public spending in environmental protection are relatively numerous, and this topic is considered a research stream in economics. Nearly all studies confirm that government spending can reduce harmful emissions, thus improving environmental quality. However, no existing papers check the influence of governance/institutional quality on the public spending – CO_2 emissions nexus. Institutional reforms tend to lead to sustainable growth and development (Acemoglu, Johnson and Robinson, 2005; Acemoglu and Robinson, 2008). More importantly, institutional reforms provide, propose, and create feasible solutions to help countries solve their internal problems and achieve the goals of the United Nations. Institutional quality is a crucial factor in dealing with environmental issues. Institutional improvement is a suitable instrument for the control of CO_2 emissions (Salman et al., 2019). Institutional quality plays a direct and indirect role in environmental protection via regulations and policies. Institutional structure (bureaucratic quality, corruption control, law and order, government stability, and democracy) may be an appropriate catalyst in the promotion of environmental quality (Uzar, 2021). Therefore, this paper suggests the research question: "Does governance contribute to the public spending – CO_2 emissions nexus?" It will look for the answer to contribute to the literature under the following hypotheses:

H1: Public spending has tended to reduce CO_2 emissions in a group of 109 developing countries from 2002 to 2021.

H2: Institutional quality/governance has tended to reduce CO_2 emissions in a group of 109 developing countries from 2002 to 2021.

H3: The interaction term has tended to reduce CO_2 emissions in a group of 109 developing countries from 2002 to 2021.

Motivated by the recognition that (1) people in developing economies are heavily affected by climate change and global warming, (2) there is an important role of governance in the public spending – CO_2 emissions nexus, this paper uses the system of GMM (Generalized Method of Moments) Arellano-Bond estimators to study the impact of public spending, governance, their interaction on CO_2 emissions for a group of 109 developing economies between 2002 and 2021. The findings of this paper should provide some policy lessons for governments in developing economies.

The paper has the following structure. Section 1 is the introduction, highlighting the practical and academic contexts for this research, while section 2 presents some facts on global CO_2 emissions. Section 3 describes the theoretical framework and literature review, while section 4 notes the methodology and research data. Section 5 reports the results and discussion, and section 6 provides the conclusion and the policy lessons.

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2 SOME FACTS ON GLOBAL CO_2 EMISSIONS

An official report by United Nations (2022) on climate change shows that in 2020, the eight largest emitters (international transport and 7 G20 members) contributed 55% of total greenhouse gas emissions: international transport, Russia, Brazil, Indonesia, India, the European Union, the United States, and China. The whole G20 contributed more than 75% of the total. However, the emissions by the top 8 fell by 3.8% to 35.5 GtCO2e in 2020 from 32.8 GtCo2e in 2019.

From the national inventories in 2020, the land use, land use change, and forest (LULUCF) sector saw a net decrease in emissions inventories of 17 G20 countries, the United States, Russia, India, the European Union, and China. The greenhouse gas emissions was 33% in Russia, 17% in the United States, 9% in India, and 8% in the European Union and 8% in China. In contrast, the LULUCF sector saw a net increase in Brazil and Indonesia, making up 22% and 44% of their total.

In most large emitters, including Indonesia, Brazil, Russia, India, and China, greenhouse gas emissions re-increased in 2021, exceeding pre-pandemic levels. The highest rises from 2019 to 2021 were found in China and Indonesia, at 5.9% and 6.8% respectively. The emissions by international transport in 2021 were still lower than 2019 levels. Greenhouse gas emissions per capita in the European Union and the United States are likely to have decreased during the past decade, but those in other regions to have increased. Least developed economies, on average, emit 2.3 tCO2e. India keeps up at 2.4 tCO2e, followed by 7.2 tCO2e in European Union, 7.5 tCO2e in Indonesia and Brazil, 9.7 tCo2e in China, and 14 tCO2e in the United States. Cumulative carbonic emissions vary significantly among global regions and countries. From 1850 to 2019, the least developed economies contributed 0.5% to total fossil carbonic emissions. Meanwhile, Brazil and Indonesia contributed 1%, India 3%, Russia 7%, China 13%, the European Union 17%, and the United States 25%.

According to Hausfather and Friedlingstein (2023), in 2022, global emissions of CO_2 (including fossil fuel and land use) rose by about 0.8%, stemming from rising fossil fuel CO_2 emissions and steady land use emissions. They remain high at 40.5GtCO2 as compared with the 2019 peak of 40.9GtCO2. Notably, the Democratic Republic of the Congo, Brazil, and Indonesia contribute about 60% to global land use emissions. In 2022, in the United States, emissions rose by approximately 1.5% due to the combination of a high decrease in coal emissions (-4.6%), a modest increase in oil emissions (+2%), and a high increase in gas emissions (+4.7%). By contrast, emissions in the EU fell by 0.8% due to global energy market disruption and low gas use linked with the war between Russia and Ukraine. As in the EU, emissions in China were reduced by 0.9% because of lockdowns connected with the pandemic. However, India is likely to see emissions rising by 6% due to a high increase in coal emissions (+5%) and oil emissions (+10%). Meanwhile, the remaining world takes a 1.7% rise in emissions, coming from increases in cement production (+3%), oil (+3.1%), and coal (+1.6%) use and a slight decline in gas emissions (-0.1%).

3 THEORETICAL BACKGROUND

3.1 THEORETICAL FRAMEWORK

López, Galinato and Islam (2011) describe a theoretical model to provide predictions for testing the nexus between the allocation of government expenditure and the environment in the general equilibrium condition. This model makes three assumptions. First, production pollution stems from the mostly industrial sector (agriculture, mining, manufacturing, and related industries), while the service sector and human capital-producing sector are relatively unpolluting (Mani and Wheeler, 1997). Second, the industrial sector (polluting sector) is more fossil fuel-intensive and capital-intensive than the human capital-producing sector (knowledge sector) and the service sector (clean sector) (Antweiler, Copeland and Taylor, 2001). Third, although public spending on private services and goods can address all three sectors, they are mostly focused on the polluting sector (López and Islam, 2008). The theoretical analysis notes some conditions under which the redistribution of public expenditure from private to public goods and services can lead to lower pollution by production. This means that when there is an increase in government spending on private goods and services and on public ones by the same ratio, the pollution-enhancing impacts of increasing the former seem to be offset by the pollution-decreasing impacts of the latter.

Regarding institutional quality, we suggest that regulations and policies issued by governments can have a significant effect on the public spending – CO_2 emissions relationship. Institutional improvement can promote the effective allocation of public spending on environmental protection. Accordingly, public spending on environmental protection should be monitored and supervised strictly and transparently, and effectively implement regulations and policies that reduce CO_2 emissions and enhance environmental quality.

3.2 LITERATURE REVIEW

The global warming phenomenon and its consequences have led to more and more research on the role of government in mitigating climate change. Therefore, in recent decades, sustainable economic development has become a crucial goal for most economies. To achieve this goal, Fernández, López and Blanco (2018) argue that there is a need to reduce and stabilize greenhouse gas emissions, implementing the transition to a zero- or low-carbon production system. Regarding this topic, several studies have focused on public expenditures on sectors that reduce polluted gases and gases that cause environmental change, while others note the role of total public spending in environmental protection.

Adewuyi (2016), Fernández, López and Blanco (2018), Petrović and Lobanov (2020), and Shao, Zhang and Irfan (2022) are studies that employ public expenditure composition in an empirical model. Adewuyi (2016) applies some estimators (PMG, MG, and fixed effects model) to examine the impact of expenditures by households, companies, and governments on CO_2 emissions in 40 large economies (10 countries with the highest level of emissions in each region: Asia, Africa,

Europe, and America) from 1990 to 2015. The results indicate public spending decreases CO_2 emissions worldwide. Meanwhile, Fernández, López and Blanco (2018) use the OLS regression to assess the impact of government expenditure on R&D on CO_2 emissions for a group of 15 European countries, the United States, and China over the period 1990-2013. The findings show that government expenditure on R&D reduces CO_2 emissions. In conclusion, this work indicates that public expenditure on R&D should be encouraged, not only as an engine of economic growth but also as a driver of sustainable development, in which economic growth can be achieved with low CO_2 emissions. Petrović and Lobanov (2020) employ some estimation methods (fixed effects model, MG, and common correlated effects pooled) to test the influence of public expenditure on R&D on CO_2 emissions for a sample of 16 OECD countries from 1981 through 2014. The results show that public expenditure on R&D decreases CO_2 emissions in these countries. Recently, Shao, Zhang and Irfan (2022) have applied the ARDL estimator to a panel dataset of the 10 largest countries in the OECD between 1990 and 2019 to check the effect of public expenditure on entertainment, culture, and society on CO_2 emissions. The results report that these expenditures reduce CO_2 emissions. According to these researchers, governments can use these expenditures to raise awareness in the population of the relationship of social responsibility, responsible consumption, and sustainability with society, health, the environment, and ecology. This finding implies that the appropriate allocation of budgets to entertainment and culture promotes the effectiveness of environmental protection through the welfare, awareness, and satisfaction of the people.

Similarly, Halkos and Paizanos (2013; 2016; 2017), Zhang et al. (2017), Huang (2018; 2021), Levytska and Romanova (2020), and Feng et al. (2022) are studies that use general government expenditure in the empirical models. Halkos and Paizanos (2013) examine the impact of government spending on the environment using a group of 77 countries from 1980 to 2000 and some estimation methods (OLS regression, fixed effects model, difference fixed effects model, and GMM Arellano-Bond). The results show that government spending reduces SO_2 emissions but does not affect CO_2 emissions. Meanwhile, public spending indirectly reduces SO_2 emissions for low-income countries and increases SO_2 emissions for high-income countries. However, public expenditure does indirectly decrease CO_2 emissions for all countries with different incomes. This implies that the effect of public spending on emissions is conditional on the level of income. Following this paper, Halkos and Paizanos (2016) apply the VAR model for the quarterly time series dataset of the United States from 1973 to 2013 to explore the impact of fiscal policy on CO_2 emissions. The findings report that the expansionary fiscal policy reduces emissions by production and consumption, while fiscal deficit due to tax cuts increases CO_2 emissions by consumption. Halkos and Paizanos (2017) apply the fixed effects model and random effects model to a panel dataset of 94 countries from 1970 to 2008. The results indicate the effect that public spending has on the reduction of SO_2 and NO_x emissions. Meanwhile, Zhang et al. (2017) consider the influence of government spending on three types

of emissions employing GMM Arellano-Bond estimation for a panel sample of 106 cities in China between 2002 and 2014. The results note this influence is different for different types of emissions, negative for SO_2 emissions, an inverted U shape for soot emissions, and a U shape for COD emissions. Furthermore, Huang (2018) uses a spatial Durbin model for a panel group of 30 cities in China from 2008 through 2013 to study the impact of government environmental protection expenditure on SO_2 emissions. The final result reveals that this expenditure decreases SO_2 emissions. Levytska and Romanova (2020) apply a modified generalized regression network model for a time series dataset of Ukraine from 1979 to 2017. They find that public spending can improve environmental protection. Recently, Huang (2021) uses the fixed effects model and difference GMM estimation for a group of 20 municipalities, county-level cities, and counties in Taiwan between 2013 and 2018 to explore the impact of public spending on environmental protection. He notes the positive impact of public spending. Lately, Feng et al. (2022) apply the system GMM estimation to measure the relationship between government spending and green economic performance for a panel sample of 46 selected countries in BRI over the period 2008 and 2018. The findings show that government spending has a positive impact on green economic performance. In addition, the analysis indicates that public expenditures in human capital and renewable energy lead to green economic performance through labour and technology progress.

Unlike the above studies, Galinato and Galinato (2016) examine the influence of change and composition in public expenditures on deforestation due to agriculture land expansion and CO_2 emissions. The empirical results indicate that government expenditure increases forest clearing for agriculture production in the short run, increasing CO_2 emissions. However, it is not significant in the long run. Meanwhile, Moshiri and Daneshmand (2020) employ an ARDL model for a time series dataset of Iran between 1976 and 2014. They do not find any evidence for the impact of public spending on environmental protection.

From the literature perspective, there is no study to explore the role of governance/institutional quality in the public spending – CO_2 emissions nexus. This paper uses the system GMM Arellano-Bond estimators (one-step and two-step) to fill this gap and make a novel contribution to the literature.

4 METHODOLOGY

4.1 EMPIRICAL MODEL

Following Feng et al. (2022), the empirical model is corrected and modified as follows:

$$CO2_{it} = \tau_0 + \tau_1 CO2_{it-1} + \tau_2 EXP_{it} + \tau_3 GO_{it} + \tau_4 (\mathrm{EXP} \times GO)_{it} + Y_{it}\tau' + \rho_i + \sigma_{it} \quad (1)$$

where i denotes the country index, while t denotes the time index. $CO2_{it}$ is the CO_2 emissions per capita (tons), a proxy for environmental quality, $CO2_{it\text{-}1}$ is the initial

level of CO_2 emissions. EXP_{it} is total government expenditure (% GDP), GO_{it} is the governance dimension (rule of law, regulatory quality, control of corruption, voice and accountability, political stability, government effectiveness), and $(EXP \times GO)_{it}$ is the interaction between government expenditure and the governance dimension. Y_{it} includes some control regressors (private investment, economic growth, and trade openness). ρ_i is an unobserved country-specific, time-invariant effect and σ_{it} is an observation-specific error term. τ_1, τ_2, τ_3, τ_4, τ' are estimated parameters. The control regressors in the empirical models are selected by reviewing the literature. Private investment promotes more production, leading to more CO_2 emissions (Halkos and Paizanos, 2013; Adewuyi, 2016; Zhang et al., 2017; Huang, 2018; Petrović and Lobanov, 2020). Meanwhile, economic growth improves the living standard of the people and produces more goods and services, increasing more consumption and pollution (Adewuyi, 2016; Zhang et al., 2017; Fernández, López and Blanco, 2018; Huang, 2018; Petrović and Lobanov, 2020; Feng et al., 2022; Shao, Zhang and Irfan, 2022). Similarly, an openness policy promotes more exports and imports, enabling people to consume more goods and services and boosting pollution (Halkos and Paizanos, 2013; Adewuyi, 2016; Huang, 2018; Petrović and Lobanov, 2020).

To estimate (1), the paper applies the GMM Arellano and Bond (1991) suggested first by Holtz-Eakin, Newey and Rosen (1988). The first difference in all regressors is taken to eliminate country-specific fixed effects (ρ_i). Following this step, the regressors in the first difference are used as instrumented variables in lags under the assumption that time-varying errors in the original models do not have serial correlations (Judson and Owen, 1999). It is the difference GMM (DGMM) that can handle simultaneity biases in estimations.

In a case in which regressors are highly persistent, their past values do not provide information about their future changes, making their lags weaker instrumental variables. Therefore, it will be necessary to combine the original equation and the equation in the difference to have a system of two equations, one in the difference that is instrumented by lags and one in the level that is instrumented by lags in the differences (Arellano and Bover, 1995). It is the system GMM (SGMM) that can promote effectiveness by handling weak instruments in DGMM and reducing the biases in estimates. The consistency of SGMM is based on the assumption that there is no serial correlation, the instruments are valid, and changes in additional instruments do not correlate with fixed effects.

In practice, the two-step SGMM (2SGMM) is more asymptotically efficient than the one-step SGMM. Unfortunately, as Roodman (2009) shows, there is a problem in employing 2SGMM for some small samples. The problem is that instruments will proliferate quadratically as the time dimension rises, so the number of instrumental variables is larger than the number of countries (panel units). Roodman (2009) suggests applying a rule of thumb to keep the number of instrumental variables lower than the number of countries.

The Arellano-Bond test, Sargan test, and Hansen test are employed to check the validity of instrumental variables in 2SGMM. The Sargan and Hansen tests discover endogenous phenomena, while the Arellano-Bond tests detect the serial correlation of the errors in the second difference. Therefore, the paper ignores AR(1) and uses AR(2).

4.2 RESEARCH DATA

The dataset consists of CO_2 emissions (metric tons per capita), total government expenditure, gross fixed capital formation, real GDP per capita, trade openness, and governance indicators extracted from World Bank and IMF databases. The research sample contains 109 developing economies[1] over the period 2002-2021.

Table 1 presents the data description, while tables 2A and 2B report the descriptive statistics. Table 2B indicates that developing economies have poor governance, so they should reform the institutional environment to promote economic activities effectively. Meanwhile, tables 3A and 3B describe the matrixes of correlation coefficients. Table 3A shows that public spending, private investment, economic growth, and trade openness are positively associated with CO_2 emissions. Table 3B notes that the correlation coefficients among governance dimensions are more than 0.8; hence, they should be employed separately in the empirical equations to eliminate collinearity.

To ensure the stability and reliability of regressors in the empirical equations, their stationarity is tested and shown in table 4. The results show that all regressors are stationary at a significance level of 1%, confirming that they have a similar integration order I(0).

Table 1

Dataset description

Variable	Definition	Type	Source
CO_2 emissions (CO_2, tons)	CO_2 emissions (metric tons per capita).	log	World Bank
Public spending (EXP, %)	Total expenditure consists of total expense and the net acquisition of nonfinancial assets.	%	IMF
Private investment (PIN, %)	Gross fixed capital formation (% GDP).	%	IMF

[1] Azerbaijan, Zimbabwe, Armenia, Zambia, Argentina, Vietnam, Albania, Ukraine, Angola, Uruguay, Algeria, Uganda, Burkina Faso, Uzbekistan, Burundi, Turkmenistan, Brazil, Turkey, Bosnia & Herzegovina, Tajikistan, Botswana, Tanzania, Bhutan, Thailand, Bolivia, Timor-Leste, Benin, Togo, Belarus, Tonga, Belize, Tunisia, Bangladesh, Sudan, Cambodia, Saudi Arabia, Senegal, China, Serbia, Chile, Sierra Leone, Chad, South Africa, Cameroon, Sri Lanka, Colombia, Congo, Dem. Rep., Romania, Comoros, Russian Federation, Congo, Rep., Rwanda, Cote d'Ivoire, Philippines, Costa Rica, Poland, Croatia, Peru, Dominican Rep., Paraguay, Egypt, Arab Rep., Panama, Ecuador, Pakistan, El Salvador, Oman, Eswatini, North Macedonia, Equatorial Guinea, Nigeria, Gabon, Niger, Georgia, Nicaragua, Gambia, Nepal, Ghana, Namibia, Guinea, Myanmar, Guatemala, Mozambique, Guinea-Bissau, Morocco, Hungary, Montenegro, Honduras, Mongolia, Indonesia, Moldova, India, Mexico, Iraq, Mauritius, Iran, Mauritania, Jordan, Mali, Jamaica, Malaysia, Kazakhstan, Madagascar, Kiribati, Libya, Kenya, Lao PDR, Kyrgyz Rep., Lebanon, and Lesotho.

Variable	Definition	Type	Source
Economic growth (GDP, USD)	GDP per capita (constant 2010 US$).	log	World Bank
Trade openness (OPE, %)	The sum of exports and imports of goods and services measured as a share of gross domestic product.	%	World Bank
Regulatory Quality (GO1)	Regulatory Quality captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.	level	World Bank
Rule of Law (GO2)	Rule of Law captures perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence.	level	World Bank
Voice and Accountability (GO3)	Voice and Accountability captures perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association, and a free media.	level	World Bank
Control of Corruption (GO4)	Control of Corruption captures perceptions of the extent to which public power is exercised for private gain, including both as well as "capture" of the state by elites and private interests.	level	World Bank
Government Effectiveness (GO5)	Government Effectiveness captures perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies.	level	World Bank
Political Stability (GO6)	Political Stability and Absence of Violence/ Terrorism measures perceptions of the likelihood of political instability and/or politically-motivated violence, including terrorism.	level	World Bank

Source: Author's preparation.

Table 2A

Descriptive statistics

Variable	Obs.	Mean	Std. dev.	Min.	Max.
CO_2	2,180	2.645	3.192	0.020	17.819
EXP	2,180	28.617	15.491	3.787	181.949
PIN	2,180	23.474	8.333	2.000	81.021
GDP	2,180	4,941.198	7,769.721	267.31	77,544.032
OPE	2,180	76.024	33.308	0.784	210.400

Source: Author's calculation.

Table 2B

Descriptive statistics (governance dimensions)

Variable	Obs.	Mean	Std. dev.	Min.	Max.
GO1	2,180	-0.525	0.604	-1.672	1.662
GO2	2,180	-0.450	0.610	-1.962	1.254
GO3	2,180	-0.425	0.813	-3.180	1.422
GO4	2,180	-0.409	0.665	-2.348	1.536
GO5	2,180	-0.517	0.610	-1.870	1.348
GO6	2,180	-0.430	0.778	-2.259	1.311

Source: Author's calculation.

Table 3A

The matrix of correlation

	CO_2	EXP	PIN	GDP	OPE
CO_2	1				
EXP	0.297***	1			
PIN	0.145***	0.104***	1		
GDP	0.865***	0.250***	0.079***	1	
OPE	0.290***	0.312***	0.172***	0.221***	1

*Note: *** denotes a 1% significance level, ** 5% significance level, and * 10% significance level.*

Source: Author's calculation.

Table 3B

The matrix of correlation (governance dimensions)

	GO1	GO2	GO3	GO4	GO5	GO6
GO1	1					
GO2	0.806***	1				
GO3	0.599***	0.514***	1			
GO4	0.732***	0.841***	0.451***	1		
GO5	0.874***	0.858***	0.629***	0.810***	1	
GO6	0.622***	0.568***	0.449***	0.665***	0.653***	1

*Note: *** denotes a 1% significance level, ** 5% significance level, and * 10% significance level.*

Source: Author's calculation.

Table 4

Fisher type unit root tests

Variables	Augmented Dickey-Fuller test		Phillips-Perron test	
	Prob > chi2		Prob > chi2	
	Without trend	With trend	Without trend	With trend
CO_2	317.964***	283.801***	372.570***	295.218***
EXP	259.473**	278.028***	306.929***	370.393***
PIN	326.516***	254.230**	273.501***	176.643
GDP	308.696***	219.896	379.940***	201.929
OPE	322.259***	337.557***	281.902***	308.407***

Variables	Augmented Dickey-Fuller test		Phillips-Perron test	
	Prob > chi2		Prob > chi2	
	Without trend	With trend	Without trend	With trend
GO1	268.640***	266.250***	385.181***	451.596***
GO2	376.661***	316.394***	429.727***	377.175***
GO3	341.992***	327.326***	450.591***	454.349
GO4	243.557	245.751*	353.052***	399.309***
GO5	321.891***	318.653***	332.987***	372.622***
GO6	285.816***	344.309***	347.170***	339.510***

*Note: *** denotes a 1% significance level, ** 5% significance level, and * 10% significance level.*

Source: Author's calculation.

5 RESULTS

5.1 2SGMM ESTIMATES

Table 5 illustrates 2SGMM estimates for the baseline regression (without the interaction term between public spending and governance), while table 6 reports 2SGMM estimates for the full model (with the interaction term). Every column in the tables is a model corresponding with a governance dimension. In all estimation procedures, the paper discovers that private investment is endogenous; hence, it uses private investment as an instrumented regressor in the GMM style and CO_2 emissions, public spending, governance, economic growth, and trade openness as instrumental regressors in the IV style.

Without the interaction term, the estimates across models note that public spending reduces CO_2 emissions, while governance increases them. With the presence of the interaction term, the estimates are still consistent, meaning that public spending decreases and governance boosts CO_2 emissions, but their interaction term lowers them. Hence, the main result is that public spending reduces CO_2 emissions, and this negative impact is amplified by governance.

Most developing economies are experiencing the extreme effects of climate change. In particular, coastal developing economies are likely to be hardest hit. Therefore, governments in these economies try to improve environmental quality through activities such as limiting plastic waste, propagating green awareness, and changing the lifestyles and consumption of the population. Public spending on these goals is always encouraged and directed to stabilize people's health and lives. In particular, government expenditures on high-tech agricultural development and environmental protection are conducted to reduce negative impacts on the environment and move towards sustainable development. Because of this, government spending reduces CO_2 emissions, validating the H1 hypothesis and this result is completely consistent with previous studies such as Halkos and Paizanos (2013; 2016), Zhang et al. (2017), Huang (2018), and Feng et al. (2022).

In contrast to public spending, governance increases CO_2 emissions, which does not support the H2 hypothesis. Does this seem counter-intuitive? Most developing

economies have poor living standards and low income, so regulations and policies (governance) are designed, issued, and implemented to promote economic development and growth that creates more jobs and improves people's living standards. Improving institutional quality/governance aims at boosting the production and consumption of goods and services. Unfortunately, production technologies and management in these economies are outdated and environmentally friendly, and products do not meet the necessary green standards, which increases CO_2 emissions. Azam, Liu and Ahmad (2021) note that institutional quality degrades environmental quality by increasing CO_2 and CH_4 emissions in a group of 66 developing countries from 1991 to 2017. This finding suggests that institutional reforms in developing countries should be performed to regulate economic activities more eco-friendly.

However, regarding environmental protection, governance has a positive role. According to an official report by the United Nations (2022), most developing economies, especially those along coasts, will be hit the hardest by climate change and global warming. Because of this, regulations and policies issued by governments in these economies will focus on public spending to enhance environmental quality. Improving governance/institutional quality will effectively promote the allocation and use of public expenditures on environmental protection. These expenditures will be supervised and monitored transparently and strictly by the people to achieve the environmental goals suggested by the United Nations. Therefore, the interaction term between public spending and governance decreases CO_2 emissions, supporting the H3 hypothesis.

Private investment has always preponderantly aimed at expanding the production of goods and services and encouraging consumption. These economic activities generate more emissions during production and consumption, so private investment will generally increase CO_2 emissions. This finding can be found in previous related studies such as Halkos and Paizanos (2013), Adewuyi (2016), Zhang et al. (2017), and Petrović and Lobanov (2020). In the same vein, economic growth focuses on raising people's living standards and incomes and creating more jobs. Economic growth implies more production and more consumption. In particular, developing economies are always trying to promote economic growth with the desire to catch up with developed countries, so economic growth increases CO_2 emissions in these countries. This result has also been shown in previous studies such as Adewuyi (2016), Zhang et al. (2017), Fernández, López and Blanco (2018), Huang (2018), Petrović and Lobanov (2020), Feng et al. (2022), and Shao, Zhang and Irfan (2022).

Unlike previous studies, this paper discovers that trade openness reduces CO_2 emissions in developing economies. However, this finding is similar to that of Huang (2018). On the one hand, an economic openness policy can promote import and export in developing economies, increasing CO_2 emissions. On the other hand, this policy enables these countries to find in and receive from other countries the advanced and eco-friendly technologies and management models that can be used to produce green, environmentally friendly products to meet stringent consumer standards in other developed countries. Therefore, the final effect is the reduction of CO_2 emissions.

Table 5

Public spending, governance, and CO_2 emissions: 2SGMM estimates, 2002-2021 (baseline regression)

Dependent variable: CO_2 emissions (tons)

Variables	GO1	GO2	GO3	GO4	GO5	GO6
CO_2 emissions (-1)	0.981*** (0.002)	0.977*** (0.002)	0.980*** (0.002)	0.979*** (0.002)	0.980*** (0.002)	0.982*** (0.002)
Public spending	-0.070*** (0.011)	-0.054*** (0.012)	-0.083*** (0.014)	-0.054*** (0.012)	-0.065*** (0.012)	-0.095*** (0.016)
Governance	2.228*** (0.420)	2.509*** (0.469)	1.709*** (0.393)	2.181*** (0.405)	1.835*** (0.416)	1.388*** (0.362)
Private investment	0.384*** (0.044)	0.369*** (0.046)	0.360*** (0.050)	0.393*** (0.048)	0.330*** (0.045)	0.396*** (0.053)
Economic growth	0.0003 (0.001)	0.0000 (0.001)	0.0023 (0.001)	-0.0004 (0.001)	0.001 (0.001)	0.001 (0.001)
Trade openness	-0.042*** (0.012)	-0.039*** (0.012)	-0.054*** (0.015)	-0.046*** (0.012)	-0.045*** (0.013)	-0.049*** (0.015)
Instrument	41	41	37	38	40	36
Country/Observation	109/1635	109/1635	109/1635	109/1635	109/1635	109/1635
AR(2) test	0.964	0.980	0.960	0.966	0.969	0.963
Sargan test	0.190	0.355	0.159	0.183	0.229	0.205
Hansen test	0.156	0.126	0.106	0.108	0.111	0.125

*Note: *** denotes a 1% significance level, ** 5% significance level, and * 10% significance level.*

Source: Author's calculation.

TABLE 6

Public spending, governance, and CO_2 emissions: 2SGMM estimates, 2002-2021 (full model)

Dependent variable: CO_2 emissions (tons)

Variables	GO1	GO2	GO3	GO4	GO5	GO6
CO_2 emissions (-1)	0.977***	0.973***	0.977***	0.979***	0.977***	0.981***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Public spending	-0.138***	-0.175***	-0.107***	-0.186***	-0.132***	-0.112***
	(0.027)	(0.035)	(0.022)	(0.031)	(0.028)	(0.021)
Governance	5.251***	6.499***	3.545***	5.234***	4.759***	3.041***
	(0.902)	(1.033)	(0.598)	(0.861)	(0.793)	(0.658)
Pub. spend * Governance	-0.097***	-0.130***	-0.052***	-0.103***	-0.082***	-0.053***
	(0.023)	(0.026)	(0.012)	(0.020)	(0.020)	(0.017)
Private investment	0.339***	0.357***	0.349***	0.393***	0.347***	0.396***
	(0.048)	(0.049)	(0.048)	(0.044)	(0.048)	(0.052)
Economic growth	0.003**	0.004***	0.003**	0.003**	0.003**	0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Trade openness	-0.025***	-0.027***	-0.050***	-0.031***	-0.033***	-0.043***
	(0.010)	(0.011)	(0.014)	(0.011)	(0.011)	(0.013)
Instrument	36	37	38	39	37	37
Country/Observation	109/1635	109/1635	109/1635	109/1635	109/1635	109/1635
AR(2) test	0.949	0.968	0.977	0.957	0.966	0.946
Sargan test	0.167	0.353	0.204	0.211	0.205	0.231
Hansen test	0.160	0.205	0.229	0.340	0.114	0.229

*Note: *** denotes a 1% significance level, ** 5% significance level, and * 10% significance level.*

Source: Author's calculation.

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5.2 ROBUSTNESS CHECK

The paper uses 1SGMM to test the robustness of 2SGMM estimates. Table 7 reports the results for the baseline regression, while table 8 notes the results for the full model. Like 2SGMM estimation, we discover that private investment is endogenous.

In line with 2SGMM estimates, 1SGMM estimates indicate that public spending reduces and governance increases CO_2 emissions, but their interaction term decreases them. Furthermore, private investment boosts CO_2 emissions, while trade openness lowers them. These results confirm that 2SGMM estimates are reliable and robust.

TABLE 7

Public spending, governance, and CO_2 emissions: 1SGMM estimates, 2002-2021 (baseline regression)

Dependent variable: CO_2 emissions (tons)

Variables	GO1	GO2	GO3	GO4	GO5	GO6
CO_2 emissions (-1)	0.981***	0.977***	0.980***	0.979***	0.979***	0.983***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Public spending	-0.045*	-0.032	-0.054**	-0.038*	-0.050**	-0.071***
	(0.024)	(0.022)	(0.024)	(0.022)	(0.021)	(0.025)
Governance	1.803***	2.533***	1.817***	2.327***	1.986***	1.277***
	(0.550)	(0.556)	(0.438)	(0.526)	(0.517)	(0.457)
Private investment	0.309***	0.310***	0.284***	0.332***	0.280***	0.311***
	(0.076)	(0.075)	(0.097)	(0.097)	(0.076)	(0.100)
Economic growth	0.0006	0.0009	0.004**	0.001	0.003	0.003
	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)
Trade openness	-0.038**	-0.043***	-0.067***	-0.051***	-0.051***	-0.057***
	(0.018)	(0.017)	(0.020)	(0.018)	(0.016)	(0.018)
Instrument	41	41	37	38	40	36
Country/Observation	109/1635	109/1635	109/1635	109/1635	109/1635	109/1635
AR(2) test	0.952	0.983	0.961	0.957	0.964	0.961
Sargan test	0.190	0.355	0.159	0.183	0.229	0.205

*Note: *** denotes a 1% significance level, ** 5% significance level, and * 10% significance level.*

Source: Author's calculation.

Table 8
Public spending, governance, and CO_2 emissions: 1SGMM estimates, 2002-2021 (full model)

Dependent variable: CO_2 emissions (tons)

Variables	GO1	GO2	GO3	GO4	GO5	GO6
CO_2 emissions (-1)	0.979*** (0.002)	0.975*** (0.002)	0.978*** (0.002)	0.978*** (0.002)	0.978*** (0.002)	0.981*** (0.002)
Public spending	-0.084* (0.047)	-0.142*** (0.049)	-0.085*** (0.028)	-0.153*** (0.049)	-0.093** (0.040)	-0.084*** (0.027)
Governance	3.803*** (1.609)	6.104*** (1.514)	3.533*** (0.811)	5.330*** (1.277)	4.049*** (1.368)	2.770*** (0.842)
Pub. spend * Governance	-0.073* (0.039)	-0.124*** (0.040)	-0.051*** (0.016)	-0.100*** (0.032)	-0.073*** (0.030)	-0.049*** (0.019)
Private investment	0.244*** (0.101)	0.282*** (0.091)	0.287*** (0.097)	0.342*** (0.097)	0.269*** (0.081)	0.315*** (0.100)
Economic growth	0.002 (0.002)	0.004* (0.002)	0.005*** (0.002)	0.004** (0.002)	0.002 (0.002)	0.003 (0.002)
Trade openness	-0.021 (0.019)	-0.032** (0.016)	-0.064*** (0.0120)	-0.046*** (0.016)	-0.029 (0.018)	-0.054*** (0.017)
Instrument	36	37	38	39	37	37
Country/Observation	109/1635	109/1635	109/1635	109/1635	109/1635	109/1635
AR(2) test	0.938	0.968	0.987	0.958	0.960	0.937
Sargan test	0.167	0.353	0.204	0.211	0.205	0.231

*Note: *** denotes a 1% significance level, ** 5% significance level, and * 10% significance level.*

Source: Author's calculation.

6 CONCLUSION AND LESSONS

Developing economies, particularly those located along a coast, can be hit hard by the rising sea levels stemming from global warming and climate change. Governments in these economies promote public spending to serve the development and economic growth and improve environmental quality. In particular, they also try to improve and reform institutional quality to achieve economic goals. Given these facts, the paper uses 1SGMM and 2SGMM to examine the role of governance in public spending – CO_2 emissions nexus for a group of 109 developing economies during the period 2002-2021. Like Halkos and Paizanos (2013; 2016), Zhang et al. (2017), Huang (2018), and Feng et al. (2022), this paper finds that public spending reduces CO_2 emissions. It also reports a positive impact of institutional quality on CO_2 emissions as shown by Azam, Liu and Ahmad (2021). However, the interaction between institutional quality and public spending decreases CO_2 emissions. These results imply that public spending lowers CO_2 emissions and this negative impact is amplified by governance. Therefore, these findings emphasize that research on the public spending – CO_2 emissions/environmental quality nexus should take into account the role of institutional quality/governance. Furthermore, private investment and economic growth increase CO_2 emissions, while trade openness decreases them.

The findings in this paper provide some policy lessons for governments in developing economies over the course of economic development and growth. Some policy implications can be identified, as follows:

- Governments in developing countries should reform and improve institutional quality to make economic activities more environment-friendly.
- They should design, issue and enforce regulations and policies (institutional quality/governance) to increase public spending, especially on developing high-tech agricultural industries, supporting start-up projects targeting green and clean products, and encouraging people to be aware of environmental protection and consume eco-friendly products. Public spending should be partly used to plant trees and improve polluted waterways.
- They should implement some policies to encourage the private sector to apply advanced and eco-friendly technologies in production and management. More importantly, products need to meet environmental standards.
- Driving economic growth to create jobs and improve people's living standards is what most governments will do. However, developing economies should focus on a circular, sustainable economy that is not harmful to the environment.
- Trade openness in developing economies has a positive impact on the environment, so governments in these countries should use some appropriate policies to encourage domestic enterprises to import advanced and eco-friendly machines and equipment and apply environment-friendly processing technology and encourage people to choose environment-friendly imported products.

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Several developing economies do not have enough data, so the research sample consists only of 109 developing countries. This is a limitation of the research. Future studies should consider the different roles of institutional quality in public spending – CO_2 emissions between developed and developing economies.

Disclosure statement

The author has no conflict of interest to declare.

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Is external debt an impediment to the South African economy?

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Abstract

The purpose of this study is to test whether the relationship between external debt and economic growth is symmetric or asymmetric in South Africa using annual time series data from 1985 to 2021. The study employed NARDL bounds and Breitung nonparametric cointegration estimation methods. Breitung, Bierens nonparametric, and ZA unit root test are used to check for the order of integration of the variables. The results from NARDL bounds and Breitung nonparametric cointegration test confirm a long run relationship between the variables. The results indicate that the responsiveness of GDP to positive shocks of external debt is less than that to negative shocks. An increase in external debt is associated with a decrease in GDP, while a decrease in external debt is associated with an increase in GDP. The study suggests that South African economy should keep its external debt sustainable so as not to harm economic growth.

Keywords: economic growth, external debt, asymmetry, fiscal policy, South Africa

1 INTRODUCTION

There is still a controversial debate about whether external debt is detrimental to economic growth in developing and developed countries. External debt is one of the major sources of income especially in developing countries since they are more likely to be faced with fiscal deficit and being vulnerable to external shocks. When a country faces a fiscal deficit, it often borrows money externally or domestically to balance its budget and satisfy social and economic priorities. According to Adebusola, Salau and Obayelu (2007) countries in Africa have an insufficient internal capital formation because of low productivity, low income, and low savings. This tends to lead to financial aid being sought from developed countries or financial institutions like the World Bank, International Monetary Fund, and foreign governments.

Economic growth takes place when government and businesses devote money to capital investments that encourage production and raise income levels. If a country has a huge foreign debt that needs to be paid back, it has less money to invest on development projects such as infrastructure, military, healthcare facilities, and research and development. This will be detrimental to the economy in the future. The biggest problem with foreign debt is that it often puts a country in a debt cycle. The debt cycle is the repeated process of borrowing money, making payments, and eventually not being able to pay (Dietz, 1989).

Furthermore, the burden of external debt can be shifted from one generation to another. However, Lerner (1961) argued that the external debt burden is shifted from one generation to another without the latter receiving any benefits if the debt is only used to finance current spending to boost consumption. Current spending is the money spent on cash payments for operating activities. Furthermore, Lerner (1961) suggested that if the external debt is used for capital spending, for example, building roads, railways and airports, then the next generation will still bear

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the burden of external debt but also enjoy benefits from the external debt that was taken on. This brings the benefit principle of public debt into the argument, since the next generation should not only bear the burden of external debt but also receive benefit from the external debt taken by the previous generation.

South Africa has been experiencing gradually increasing rates of external debt from 2006 until 2021. It was estimated by the minister of finance (Mr Godongwana) in the 2022/23 Budget Review that government debt will stabilise in financial year 2025/26. If South Africa's government debt continues to increase after the stabilisation point, the debt will harm economic growth. This will in turn result in there being less money to spend on infrastructure investment, less saving, low production, devaluation of domestic currency, all of it resulting in South Africa losing international market access. This is in line with a debt Laffer curve, which states that as the face value of debt increase the market value of debt also increase until a certain point (that is a threshold). Therefore, after this point the debt will be detrimental to the wealth of the nation. This is when it is difficult for the government to service its debts, because the debt is draining a lot of money that is supposed to be used for current and capital spending.

Public debt consists of domestic and external debts; however, the focus of this study is on external debt. This is because servicing external debt is more challenging as compared to domestic debt since external debt is mostly affected by external shocks that could lead to a devaluation of domestic currency. As a results, when the domestic currency depreciates then the interest payments become more expensive. Furthermore, the external debt burden is more likely to be transferred to the future generation which makes it suitable for the scope of this study. Figure 1 shows the long run trends of external debt as a percentage of GDP and gross domestic product measured at market price in South Africa from 1985 to 2021. Figure 1 shows that external debt and gross domestic product moved together from 1985 to 2021 but in opposite directions: when external debt increases, gross domestic product decreases. Therefore, this indicates that external debt is one of the drivers of economic growth in South Africa. Figure 1 shows that external debt decreased sharply from 40.1% in 1985 to 19.3% in 1994. During the period of 1985 to 1994 the highest external debt percentage of 40.1% was recorded in 1985. This spike was supported by the debt crises that took place in South Africa in 1985 (Hirsch, 1989).

During the period of 1995 to 2004, the external debt fluctuated steadily between 17.6% to 26.3%. It reached a peak of 26.3% in 2002. This spike was supported by foreign borrowing by the national government through bond issuing, and debts that were made to support military purchase programme (SARB, 2003). The external debt to GDP ratio increased sharply from 16.9% in 2005 to 50.5% in 2020, then relatively decreased to 38.3% in 2021. This rise of external debt to GDP was fuelled by countercyclical fiscal policies that were implemented in 2009 to overcome the huge impacts of local and global recessions (National Treasury, 2010). The 2010 FIFA World Cup also contributed to the rise of external debt to GDP of

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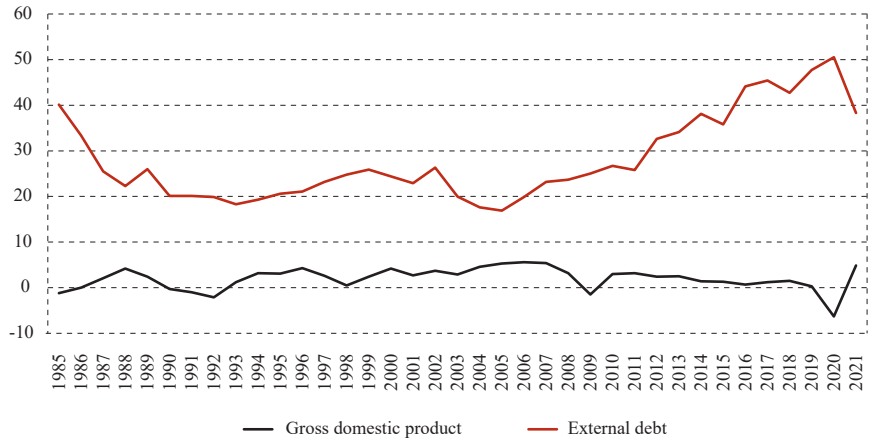
South Africa during this period because spending on infrastructure had to increase. During this period the highest ratio of external debt to GDP was recorded at 50.5% in 2020, which resulted from debts that were incurred to support public health and economic measures aimed at containing and mitigating the COVID-19 outbreak. As per the trends observed in South Africa's external debt, it is evident that the share of external debt in the country's GDP is increasing. From 2005 to 2021, the percentage of external debt in GDP has increased by 21.4%, from 16.9% to 38.3%. This suggests that in the coming years, external debt may account for a larger share in comparison to domestic debt, although the percentage share of domestic debt in GDP is still greater than that of external debt. Therefore, South African policymakers must make sure that they manage external debt in a good manner and ensure fiscal sustainability.

FIGURE 1

Gross domestic product at market price and external debt as % of GDP trends in SA



Source: Author's own computation from data from South African Reserve Bank.

Previous empirical studies such as Lin and Sosin (2001), Ayadi and Ayadi (2008), Senadza, Fiagbe and Quartey (2017), Ighodalo Ehikioya et al. (2020), and Manasseh et al. (2022) were based on linear and threshold modelling when investigating the impact of external debt on economic growth in South Africa. These studies did not analyse whether there is an asymmetric relationship between South Africa's foreign debt and economic growth. Therefore, there are only limited studies investigating the asymmetric relationship between foreign debt and economic growth in South Africa in the same way as NARDL. According to Shin, Yu and Greenwood-Nimmo (2014) NARDL is "capable of simultaneously and coherently modelling asymmetries both in the underlying long-run relationship and in patterns of dynamic adjustments" as compared to other nonlinear models. Investigating the relationship between foreign debt and economic growth in a linear regression could lead to misleading statistical inferences, because linear regression is unable to fit complex datasets accurately. In real life situation, the relationship

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between foreign debt and economic growth cannot be linear, and straight line cannot fit the dataset properly. Due to this, it is essential to investigate the nonlinear relationship that exists between economic growth and external debt. Furthermore, the goal of this study is to investigate the asymmetric influence of foreign debt on South African economic growth. This study uses a nonlinear autoregressive distributed lag model (NARDL) to investigate this relationship. This technique is different to those of previous empirical studies based on the South African case. The Nonlinear-ARDL model has an advantage of testing whether the external debt has an asymmetric or symmetric impact on economic growth in South Africa. This study, on the other hand, provides solutions to the following three issues concerning the relationship between foreign debt and economic growth. The first problem is whether the relationship between external debt and economic growth is asymmetric or symmetric. The second problem is the reaction of economic growth to positive and negative values of external debt. Finally, this study seeks to provide an insight into whether increasing or decreasing external debt would accelerate or decelerate economic growth in South Africa, and to give an understanding about how quickly or slowly the South African economy will converge to the long run equilibrium due to external debt structural changes. This study is structured as follows: section 2 reviews the theoretical and empirical literature, section 3 presents the methodology of the study, section 4 discusses the empirical results, and section 5 provides the conclusion of the study.

2 LITERATURE REVIEW

Debts are incurred by the government to help pay for public goods to enhance people's standard of living and improve the economy (Ogunmuyiwa, 2011). Foreign debt is one of the factors that play a significant role in building a country's capital investment (Ayadi and Ayadi, 2008). External debt is also taken on to help the economy in times of economic crisis and natural disasters. However, future debt servicing is harmful to the economy since a big amount of national revenue is spent on repaying the debt. There are two underpinning theories for this study: the Debt Laffer Curve and Debt Overhanging Hypothesis. The Debt Laffer Curve was devised by Sachs (1989) who claimed that an increase in debt contributes positively in the economy until it reaches a stabilisation point, if a debt continues to increase after this point it becomes harmful for the economy. Krugman (1988) proposed the Debt Overhanging Hypothesis, which states that a nation is affected by debt overhanging when the present value of the transfers it is expecting to receive in the future is less than the debt itself. This situation could put lenders in a state whereby they are no longer confident of recovering their money. The empirical literature is grouped into three parts; the first part consists of country-specific studies, which are studies that use time-series econometric methodology, the second part focuses on studies using panel data econometric methodology, and the last part consists of South African studies.

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2.1 COUNTRY SPECIFIC STUDIES

There is an intensive literature that investigate the impact of external debt on economic growth using the time-series methodology. Amongst others, Shahnawaz, Hayat and Hayat (2010) investigated the link between Pakistan's foreign debt and economic growth. The study used yearly data from 1972 to 2005. The findings indicated an inverse connection between foreign debt and economic growth. Ajayi and Oke (2012) analysed how Nigeria's foreign debt affects GDP growth. The study used an ordinary least square (OLS) estimation method. The findings demonstrated that a high level of foreign debt has a negative impact on economic growth. For the period since 1990, Kharusi and Ada (2018) examined how the external debt of Oman affected economic growth, utilizing yearly data. The study investigated the short run association between foreign debt and economic growth using autoregressive distributed lag model. The findings revealed a negative link between foreign debt and economic growth.

Using time series data from 1970-2017, Matuka and Asafo (2018) investigated the effect of Ghana's foreign debt on GDP growth. In this analysis, the study used Johansen cointegration test and the vector error correction model. The results found a positive correlation between external debt and economic growth. Shkolnyk and Koilo (2018) investigated the link between foreign debt and economic growth in Ukraine and other developing countries from 2006 to 2016. To study this association, the authors used the ARDL model. The study showed varying findings, indicating that the link is positive in certain nations and negative in others.

The study conducted by Govdeli (2019) aimed to examine the effects of external debt stock, openness, and the consumer price index on the Turkish economy. The study utilised a time series dataset spanning the years 1970 to 2016. The study used the ARDL bounds estimation method. The bounds test confirmed a cointegrating relationship between the variables. Turkey's foreign debt was determined to have a favourable effect on the country's economic growth.

Using time series data from 1980 to 2018, Makun (2021) examined the connection between Fiji's economic expansion and foreign debt. To determine this connection, the study used neoclassical growth and ARDL models. The results from the linearity measure indicated that foreign debt negatively affects economic growth, while nonlinearity results showed that foreign debt affects economic growth differently. The threshold results show that external debt positively affects economic growth until it reaches a threshold level, then after the threshold level external debt starts to harm economic growth.

2.2 CROSS-COUNTRY STUDIES

The studies that used panel data approach are presented in this section of the study. Among others, Asafo, Matuka and Dominic (2019) examined the connection between foreign debt and economic growth in 48 SSA nations from 1970 to 2017. The authors used a two-step generalised methods of moments (GMM) estimation technique. The findings revealed that foreign debt has a negative influence on economic growth.

Lau, de Alba and Liew (2022) estimated the relationship between external debt and economic growth using a panel of 16 Asian countries over a period of 1980 to 2016. The study used the Johansen and Juselius cointegration test and error correction model. The results demonstrated that external debt harms economic growth in many countries.

Özyilmaz (2022) analysed the effect of external debt on economic growth using a panel of E7 countries over a period of 1992 to 2020. The study used Westerlund cointegration test, then used common correlation effects estimator (CCE) and augmented mean group estimator (AMG) for coefficient estimation. The results showed a long run relationship between the variables, and that there is a negative relationship between external debt and economic growth for E7 nations.

Alemu, Choramo and Jeldu (2023) investigated the effect of external debt and institutional quality on economic growth in a panel of East African countries for the period from 1998 to 2019. The study used a panel autoregressive distributed lag (PARDL) model estimation technique. The results showed a positive relationship between external debt and economic growth up to a threshold level of 62.9%, then beyond this threshold external debt becomes harmful to economic growth.

There is an extensive empirical literature that exists on the relationship between external debt and economic growth in various nations. Various studies from specific and cross-country studies have discovered a negative association between external debt and economic growth. Previous studies have found a long run association between foreign debt and economic growth. Although there may be various ways in which external debt affects economic growth, available evidence indicates that foreign debt has an immediate influence on economic growth.

2.3 SOUTH AFRICAN STUDIES

The issue of whether the foreign debt has a detrimental or favourable effect on economic growth has received significant attention in both developed and developing countries, however, in South Africa there are few empirical studies. Among others, Lin and Sosin (2001) used a panel of 77 nations during the period spanning from 1970 to 1992 to analyse the connection between foreign debt and economic growth. The countries were divided as follows: African countries including South Africa (N = 24), Latin American countries (N = 18), Asian and other developing countries (N = 17), and industrialised countries (N = 18). The study used a cross-sectional regression for this purpose. The results indicated that in African countries the external debt is negatively and statistically significant related to economic growth, while for industrialised and Latin American countries it is negative but statistically insignificant to explain its effect on economic growth. The results from the subsample of Asian and other developing countries showed a positive and insignificant relationship between external debt and economic growth.

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Ayadi and Ayadi (2008) studied the influence of high external debt on economic growth in South Africa and Nigeria. The study used OLS and non-linear Elbadawi's estimation methods for this purpose. External debt has a detrimental impact on economic growth in South Africa and Nigeria. Furthermore, the results showed that South Africa has the advantage of using external debts to derive development as compared to Nigeria. The results also showed that foreign debt contributes positively towards the development in Nigeria until it becomes harmful showing the presence of non-linearity effects. Senadza, Fiagbe and Quartey (2017) analysed the effect of external debt on economic growth in a panel of 39 Sub-Saharan African (SSA) countries and South Africa included for a period of 1990 to 2013. The study used the system generalised method of moments estimation method. The results indicated that foreign debt is negatively related to economic growth in SSA countries. The results also showed the existence of nonlinear correlation between external debt and economic growth.

Ighodalo Ehikioya et al. (2020) used a panel of 43 African nations, including South Africa, to study the relationship between external debt and economic growth from 2001 to 2018. The study analysed the long-term correlation between the variables using the Johansen cointegration test. Parameters were estimated using the system generalised method of moments (GMM). A long-run association between foreign debt and economic growth was established. The findings revealed a quadratic link between foreign debt and economic growth, whereby external debt boosts economic growth to a certain point, beyond which it becomes detrimental to economic growth. Manasseh et al. (2022) studied the influence of foreign debt on economic growth in 30 SSA countries including South Africa from 1997 to 2020. The system GMM estimation approach was employed in the study. The findings indicated a negative link between SSA nation's foreign debt and economic growth.

The current study is different from others that have looked at the relationship between South Africa's foreign debt and economic growth. This study contributes to the body of knowledge in the following ways: Firstly, to provide a policy direction, the study used a time series analysis to evaluate the relationship between foreign debt and economic growth in South Africa. This analysis is different from that of Lin and Sosin (2001), Senadza, Fiagbe and Quartey (2017), Ighodalo Ehikioya et al. (2020), and Manasseh et al. (2022) in which analyses were based on a panel data approach. The major disadvantage of panel data analysis is unobserved heterogeneity due to unmeasured differences between the cross-sectional units. Therefore, this approach could lead to inappropriate and misleading results.

Secondly, the recent study looked at the relationship between South Africa's foreign debt and economic growth using a variety of time series econometric techniques. This approach is different to the study of Ayadi and Ayadi (2008) who used OLS and non-linear Elbadawi's estimation methods while the current study applied the NARDL estimation method. As previously noted by Panopoulou and Nikitas (2004) "autoregressive distributed lag (ADL) models perform better than OLS models both in terms of estimation precision and reliability of statistical inferences". NARDL

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model by its nature is powerful because it can be used in small sample sizes. Other advantages of the NARDL model are that it can cater for the variables that are integrated at I(0), I(1), or a mixture of the two. NARDL also corrects serial correlation since the dependent variable is regressed on its previous values.

Thirdly, the study investigated nonlinearity in the foreign debt and economic growth before estimating NARDL to ensure that nonlinearity exists in that specific variable. Nonlinearity test in the variables should be explored to ensure the model is properly specified. Lastly, the study also contributes by including one variable in the adopted model which is exchange rates. It is necessary to include the exchange rate in this study since external debt involves making payments outsides the country. The studies by Ayadi and Ayadi (2008) and Ighodalo Ehikioya et al. (2020) were based on linearity and threshold analysis that do not capture dynamic adjustments, which NARDL can, therefore, they are different to the current study since the focus is on the asymmetric effects of external debt on economic growth using the NARDL approach. This study fills the gap and corrects the limitations of the previous empirical studies by examining the nonlinear effect of external debt on economic growth based on asymmetric approach.

3 METHODOLOGY

This study looks at the asymmetric effect of foreign debt on GDP growth in South Africa from 1985 to 2021. The nonlinear autoregressive distributed lag (NARDL) model, developed by Shin, Yu and Greenwood-Nimmo (2014), is used in this investigation. The variables are exposed to unit root tests to ensure that they are stationary. Nonparametric unit root tests by Bierens and Breitung are employed in this analysis.

3.1 EMPIRICAL MODEL

This paper adopts and modifies the empirical model of Shahnawaz et al. (2010) by including the exchange rate variable to capture the effect of exchange rates since the payments of external debt are transferred to the rest of the world. Then, the study removed debt servicing in adopted model, because external debt is more likely to move together with debt servicing cost. Therefore, this may lead to multicollinearity problems in the model. The empirical model is written as follows:

$$GDP_t = \alpha_0 + \alpha_1 ED_t + \alpha_2 EXR_t + \mu_t \quad (1)$$

Where GDP_t represents the gross domestic product at market price, ED_t stands for external debt as a percentage of GDP, EXR_t represents foreign exchange rate (rand per US$), and μ_t is an error term from population regression.

$$LGDP_t = \alpha_0 + \alpha_1 LED_t + \alpha_2 LEXR_t + \varepsilon_t \quad (2)$$

ε_t represents a stochastic error term. α_0 is the intercept, and α_1 and α_0 represent slope parameters. The equation 2 is a revised version of equation 1 where the model is expressed in percentages. The variables are already explained in equation (1). A rise

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in external debt levels is expected to have a negative impact on economic growth, as it leads to an increase in debt payment expenses. This, in turn, reduces the amount of funds available for private and state investment, resulting in long-lasting adverse effects on the gross domestic product (GDP). Furthermore, there is an expected negative relationship between the exchange rate and economic growth. It is anticipated that when the domestic currency appreciates this will lead to a decrease in exports and an increase in imports. This implies a current account deficit in the BoP; therefore, this would eventually lead to declining economic growth since the money is going out of the economy.

3.1.1 ESTIMATION TECHNIQUE: NONLINEAR AUTOREGRESSIVE DISTRIBUTED LAG MODEL

This study employed the NARDL model by Shin, Yu and Greenwood-Nimmo (2014) which is the nonlinear form of the autoregressive distributed lag (ARDL) model of Pesaran, Shin and Smith (2001). The NARDL approach is favoured because it allows for asymmetries caused by negative and positive shocks in macroeconomic variables. This method is also better than others since it may be used regardless of whether the order of integration is I (0), I (1), or a mix of both.

The NARDL model is not applicable if there is a variable that is integrated of I(2), therefore, it is essential to investigate the unit root in a series. Therefore, before estimating nonlinear ARDL model, the study performs Bierens nonparametric, Breitung nonparametric, Zivot-Andrews unit root tests to determine whether the variables are not integrated at I(2).

The previous equations are estimated with the perspective that external debt has a linear effect on economic growth. However, the main purpose is to determine whether the external debt has an asymmetric impact on economic growth. External debt (ED) is divided into two components, one of which captures positive shocks on external debt stock (ED_t^+) and the other part of which captures negative shocks in external debt (ED_t^-):

$$ED_t^+ = \sum_{j=1}^{t} \Delta ED_j^+ = \sum_{j=1}^{t} Max(\Delta ED_j^+, 0) \tag{3}$$

$$ED_t^- = \sum_{j=1}^{t} \Delta ED_j^- = \sum_{j=1}^{t} Min(\Delta ED_j^-, 0) \tag{4}$$

To obtain non-linear ARDL equations, we replace ED_t with ED_t^+, and ED_t^- in equation 2, therefore, the error correction of the NARDL form may be stated mathematically as follows:

$$\begin{aligned} \Delta LGDP_t = {} & \alpha_0 + \sum_{k=1}^{p} \alpha_1 \Delta LGDP_{t-k} + \sum_{k=1}^{p} \alpha_2 \Delta LEXR_{t-k} \\ & + \sum_{k=0}^{p} \alpha_3 \Delta LED_{t-k}^+ + \sum_{k=0}^{p} \Delta \propto_4 LED_{t-1}^- + \partial_1 LGDP_{t-1} \\ & + \partial_2 LEXR_{t-1} + \partial_3 LED_{t-1}^+ + \partial_4 LED_{t-1}^- + \varepsilon_t \end{aligned} \tag{5}$$

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$$\Delta LGDP_t = \emptyset_0 + \sum_{k=1}^{p} \emptyset_1 \Delta LGDP_{t-k} + \sum_{k=1}^{p} \emptyset_2 \Delta LEXR_{t-k} + \sum_{k=0}^{p} \emptyset_3 \Delta LED^{+}_{t-k} + \sum_{k=0}^{p} \Delta L \emptyset_4 ED^{-}_{t-1} + \pi_0 ECM_t + \varepsilon_t \quad (6)$$

whereas Δ denotes the first difference and k represents the lagged values, α_1, α_2, and α_3 and $\emptyset_1, \emptyset_2, \emptyset_3$ and $\emptyset_4$ are short-term coefficients, $\partial_1, \partial_2, \partial_3$, and ∂_4 are the long run coefficients, and ε_t is the stochastic component. The bounds cointegration test is performed to indicate whether there is a long run relationship among the variables. The null hypothesis which indicates no cointegration, is $H_0 : \partial_1 = \partial_2 = \partial_3 = \partial_4 = 0$ which is tested against the alternative hypothesis of $H_1 : \partial_1 \neq \partial_2 \neq \partial_3 \neq \partial_4 \neq 0$. The null hypothesis will be rejected if the estimated F statistic is greater than the upper limit critical value I(1) for the number of explanatory variables (k) proposed by Pesaran, Shin and Smith (2001). The null hypothesis cannot be rejected if the F statistic is less than the lower limit critical value I (0). The F statistic being between I (0) and I (1) indicates a lack of certainty regarding cointegration.

After estimating equation "5 and 6, the study performs a Wald test to identify short run ($\alpha_3^+/\alpha_1 = \alpha_4^-/\alpha_1$) and long run ($\partial_3^+/\partial_1 = \partial_4^-/\partial_1$) asymmetric effects of ED on GDP."

3.1.2 BREITUNG'S NONPARAMETRIC COINTEGRATION TEST

To check whether the relationship is robust to the method that was used, this study employed two cointegration methods which are the NARDL bounds test and Breitung's nonparametric cointegration test. Breitung's nonparametric cointegration test assumes that y_t, $t = 1, ..., n$, is a 2-dimensional unit root behaviour in the form of:

$$y_t = y_{t-1} + m + u_t \quad (7)$$

Where u_t "is assumed to be stationary with a constant mean 2-dimesional time series process, and m refer to a 2-dimensional vector of drift parameters. If = 0, then let z_t be the demeaned vector time series y_t. The partial sums of z_t can be computed as follows:"

$$z_t = z_1 z_2 + \cdots + z_t \quad (8)$$

The matrices A and B of the partial product can be defined as follows:

$$A = z_1 z_1' + z_2 z_2' + \cdots + z_n z_n' \quad (9)$$

$$B = z_1 z_1' + z_2 z_2' + \cdots + z_n z_n' \quad (10)$$

Let c_1 and c_2 "be the increasingly ordered generalised eigenvalues of A with respect to B. If y_t is cointegrated with cointegration rank r, then (n^2). $[c_1 + \cdots + c_{2-r}]$ converges in distribution to a function of a standard wiener process, which is free of nuisance parameters, whereas for $k > 2 - r$, (n^2). c_k converges to infinity. Therefore, the Breitung test is tested right sided, starting from the null hypothesis $r = 0$.

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The cointegration rank r corresponds to the first accepted null hypothesis. If none is accepted the cointegration rank r is $r = 0$, which implies that y_t is (trend) stationary."

3.2 DATA SOURCE

The study utilised yearly data from 1985-2021. The reason for starting from 1985 is that, that the study wants capture the debt crisis that hit South Africa in 1985. The data were collected from different sources. The availability of data determined the study period. The statistical software packages used are Stata 16, EViews 13, and EasyREG. Gross domestic product (GDP) as a measure of economic growth is measured as a percentage change at market price. External debt (ED) is proxied as a percentage of GDP and exchange rate (EXR) is measured in rand per US$. Table 1 shows description of the variables. The data for GDP and ED is collected from SARB, while EXR is collected from the World Bank.

Table 1

Description of the variables

Variables	Description of the variables	Source
GDP_t	Gross domestic product at market price	South African Reserve Bank
ED_t	External debt as % of GDP	South African Reserve Bank
EXR_t	Exchange rate in dollars	World Bank

Source: South African Reserve Bank; World Bank.

Table 2

Descriptive statistics

Variables	Mean ± Standard deviation	Jarque-Bera Statistic
GDP_t	1.989 ± 2,433	16.735***
ED_t	28.170 ± 9.394	5.637
EXR_t	-5.308 ± 12.812	24.773***

*Note: Statistically significant at *10%, **5%, ***1%.*

Source: Author's own computation.

Table 2 presents a descriptive statistic, where the second column shows standard deviation and mean, while the third column shows Jarque-Bera statistics for normality. The results show that the standard deviation for GDP is very low, providing evidence of low volatility of data around the estimated mean, while ED and EXR have relatively high standard deviations, which indicates a high variability of data around the mean. The Jarque and Bera (1980) test is employed to check the normality in the distribution of the residuals. In the null hypothesis of this test, the residuals are normally distributed. The results indicate that external debt is the only variable that does not accept the null hypothesis of normal distribution.

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3.3 NON-LINEARITY TEST

Since the focus of this paper is based on nonlinear modelling, it is necessary to test if the variables are nonlinear. The nonlinearity in the variables is tested using BDS test. The BDS test results are summarised in table 3. The null and alternative hypotheses for BDS test are linearity and nonlinearity, respectively. The null hypothesis of linearity is rejected in favour of nonlinearity as shown in table 3. The findings from BDS test give strong evidence that these variables are nonlinear.

Table 3

BDS test for nonlinearity

Variables	Dimensions	BDS statistics
ED	2	0.155***
	3	0.201***
	4	0.203***
	5	0.193***
	6	0.183***
GDP	2	0.021***
	3	0.015***
	4	0.012***
	5	0.011***
	6	0.009***
EXR	2	1.087
	3	0.025**
	4	0.036**
	5	0.055*
	6	0.410

*Note: Statistically significant at *10%, **5%, ***1%.*

Source: Author's own computation.

3.4 NON-STATIONARITY TESTS

The unit root in the variables is examined using the nonparametric unit root tests by Breitung (2002) and Bierens (1997). The study used another unit root test by Zivot and Andrews (2002) (ZA) to capture the effect of structural breaks since the country is more likely to take external debt during economic crisis, natural disasters, and policy regimes. The null hypothesis for ZA test is unit root, while the alternative gives no unit root with one break. These two nonparametric unit root tests can find unit roots while considering the fact that time series may not be linear. So, they make it less likely that unit root in a variable will be wrongly found because of these nonlinearities. The null hypothesis of nonparametric unit root tests is unit root versus the alternative hypothesis of stationarity with nonlinear trend. These tests are divided into two sections. The first section contains nonparametric unit root tests, and the second section contains unit root test with structural break.

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3.4.1 NONPARAMETRIC UNIT ROOT TESTS

The results from nonparametric unit root tests are presented in table 4. The results show that, except external debt (ED) other are integrated at order I(1) at 5% significance level under Bierens and Breitung tests. External debt (ED) has a unit root at I (0) and I (1) under Bierens and Breitung tests.

TABLE 4

Bierens and Breitung nonparametric unit root test

Variables	Level		First difference	
	Bierens	Breitung	Bierens	Breitung
ED	-9.462 (0.610)	0.017 (0.930)	-6.858 (0.860)	0.003 (0.200)
GDP	-28.872 (0.140)	0.008 (0.540)	-1,988.933** (0.020)	0.001** (0.000)
EXR	-43.247 (0.110)	0.002** (0.000)	-286.354** (0.040)	0.001** (0.000)

*Note: Statistically significant at *10%, **5%, ***1%. The probability values are in brackets.*

Source: Author's own computation.

3.4.2 UNIT ROOT TEST WITH STRUCTURAL BREAK

Table 5 demonstrates the results of ZA test for stationarity. The unit root test with structural break results by ZA are shown in table 5. The results reveal that stationarity is confirmed for all the variables at I(0) in the presence of one structural break. Since the stationarity is not confirmed at Level by Bierens and Breitung tests but only confirmed by ZA test, therefore, using the majority rule there is a need to estimate cointegration between the variables.

TABLE 5

Zivot-Andrews unit root test

Variables	Level		
	Intercept	Trend	Intercept and trend
ED	-4.893*** (2012)	-3.940** (2006)	-4.404*** (2003)
GDP	-5.070** (1994)	-5.236*** (2006)	-5.264** (2009)
EXR	-7.269*** (2003)	-4.918 (2005)	-7.144*** (2003)

*Note: Statistically significant at *10%, **5%, ***1%. The break years are in brackets.*

Source: Author's own computation.

4 EMPIRICAL RESULTS

4.1 COINTEGRATION TESTS

The long run association between the variables is performed in this section using two cointegration tests. The study uses the NARDL bounds cointegration test; however, to check the robustness of bounds test the study used the Breitung (2002) nonparametric cointegration test.

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4.1.1 NONLINEAR ARDL BOUNDS COINTEGRATION TEST

The results for the long run relationship between the variables using bounds test are shown in table 6. The F-statistics is greater upper bound I(1), which implies that the cointegration is confirmed between the variables. This means that, there is a long correlation amongst the variables.

Table 6

NARDL bounds cointegration test

F-statistics	Critical values					
	1%		5%		10%	
6.421***	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
	4.428	5.816	3.164	4.194	2.618	3.532

*Note: Statistically significant at *10%, **5%, ***1%.*

Source: Author's own computation.

4.1.2 BREITUNG'S NONPARAMETRIC COINTEGRATION TEST

To check the robustness of bounds test in detecting cointegration, the nonparametric cointegration test of Breitung (2002) is performed and presented in table 7. The results confirm the presence of cointegration at 10% significance level for the combination of GDP and ED, whereas it is confirmed at the 5% level of significance for the combination of GDP and EXR. Therefore, Breitung (2002) nonparametric cointegration test results are consistent with those of the nonlinear bounds cointegration test. This enables the estimation of NARDL long run parameters.

Table 7

Breitung's nonparametric cointegration test

Variables		H_0 *vs* H_1	Simulated T-statistics	Critical value (10%)	Critical value (5%)	Simulated prob-value	r
GDP	ED	r = 0 vs r > 0	701.40*	596.20	713.30	0.0352	1
		r = 1 vs r > 1	57.96	222.40	281.10	0.8430	
GDP	EXR	r = 0 vs r > 0	988.09**	596.20	713.30	0.0053	1
		r = 1 vs r > 1	131.92	222.40	281.10	0.2989	

*Note: Statistically significant at *10%, **5%, ***1%.*

Source: Author's own computation.

4.2 NARDL LONG RUN ESTIMATED PARAMETERS

The results for long run parameters are summarised in table 8. The Akaike information criterion is used to estimate the optimal number of lags, therefore, the NARDL (1, 0, 0) is selected with one lag in the dependent variable and zero lag in the independent variables. The results demonstrate that both positive and negative shocks of external debt are statistically significant at the 1% level of significance. The parameters for positive and negative shocks are -0.171 and -0.267, respectively. However, the sensitivity of GDP to the positive shocks is less than to negative shocks of external debt. Therefore, a 1% rise in foreign debt results in GDP decreasing by 0.171%. These findings match the results found by Ayadi and Ayadi (2008),

Shahnawaz et al. (2010), Ajayi and Oke (2012), and Asafo, Matuka and Dominic (2019). However, the studies that contradict these results are Matuka and Asafo (2018), Shkolnyk and Koilo (2018), and Govdeli (2019). Moreover, a 1% decline in foreign debt results in GDP rising by 0.267%.

The negative relationship between external debt and economic growth is confirmed. However, these results indicate that economic growth grows faster when the external debt is cut as compared to a situation where the external debt is increased. A decrease in external debt would lead to a low debt servicing cost, but when the country has the high rate of debt, a portion of the national income is used to service debt through its interest and principal repayment. Therefore, a decrease in debt can free up the resources that were supposed to be used for debt servicing, allowing them to be invested in other segments of the economy such as infrastructure, education, and health. The results further reveal that exchange rate is statistically insignificant to explain GDP with a positive coefficient.

4.3 NARDL SHORT RUN ESTIMATED PARAMETERS

The study also estimated the short run parameters after estimating long parameters. Table 9 shows the results for short run parameters. The reason for estimating short run parameters is that it helps to find out if were there any deviations from the long run equilibrium throughout the period of the study. This will assist us to check how fast or how slow it takes disequilibrium to be adjusted to long run equilibrium. The error correction term ECT (-1) indicates the pace of convergence of the dependent variable to the long run equilibrium. The results show that the coefficient for ECT(-1) is negative and significant. The ECT(-1) indicates a quicker convergence to the long run equilibrium. In one year, 83.8% of disequilibrium is corrected. In other words, it would take one year and some few months for South Africa's external debt to be adjusted to long run equilibrium.

4.4 SHORT RUN AND LONG RUN ASYMMETRY

The study also investigated whether there is a long run or short run asymmetry in the coefficients. Table 10 shows the results for asymmetry. The results only found coefficients' asymmetry in the long run not in the short run. The results show that null hypothesis of no asymmetry cannot be accepted at the 10% significance level. Finally, the study confirms that there is nonlinearity, therefore, the coefficients have different impacts on GDP.

4.5 RESIDUALS DIAGNOSTICS AND STABILITY DIAGNOSTICS

Diagnostic tests are undertaken to ensure that no diagnostic test is violated. The study used Glejser (1969) test for heteroscedasticity, Ramsey (1969) RESET test for model misspecification, and Breusch-Godfrey LM test for serial correlation. The results are presented in table 11. The results show that model passed all the diagnostic tests. The model stability is examined through CUSUM test. The graphs for CUSUM is shown in figure 2. Therefore, figure 2 confirms coefficient stability. This is because the CUSUM line fall between the critical bands at 5% significant level.

4.6 DYNAMIC MULTIPLIER

Figure 3 shows the dynamic multiplier for positive and negative shocks of external debt. In figure 3, the gray shaded rectangle indicates asymmetry at 95% confidence interval. The gray line shows a positive shock, meaning that, it provides an understanding about the response of GDP to positive shocks in the external debt. On the other hand, the yellow line shows a negative response, which indicates the response of GDP towards the negative shocks in the external debt. The figure demonstrates that both positive and negative shocks are stable in the long run. Furthermore, the results indicate that a decrease in external debt has a bigger impact on GDP than an increase.

Table 8

Long-run NARDL results

Dependent variable: GDP

Variables	Coefficient	Prob.
EXR	0.013	0.7455
ED_ POS	-0.171	0.0044***
ED_ NEG	-0.267	0.0080***
INTERCEPT	-3.020	0.1773

*Note: Statistically significant at *10%, **5%, ***1%.*

Source: Author's own computation.

Table 9

Short-run NARDL results

Dependent variable: ΔGDP

Variables	Coefficient	Prob.
GDP (-1)	-0.838	0.0000***
EXR	0.011	0.7403
ED_ POS	-0.143	0.0079***
ED_ NEG	-0.224	0.0117**
Intercept	-2.530	0.1800
ECT(-1)	-0.838	0.0000***
R^2	0.507	
Adjusted R^2	0.443	

*Note: Statistically significant at *10%, **5%, ***1%.*

Source: Author's own computation.

Table 10

Long run and short run asymmetry

Variable – External debt	F-statistics	Probability value
Long run $\left(\partial_3^+/\partial_1 = \partial_4^-/\partial_1\right)$	3.412	0.0743*

*Note: Statistically significant at *10%, **5%, ***1%.*

Source: Author's own computation.

TABLE 11

Diagnostic tests

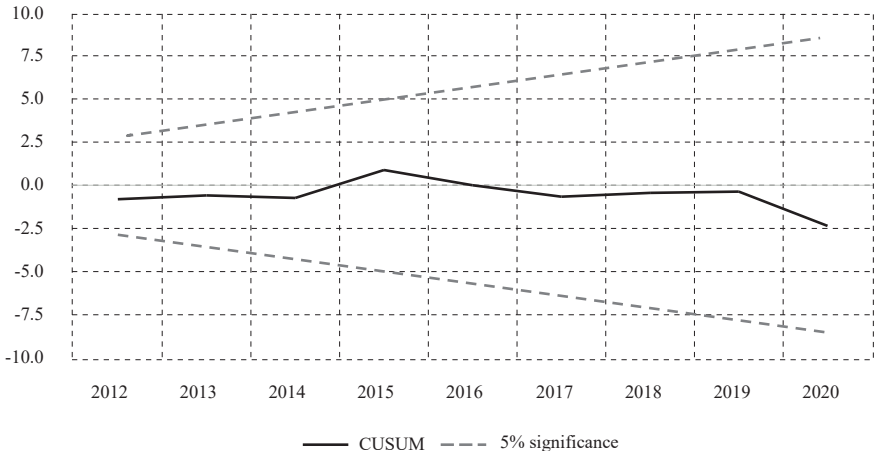
	Serial-correlation	Heteroscedasticity	RESET test
Statistical test	1.924	5.114	0.766
Probability value	0.382	0.276	0.399

*Note: Statistically significant at *10%, **5%, ***1%.*

Source: Author's own computation.

FIGURE 2

CUSUM graph

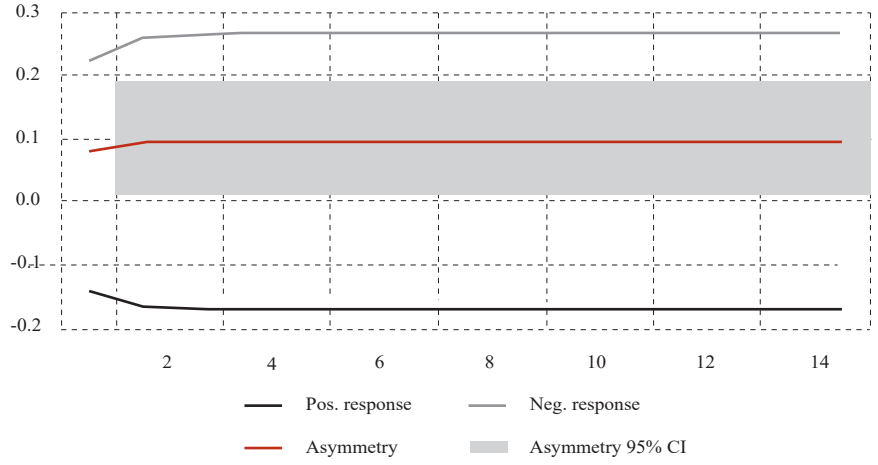


Source: Author's own computation.

FIGURE 3

Dynamic multiplier graph

EXTERNAL_DEBT on GDP shock evolution



Source: Author's own computation.

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5 CONCLUSION

The purpose of this study is to model a long run asymmetric impact of external debt on economic growth in South Africa. The study uses annual dataset for a period of 1985 to 2021. It also uses a nonlinear autoregressive distributed lag model for parameter estimation. The results show that negative shocks of external debt have a big impact as compared to positive shocks on economic growth. The results indicate that an increase in external debt leads to a decrease in economic growth, while a decrease in external debt increases economic growth. The results suggest that for South Africa's economic growth to improve the external debt must decrease. The results also suggest that South Africa should ensure that external debt is managed in a sustainable manner to prevent it from hampering economic growth and that the South African economy must achieve fiscal sustainability. The exchange rate is found to be statistically insignificant to explain economic growth.

This study strictly focused on the immediate impact of external debt on economic growth. However, external debt can also affect economic growth indirectly through its effects on public investment. The amount of public debt does not seem to affect public investment, but the amount of debt servicing does. If in a heavily indebted country a large amount of national income is used to service debt there is less money left for public investment. Therefore, this study recommends that future studies should focus on the indirect impact of external debt on economic through public investment.

Disclosure statement

The author has no conflict of interest to declare.

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