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CONTENTS

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Dependent Self-Employment in Slovakia – Opportunity or Necessity?

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Abstract

Recently, the European labour market has witnessed a shift in work structures, notably with self-employed individuals without employees. Many of these individuals are performing self-employment involuntarily, aiming for stable full-time employment. Due to insufficient income, instability, limited career prospects, and inadequate access to social protection, they are dissatisfied with their self-employed status. This dissatisfaction could potentially affect their overall job satisfaction and performance. The goal of this study, conducted on the basis of original primary survey among self-employed persons in Slovakia in 2022, is to explore the motivations influencing self-employment. Specifically, the research aims to examine the initial driving factors behind self-employment among 306 individuals, categorized into 194 traditional independent self-employed and 112 economically dependent self-employed persons. Results indicate that among economically dependent self-employed persons, necessity-driven motives prevail, particularly necessity to enter family business, job loss, and employer-induced self-employment. For traditional independent self-employed persons, opportunity-driven motives predominate, notably pursuit of better working conditions, desire for independence, and efforts to earn more.

Keywords	***DOI***	***JEL code***
Self-employment, traditional independent self-employed persons, economically dependent self-employed persons, business motivation, opportunity-driven self-employment, necessity-driven self-employment	*https://doi.org/10.54694/stat.2023.45*	*C25, C38, D91, L26*

INTRODUCTION

Since the 1970s, there has been a noticeable increase in the number of businesses owned individually, largely attributed to advancements in technology and the impact of globalization. This transition has underscored the rising significance of knowledge as a crucial factor in production, surpassing

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the importance traditionally given to capital. This shift has notably created new opportunities for small and micro enterprises. Alongside this increase in individually owned business across various countries, there has been a significantly growing trend towards self-employment.

Scholars and researchers highlight the crucial role of self-employment and entrepreneurship in driving economic development across nations, regions, and labor markets. Various initiatives like the Observatory of European Small and Medium Enterprises, the European Council for Small Business, and Eurobarometer underline policymakers' recognition of self-employed persons' significance in communities, emphasizing support frameworks for existing and prospective entrepreneurs.

A broad distinction often drawn in self-employment is between ventures born out of necessity and those arising from opportunity. Opportunity-driven self-employment typically begins after recognizing a viable business opportunity, while necessity-driven self-employment stems from the lack of viable alternative employment. While necessity-driven self-employed persons yield considerably lower turnovers compared to their opportunity-driven counterparts, their annual revenue, on average, is adequate for sustaining livelihoods (Van Stel and De Vries, 2015).

The objective of this study is to investigate the motivations behind entrepreneurial decisions among self-employed individuals in Slovakia, differentiating between traditional independent self-employed persons and economically dependent self-employed persons. The research aims to discern the primary drivers behind these distinct forms of self-employment, identifying whether necessity-driven or opportunity-driven motives prevail. Additionally, it seeks to analyse the correlation between these motives and the type of self-employment pursued, evaluating the impact on job satisfaction, particularly focusing on the lower job satisfaction observed among economically dependent self-employed individuals motivated by necessity. The study also intends to assess the repercussions of these motivations on job satisfaction, essentially aiming to fill the gap in understanding how these motives affect overall satisfaction levels. The study is divided into five parts, namely literature review, methodological part, results, discussion, and conclusion.

1 LITERATURE SURVEY

From the perspective of self-employment as an opportunity space, researchers emphasize its positive attributes, including autonomy in decision-making, freedom to choose tasks, flexibility in scheduling, and skill development (Verheul et al., 2002; Prottas and Thompson, 2006; Meager, 2015). There exist various narrower definitions based on specific criteria. For instance, De Vries et al. (2013) define self-employed as persons that offer only their labor (knowledge and skills) rather than goods. Another criterion, proposed by Rapelli (2012: 11), confines self-employed persons to service or intellectual activities, excluding farming, craft, or retail sectors, categorizing this group as 'I-pros' (independent professionals).

However, despite numerous studies exploring the positive outcomes for waged employees, there remains limited understanding regarding the subjective well-being (SWB) of self-employed individuals (Dolinsky and Caputo, 2003; Sevä et al., 2016 a, b). Findings from Blanchflower (2004), Benz and Frey (2008), Sevä et al. (2016 a, b), and Andersson (2008) have established a definite correlation between self-employment and SWB.

While the literature acknowledges that self-employment positively influences job satisfaction, its effects on other life domains and overall life satisfaction remain less clarified. Researchers have focused on overall life satisfaction and various domain satisfactions among self-employed individuals. Binder and Coad (2016) discovered that voluntary ('opportunity' or pull) self-employment yielded positive benefits beyond work satisfaction, leading to higher overall life satisfaction and increased health satisfaction in the initial three years of self-employment. However, individuals forced into self-employment ('necessity' or push) due to unemployment experience no such advantages. Moreover, both types of self-employments tend to result in growing dissatisfaction with leisure time. Although high work satisfaction among

the self-employed is often interpreted as greater happiness, the evidence supporting the relationship between self-employment and happiness is notably mixed and weaker than that for work satisfaction alone.

Self-employed persons constitute a highly heterogeneous labor force with varying productivity levels. Highly skilled freelancers on one end of the spectrum provide professional services, fostering innovation, flexibility, and resilience for businesses (Burke, 2012). Conversely, less productive economically dependent self-employed individuals, lacking alternative employment options, exhibit weak entrepreneurial potential (Van Stel and De Vries, 2015). Specific subset of self-employed persons are solopreneurs, it means self-employed without employees (Pilková, 2019; Stam and Van de Vrande, 2017; Waas, 2017). Literature also refers them as freelancers (Huđek, Tominc and Širec, 2020; Hussenot and Sergi, 2018), home-based business owners (Stam and Van de Vrande, 2017; Reuschke, Clifton and Fisher, 2021), or own-account self-employed persons (Petrescu, 2016; Van Stel and De Vries, 2015). According to the Global Entrepreneurship Monitor (Bosma and Kelley, 2018), a solopreneur operates independently without co-founders or employees and does not seek to employ others. This definition aligns closely with the widely accepted notion of solopreneurship, particularly as emphasized by the European Union's distinction (European Commission, 2005), where the key differentiator for solopreneurs from other Small and Medium-sized Enterprises (SMEs) lies in their lack of responsibility for additional employees.

The decision to embark on self-employment is undoubtedly a complex one that not only impacts the aspiring self-employed persons but also significantly affects close family members, their way of life, and financial security. Simoes and Crespo (2016) comprehensively reviewed studies exploring motivational factors driving individuals toward self-employment. They summarized 12 critical entry factors into self-employment, categorizing them into seven groups: 1. individuals' background characteristics (age, gender, marital status, and children); 2. family background (parents, partners); 3. personal characteristics (mainly psychological attributes like self-esteem, optimism, risk attitude, and emotional stability); 4. human capital (education, experience); 5. health status; 6. nationality and ethnicity; 7. access to finance. The authors note that while certain factors yield clear conclusions regarding their significance based on prior research, most require further study to establish their importance definitively.

In entrepreneurial theory, a pivotal aspect is the motivation propelling business initiation, which significantly influences the quality of self-employment activities. Previous research scrutinized whether the motive driving self-employment is opportunity-based or out of necessity. Paul Reynolds, credited as the father of the Global Entrepreneurship Monitor, highlighted these two fundamental motive types in a 2001 report (Van Stel et al., 2003). Nevertheless, as highlighted by De Vries et al. (2013), the research literature still lacks comprehensive coverage of the diverse range of motives inspiring individuals to become self-employed. Addressing this shortfall, their study examines 3 hypotheses: 1. whether self-employed persons driven by necessity as their initial motive exhibit less resilience than those propelled by opportunity; 2. what is the impact of formal education on the performance of self-employed persons categorized by motive (opportunity-driven and necessity-driven); 3. what is the impact of on-the-job training on the performance of self-employment, segmented by motive (necessity and opportunity).

While their research partially confirms Hypothesis 1, indicating differences between the two groups of self-employed persons, they conclude that these distinctions aren't substantial enough for policymakers to influence the trend of self-employment activities. Similarly, the discernible impact of human capital remains inconclusive, necessitating further investigation. Recommendations include exploring the innovativeness and growth aspirations of self-employment. However, these suggestions bear limitations, especially considering that more innovative and growth-oriented self-employed persons may tend to recruit partners, thereby transitioning away from the category of solopreneurs.

To explore the self-employment as an opportunity, the Self-Determination Theory (SDT) offers a framework for studying human motivation and personality, analysing their roles in cognitive and social development. It concentrates on social and contextual factors influencing individuals' well-being,

performance, and overall initiative. The theory posits three universal factors affecting individual motivation, performance, and well-being: autonomy, competence, and relatedness (Deci and Ryan, 1985, 2000; Deci and Ryan, 2000). Autonomy pertains to self-regulated actions, independence, and self-organization. Competence involves deriving satisfaction and outcomes from activities, evolving, and obtaining desired benefits. Relatedness directs on the need for interpersonal connections, mutual interaction, sharing, altruism, and social well-being.

Research underscores differences between own-account self-employed persons (Petrescu, 2016; Van Stel and De Vries, 2015) and those with additional employees concerning their subjective well-being (SWB), job satisfaction, and work-family conflict (Binder and Coad, 2013; Bunk et al., 2012; Sevä et al., 2016 b; Stephan and Roesler, 2010). Mixed research results exist regarding the relationship between self-employment and happiness or life satisfaction. Some studies show significant effects for specific groups, highlighting the heterogeneity within this category (Binder and Coad, 2013). Certain studies suggest that self-employed individuals with employees report higher life satisfaction compared to regular employees, while those without employees show less satisfaction and enthusiasm for business development and growth (Sevä et al., 2016 b). Additionally, Petrescu (2016) revealed that self-employed persons with employees reported higher happiness levels than those who work alone. These variations could be due to waged employees not experiencing the same degree of freedom and autonomy as self-employed individuals with employees, which significantly influences overall job satisfaction (Lange, 2012).

Overall, it appears that self-employment enhances the well-being of individuals only when chosen voluntarily, fulfilling thus their need for autonomy (Deci and Ryan, 2000). However, when unemployed individuals are forced into self-employment by necessity, the anticipated benefits may not materialize. While self-employment can serve as an escape from unemployment, policymakers should recognize that those pushed into it may not reach independency and the same benefits as a comparison group of regular employees.

The trend of self-employment is expected to expand due to emerging gig economy models, the sharing economy, and project-based labor approaches. In the European Union, statistics from 2016 indicated that 40% of self-employed individuals without employees held managerial, professional, or technical roles (Eurostat, 2017). While entrepreneurial activities within independent self-employment (possibly also with employees) remain relatively stable, the rising percentage of dependent self-employment is driving the upward dynamics (Pilková et al., 2019: 32).

A subset of necessity-based (push) self-employed persons comprises dependent self-employed workers, who execute the same tasks for their client firms as they did previously when employed (Dvouletý and Nikulin, 2023). Their job responsibilities remain largely unchanged, yet their employment protection is lower than when they were employees. Additionally, client firms (former employers) benefit by not having to contribute to their social security obligations (Román et al., 2011), and by avoiding complicated process of employment contract termination (Brodie, 2005; Román et al., 2011).

According to the Global Entrepreneurship Monitor findings in 2018 (Bosma and Kelley, 2018), dependent self-employment among Slovaks typically exhibits the following characteristics:

- Entrepreneurs predominantly enter self-employment due to necessity, reflected in a notably low motivation index. This type of entrepreneurship appeals more to older age groups, particularly those aged 45 and above, as well as seniors aged 55 and older;
- It is a more favourable choice for women compared to men;
- Regarding education, dependent self-employment tends to be favoured by individuals with secondary and post-secondary education;
- Their perception of entrepreneurs and their social attitudes towards entrepreneurial status are more positive. However, they display lower confidence levels and exhibit more fear of failure;
- Aspirations for innovation and international orientation among Slovak dependent self-employed persons are lower compared to early-stage entrepreneurs.

2 DEPENDENT SELF-EMPLOYMENT IN SLOVAKIA

Existing analyses and findings (Analýza vybraných aspektov podnikania, 2020) indicate that official data on the number of self-employed individuals fail to acknowledge the phenomenon of dependent self-employment, which is quite frequent in Slovakia. This involves individuals formally appearing as solopreneurs (usually traders) but, in reality, performing tasks that meet the criteria of dependent employment defined in Act No 311/2001 Coll. the Labour Code (i.e., an employer-employee relationship characterized by employer superiority, employee subordination, work conducted as per employer directives, on behalf of the employer, and within employer-determined working hours).

This concept, known as bogus/false self-employment (Thörnquist, 2015; Heyes and Hastings, 2017) or the the 'švarcsystem,' is named after Czech entrepreneur Miroslav Švarc, who was among the first to significantly utilize the services of self-employed individuals instead of hiring employees (Myant, 2013; Schneider and Kearney, 2013). Although subsequently prohibited, the term is still used today to describe the type of dependent work performed by formally independent self-employed persons.

Despite displaying characteristics of dependent employment, the work conducted under this system lacks an employment relationship based on an employment contract between the contracting party and the performing party. Instead, it constitutes a commercial-legal association designed to optimize tax treatment for both involved parties. The 'švarcsystem' prevails notably in the construction industry (Kösters and Smits, 2021; Nikulin, 2021) but is also observable in other sectors (Kirk, 2020; Turnbull, 2020; Gruber-Risak, 2021).

The only official source of data on the size and structure of the labour force is the Labour Force Survey, which is the largest household survey in Europe. It provides quarterly and annual information on persons aged 15 and over. The content of its ad-hoc module for 2017 was to obtain key insights on the self-employed and those with ambiguous occupational status, in addition to knowledge of background variables. One of its the main purposes was to estimate the number of dependent self-employed.

According to the operational definition adopted by Eurostat, economically dependent self-employed defined as self-employed without employees who worked during the last 12 months before the reference week of the survey for only one client or for a dominant client and this client decides about his/her working hours. In terms of the LFS ad-hoc variables, economically dependent self-employed persons are those who are self-employed without employees with only one or one dominant client who decides his/hers working hours (Eurostat, 2018: 97).

The results of the ad-hoc survey indicate that only a small percentage of the self-employed are classified in the category of dependent self-employed (as defined above). At EU level, the dependent self-employed amount to 3.5% of the self-employed and 0.5% of the total employment. The share of dependent self-employed exceeds 1% of the total employment only in two countries (Slovakia and the United Kingdom – see last column of Table 1). This very low share creates problems concerning the analysis of the results (it is worth noting that the estimated number of dependent self-employed is below the publication threshold in 7 countries) (Eurostat, 2018).

The results of the 2017 ad-hoc module show that Slovakia has the highest share of economically dependent self-employed persons among the EU28 countries (9.9%), followed by Cyprus (7.5%) and the United Kingdom (6.8%). The above-mentioned results are documented in the penultimate column of Table 1.

At the EU level, the percentage of self-employed with one (or one dominant) client is about 17% of the total self-employed and ranges from 8% in Croatia to 33% in Slovakia. The main reason for the low percentage of dependent self-employed is the fact that the number of self-employed who reports that their clients decide their working time is small (Eurostat, 2018).

Table 1 Employed persons by professional status (in thousand persons)

Working status	Employed persons	Employees	Self-employed persons	Self-employed persons with employees (employers)	Self-employed persons without employees (own-account workers)	Independent self-employed without employees (own-account workers)	Dependent self-employed without employees (own-account workers)	Self-employed without employees (own-account workers), dependency not known	Contributing family workers	No response	% of dependent self-employed over self-employed	% of dependent self-employed over employed
EU-28 countries (2013–2020)	227 457.1	192 131.2	32 837.2	9 286.8	23 550.4	21 939.3	1 124.8	486.4	2 436.3	52.4	3.43	0.49
Belgium	4 627.5	3 963.5	630.4	195.5	434.9	425.0	9.4	:	33.6	:	1.49	0.20
Bulgaria	3 147.2	2 773.6	352.1	113.7	238.4	229.8	:	:	21.5	:		
Czechia	5 207.3	4 330.2	855.5	159.6	695.9	638.1	50.2	7.7	21.3	:	5.87	0.96
Denmark	2 790.8	2 558.2	223.3	97.3	125.9	116.9	9.1	:	9.3	:	4.08	0.33
Germany	41 481.8	37 213.8	4 155.6	1 836.2	2 319.4	2 132.0	83.4	104.0	112.4	:	2.01	0.20
Estonia	651.9	586.2	64.3	30.1	34.2	33.0	:	:	:	:		
Ireland	2 171.1	1 839.7	319.0	97.2	221.8	178.1	7.0	36.7	12.3	:	2.19	0.32
Greece	3 786.3	2 504.0	1 130.8	271.8	859.0	834.9	4.9	19.2	151.4	:	0.43	0.13
Spain	18 816.9	15 682.1	3 037.7	1 027.8	2 009.9	1 949.4	39.6	20.9	90.2	6.9	1.30	0.21
France	26 823.3	23 727.0	3 002.5	1 114.6	1 887.9	1 804.5	50.5	:	93.8	:	1.68	0.19
Croatia	1 631.3	1 428.1	184.4	89.9	94.6	93.9	:	:	18.7	:		
Italy	23 017.8	17 720.9	4 992.4	1 380.3	3 612.1	3 371.4	218.3	22.5	304.4	:	4.37	0.95
Cyprus	379.3	332.1	44.1	7.8	36.3	33.0	3.3	:	3.0	:	7.48	0.87
Latvia	891.7	782.3	100.0	38.9	61.1	58.6	:	:	9.3	:		
Lithuania	1 355.5	1 189.1	154.8	34.5	120.4	118.8	:	:	11.6	:		
Luxembourg	271.2	244.1	23.9	9.5	14.4	10.1	:	3.6	2.3	:		
Hungary	4 419.6	3 970.5	437.7	208.4	229.3	214.8	8.7	5.8	11.4	:	1.99	0.20
Malta	220.6	187.0	33.4	10.8	22.7	22.0	:	:	:	:		
Netherlands	8 579.4	7 228.2	1 327.2	323.0	1 004.2	917.9	71.4	14.9	24.0	:	5.38	0.83
Austria	4 247.6	3 730.5	461.8	197.3	264.5	253.1	11.4	:	55.4	:	2.47	0.27
Poland	16 460.0	13 151.7	2 864.5	617.6	2 246.9	2 162.1	73.2	11.6	443.7	:	2.56	0.44
Portugal	4 693.1	3 927.6	743.7	218.2	525.5	378.3	10.5	136.7	21.8	:	1.41	0.22
Romania	8 967.1	6 381.7	1 744.7	92.0	1 652.8	1 574.9	76.0	:	840.6	:	4.36	0.85
Slovenia	952.7	813.1	112.7	37.3	75.4	70.3	5.1	:	26.9	:	4.53	0.54
Slovakia	2 526.2	2 141.8	382.7	81.5	301.1	259.0	37.9	:	:	:	9.90	1.50
Finland	2 473.2	2 151.4	310.7	93.3	217.3	173.5	6.5	37.3	11.1	:	2.09	0.26
Sweden	5 021.8	4 590.7	421.7	155.8	265.9	248.3	17.6	:	9.4	:	4.17	0.35
Iceland	195.6	173.5	21.6	7.0	14.5	13.0	1.3	:	:	:	6.02	0.66
Norway	2 651.4	2 474.9	174.4	47.7	126.7	110.4	6.8	9.5	:	:	3.90	0.26
Switzerland	4 605.0	3 919.9	596.1	287.7	308.5	303.5	3.4	:	88.9	:	0.57	0.07
United Kingdom	31 845.3	26 982.1	4 725.4	746.8	3 978.7	3 637.7	319.2	21.8	93.4	44.3	6.75	1.00
Turkey	28 377.2	19 099.4	6 019.1	1 313.4	4 705.7	4 626.7	78.9	:	3 258.7	:	1.31	0.28

Source: Eurostat, Labour Force Survey (2017)

The Slovak Business Agency also publishes the LFS data in its study (Analýza vybraných aspektov podnikania SZČO, 2020), which states that in Slovakia there were almost 240 000 sole traders without employees in the 1st quarter of 2019, and in the period from 2010 to 2019, the share of those whose work showed signs of dependent activity was between 40 and 48%. However, the methodology for identifying this share is absent in the paper and in the corresponding materials.

The notably high proportion of dependent self-employed in Slovakia raises concerns, prompting the necessity to address this situation, particularly concerning their specific status within the labour market. This encompasses aspects such as individual well-being and the requirement for equitable legal protections tailored to their circumstances.

3 METHODS

Although the LFS in Slovakia is an unambiguous source of data on the number of employed people, there is currently no official methodology for identifying dependent self-employed from observed data, which would allow estimation of their numerical status and multidimensional structure.

The "gap" in this information segment is attempted to be substituted by empirical research that theoretically builds on the Global Entrepreneurship Monitor (Bosma and Kelley, 2018) that placed special emphasis on solopreneurship in 2018. The empirical online survey aimed to explore the status, challenges, advantages, and disadvantages associated with sole proprietorship marked a unique pilot study observing the Slovak entrepreneurial landscape with a specific. Additionally, it served as a cognitive testing phase, validating the clarity and comprehensibility of various question types.

For our survey, we adopted a modified and rigorously validated international methodology utilized in the GEM research project. Given the constrained resources of our project – limited personnel, time, and financial capacity – we concentrated on specific determinants of self-employment potential within the aforementioned methodological framework:

1. Social perspectives on self-employment:
   - Consideration of self-employment as an advantageous career choice,
   - Evaluation of the social status of self-employed persons in Slovakia,
   - Assessment of the ease associated with commencing a business.
2. Self-assessment of knowledge, skills, and self-employment abilities:
   - Self-appraisal and confidence in self-employment traits,
   - Apprehension regarding potential failures.
3. Motivations behind initiating a self-employment:
   - Pursuit of opportunities for increased independence or income,
   - Compelled by necessity, offering an alternative to unemployment.

Questionnaire survey was conducted in December 2022. The introductory part of the questionnaire outlined the topic and purpose of the survey and assured the respondents of anonymity. The questionnaire comprised six sections including various aspects: basic information about respondents, details regarding trade business, business relationships, reasons for initiating the business, current perceptions of the trade business, and finally, two open-ended questions, summing up to a total of 29 questions. Most questions were close-ended, offering single-choice responses, with three allowing multiple-choice selections. For scaling queries, a 5-point Likert scale was employed.

Within the scope of factors influencing self-employment potential, we focused on motivational aspects. Our inquiry aimed to validate the premise of two fundamental groups, categorised as follows: 1. motivation driven by opportunity (seeking improved working conditions, aspiring for independence/being one's own boss, and the ambition to enhance earnings – motives 1–6 in Table 2), and 2. motivation arising from necessity (such as strengthening family business, job loss, challenges in securing employment, and forced commencement of a trade at the employer's request –

motives 7–10 in Table 2). Degree of agreement with the choice of motive for starting a business was expressed on a scale of 1 (complete disagreement) to 5 (full agreement). Simultaneously, we assessed these motivational factors with regard to self-employed persons' gender and the duration of their business.

Table 2 Motives for starting self-employment

	Motive
1	Family reasons – I wanted to work from home
2	I wanted to be independent "my own boss"
3	I wanted better working conditions
4	I wanted to earn more money
5	There was an opportunity to get resources to start a business
6	I saw an opportunity to sell my products/services
7	I had trouble finding a job
8	I became redundant in the company where I worked (lost my job)
9	I joined a family business
10	My employer wanted me to have a trade

Source: Own questionnaire survey

The research population consisted of sole traders without employees doing business in Slovakia, the size and structure of which is the subject of the LFS (Štatistický úrad SR, 2023). The sample was composed of persons willing to fill out the questionnaire, using the pre-trained interviewers. No specific criteria for choosing the participants (except of being self-employed trader without employees) was used. These interviewers addressed the respondents, explained the purpose of the survey, and explained how to complete the questions. They then provided respondents with a link, which respondents used to complete the online questionnaire. We did not pre-determine the sample size, leaving it up to the willingness of potential respondents to complete the questionnaire, with a final sample size of 306 respondents. For this reason, it was not possible to determine non-response.

We wanted to include not only traditional self-employed people in the survey, but also a specific group known as dependent self-employed persons. Since, as already mentioned, there is no official methodology in characterizing this labour market segment, the survey considered them as individuals who operate independently without co-founders or employees (based on Code of Practice on Determining Employment Status, 2021; Economically dependent self-employed workers, 2014; Decent Work Agenda in Portugal, 2023). Furthermore, it acknowledged that self-employment represented the primary income source for such individuals (Code of Practice on Determining Employment Status, 2021; Status of self-employed persons, 2007), with their activities predominantly directed towards one business partner (Competition Act, Ireland; Status of self-employed persons, Spain), generating at least 75% of their income from activity for one partner (Status of self-employed persons, 2007; www.scheinselbststaendigkeitstest.de; Fornero Law No 92/2012, Italy).

Descriptive statistics and multiple response analysis techniques were used to evaluate respondents' responses to each question. Frequency tables and visualization techniques were used to describe and visualize the distribution of variables, factor analysis served to reduce the range of variables, and binary logistic regression modelled the classification of traders into classic and dependent groups, and a significance level of 0.05 was used for inductive procedures.

This paper unveils distinctive findings, particularly concerning the third monitored component – motivation to commence a business.

4 RESULTS

Since the conducted research is a pilot probe into the pre-problematics of dependent self-employment in Slovakia, the ambition of the authors was to obtain unique information about dependent self-employed persons regardless of achieving the representativeness of the sample in terms of all key features.

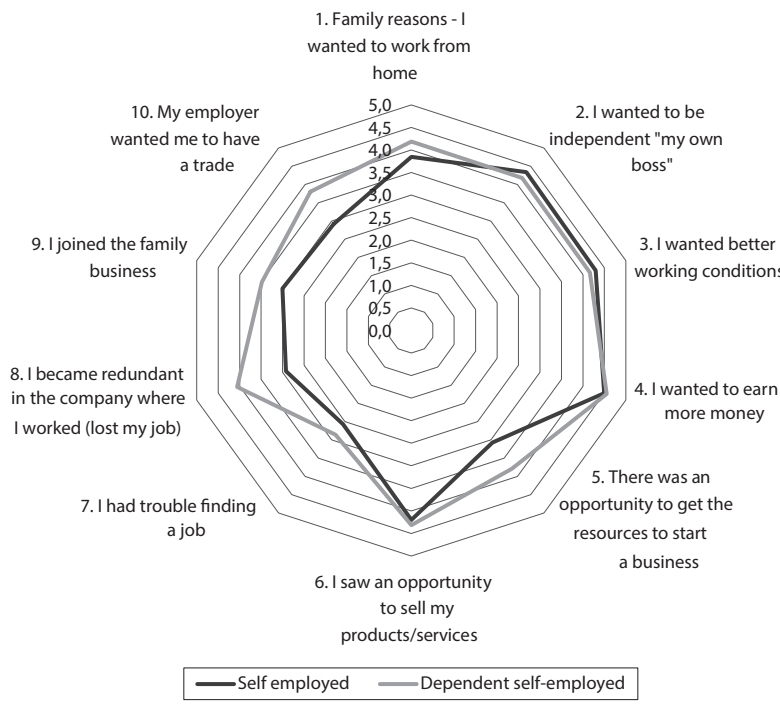
The examined respondent sample consisted of 306 self-employed persons, comprising 194 classical traders (63.4%) and 112 dependent self-employed persons (36.6.%). We verified the quality of the sample using data on the Statistical Office (Štatistický úrad SR, 2023). Sample was representative by the gender (p-value = 0.11), the age category and education variables didn´t follow the same distribution as the whole population of self-employed persons in Slovakia (both p-values < 0.001).

The sample of respondents included 166 younger respondents (under 40 years of age), of which 55.4% were classical traders and 44.6% were dependent self-employed persons. In the subsample of older respondents (above 40 years), the representation was strongly in favor of classical traders (72.9%), the proportion of dependent self-employed persons was 27.1%.

Within the domain of motivations driving business commencement, respondents were presented with a selection of 10 reasons that influenced their decision to initiate a business (Table 2).

We categorized the provided motives into two distinct groups. Motives 1 to 6 were categorized as 'opportunity motives,' signifying the perspectives and opportunities that attract individuals to embark on self-employment. On the other hand, motives 7 to 10 were classified as 'necessity motives,' reflecting the impetus to start a business due to external pressures or internal compulsions. Evaluation of the motives by respondents in the structure by the self-employment type can be seen in the Figure 1.

Figure 1 Degree of agreement with the choice of motive for starting a business by type of self employment



Source: Own elaboration

We used the factor analysis to reduce the number of self-employment motives and to generate a set of motives as new factors. The outcomes of the factor analysis conducted on all participating self-employed persons are presented in Table 3 (Varimax method, KMO = 0.734). Out of the ten themes presented, only seven proved to have statistical significance in forming the components. This method naturally categorized the offered self-employment motives into the anticipated groups – Component 1 being necessity and Component 2 being opportunity.

Within the necessity factors, the primary motivation was to join (support) a family business, followed by motives 9, 8, and 10. Concerning the opportunity factors, the strongest was motive 3 – the aspiration for improved working conditions – along with motives 2 and 4. Three opportunity motives (1, 5, and 6) were deemed insignificant and thus excluded from the components. The factor scores derived from both components were utilized in the subsequent phase of the analysis.

Table 3 Motives and their assignment to components (the result of using factor analysis)

Motive number	Motive	Component	
		1	2
9	I joined a family business	.859	–.005
8	I became redundant in the company where I worked (lost my job)	.854	.033
10	My employer wanted me to have a trade	.777	.074
7	I had trouble finding a job	.739	.033
3	I wanted better working conditions	.092	.849
2	I wanted to be independent "my own boss"	.034	.822
4	I wanted to earn more money	–.016	.810

Notes: Extraction method: Principal Component Analysis. Rotation method: Varimax with Kaiser Normalization.
Source: Own elaboration

We utilized the logistic regression method to construct a model predicting the likelihood of an individual being either a traditional delf-employed persons or a dependent self-employed one. Assuming a representative sample, we could interpret the results as follows.

Analysing the outcomes of logistic regression method (as illustrated in Table 4), the opportunity factor emerged as statistically insignificant (p-value = 0.941), showing no significant correlation with the trade type (traditional or dependent self-employment). This was further supported by correlation analysis, which revealed Spearman's rho = –0.066 and a p-value of 0.288. Motives associated with the opportunity factor seem to exert an equally negligible influence on both traditional self-employed persons and dependent self-employed, failing to distinctly delineate the self-employment types. For modelling purposes, the dependent variable was defined as follows: 0 – 'traditional' self-employed persons, 1 – dependent self-employed persons. Statistically insignificant sociodemographic variables such as age (8 age categories from 1 – less than 20 years to 8 – 65+), education (7 educational categories from 1 – no education to 7 – 3rd level university education), maritual status (4 categories: 1 – married, 2 – single, 3 – divorced, 4 – widowed), and region (8 regions in Slovakia) were excluded from the model (all p-values > 0,05), only the variables gender (0 – male, 1 – female) and length of trade (how many years they have been running the trade) were included in the model. We also incorporated the opportunity and necessity factors into the model.

Table 4 Binary logistic regression model (with the necessity and opportunity factors)

Variables in the equation

	B	S.E.	Wald	df	Sig.	Exp(B)
Gender	–.902	.316	8.139	1	.004	.406
Length of trade	–.057	.018	9.533	1	.002	.945
Necessity motive	.270	.136	3.962	1	.047	1.310
Opportunity motive	–.010	.138	.006	1	.941	.990
Constant	.119	.216	.303	1	.582	1.126

Source: Own elaboration

Next model includes only the necessity factor (correlated with type of trade, Spearman's rho = 0.113, p-value = 0.068) and other statistically significant variables.

Table 5 Binary logistic regression model (included only statistically significant variables)

Variables in the equation

	B	S.E.	Wald	df	Sig.	Exp(B)
Gender	–.904	.315	8.249	1	.004	.405
Length of trade	–.057	.018	9.624	1	.002	.945
Necessity motive	.270	.136	3.965	1	.046	1.310
Constant	.121	.215	.315	1	.575	1.128

Source: Own elaboration

Based on the 2022 questionnaire survey data among self-employed persons in Slovakia, our classification of self-employment motives and the model predicting self-employed person's likelihood of belonging to the dependent self-employed group suggest that individuals in this category are more likely to be male, operating as sole traders for a relatively shorter duration, and driven more strongly by necessity motives for self-employment.

However, the model's accuracy is relatively low (Nagelkerke R square = 0.117), correctly classifying 68.1% of respondents, with 90.7% identified as traditional self-employed persons and only 27% as dependent self-employed persons. Factors beyond those incorporated in the model (or questionnaire) are likely to significantly impact the classification of an individual as a dependent self-employed person.

A more in-depth analysis of self-employment motives and perceptions concerning the benefits of self-employment versus employment reveals that when the solopreneur group is more influenced by necessity motives (dependent self-employment), they exhibit lower job satisfaction (indicating lesser satisfaction with their job as a benefit of solopreneurs; Spearman's rho $r_s = –0.242$, p-value = 0.019). Conversely, they perceive higher work efficiency and performance as advantages of solopreneurs ($r_s = 0.23$, p-value = 0.022). In the cohort of traditional self-employed persons, a statistically significant positive correlation is evident between the pursuit of opportunity motives and perceiving higher income as self-employment advantage ($r_s = 0.157$, p-value = 0.043). In other words, a stronger inclination towards opportunity motives results in self-employed persons perceiving higher income as a benefit of solopreneurs.

Regarding future self-employment preferences, there is a positive association with the influence of opportunity motives – self-employed persons with a prevalence of these motives tend to lean towards remaining self-employed rather than seeking employment in the future ($r_s = -0.145$, p-value = 0.064).

5 DISCUSSION

Various international and domestic studies (Rapelli, 2012; Binder and Coad, 2016; Deci and Ryan 2000; Burke 2012; Pilková et. al., 2019; Analýza vybraných aspektov podnikania SZČO) including GEM reports for 2018 and 2019 indicate that dependent self-employed persons primarily venture into self-employment due to the lack of alternative job opportunities, essentially driven by necessity.

In our research, we were concerned with identifying factors that might influence the decision to enter into self-employment that exhibits characteristics similar to dependent self-employment. Interestingly, our survey indicated that the issue of job availability held the least significance in the decision to become a dependent self-employed person. This finding is in contrary to the research study in Romania (Grigorescu, Pîrciog and Lincaru, 2020), or in the United Kingdom (Danson, Galloway and Sherif, 2021). On the other side, the research focusing on the OECD countries pointed that levels of unemployment were unrelated to the future levels of self-employment (Örtqvist and Ejdemo, 2021). However, it is noteworthy that entering the family business, recognized as the primary motivating factor, serves as a solution to the dearth of alternative job opportunities. This action might be interpreted as an attempt to avoid unemployment status or to counteract the lack of other occupational prospects in the labor market. This is also in line with the research findings of Gimenez-Nadal and co-authors (2018), who pointed out that self-employment represented a possible way for parents (mostly mothers) to have more control over the allocation and use of time (especially flexible working hours). Also, joining a family business may be an involuntary step (the so-called necessary evil for the purpose of preserving good family relations or for the purpose of preserving the business during generational turnover) (Vera and Dean, 2005; Ashourizadeh et al., 2021). On the other hand, such a decision can also be seen as taking advantage of the opportunity offered by the family, especially in a situation where the family business is prospering.

Other motives examined within the necessity-driven self-employment encompassed job loss and the push to establishment of trade by employers (so called 'švarcsystem' (Myant, 2013; Schneider and Kearney, 2013)). Our findings suggest that all scrutinized necessity-driven determinants are perceived and ranked as more potent catalysts for startup initiatives by dependent self-employed persons compared to their traditional counterparts.

The factor of opportunity as a motivational driver for self-employment appears stronger than circumstances compelling self-employment as a necessary career choice. However, the results from our survey suggest that the opportunity factor to initiate a self-employment is not statistically significant in the model, failing to classify individuals as classic or dependent self-employed. Variables associated with this factor equally affect both self-employment types. Nevertheless, it's important to note that for classic self-employed persons, the opportunity factors and their fulfilment are within their control, unlike for dependent self-employed persons. In the latter case, although the opportunity factors are perceived positively, their realization relies not solely on themselves but on the nature of the contractual relationship with the business partner under which they conduct their dependent self-employment. In particular, non-compliance with the Labour Code (regarding holidays, breaks, trade unions, etc.) tends to emerge as an issue. In our survey, the motivating factors representing opportunity in starting a self-employment included the desire for improved working conditions, autonomy (as one's own boss), and the ambition to earn more money.

Interesting findings are linked with the age of self-employed respondents. Results show higher proportion of dependent self-employed persons in the group of younger respondents (under years of age) than in the group of older respondents (over years of age). It is in accordance with the last European

Union report on dependent self-employment (Extent of dependent self-employment in the European Union, 2023) based on which the younger self-employed persons are more likely to be dependent than older ones. This is, however, in contrast to the GEM findings (Bosma and Kelley, 2018), according to which necessity driven self-employed persons (which we can identify as dependent self-employed) are more likely to occur in the older age groups, particularly those aged 45 and more. Possible explanation is influence of Covid-19 pandemic that has had an unprecedented impact on the labour market and the development of self-employment.

Our results are not consistent with GEM (Bosma and Kelley, 2018), either in terms of gender of dependent self-employed persons. Based on our research, males operating as sole traders for relatively shorter period and driven more strongly by necessity motives are more likely of becoming dependent self-employed. GEM (Bosma and Kelley, 2018), findings, on contrary, pointed to the more frequent occurrence of dependent self-employment in the group of women.

Not only status, it means traditional and dependent self-employment and motives of them, but also subjective perception of the satisfaction with the self-employment perception was the object of our research. Our results support findings of Binder and Coad (2016), Sevä et al. (2016 b), and Deci and Ryan (2000), that self-employed persons driven by necessity motives exhibit lower job satisfaction that those, driven by opportunity motives. From a theoretical standpoint, this finding aligns with self-determination theory, positing that individuals derive well-being benefits solely from autonomous action. Conversely, being pushed into self-employment is in contrary to the autonomy (Schwarz and Strack, 1999; Krueger and Schkade, 2008).

CONCLUSION

The goal of this study was to explore the motivation factors influencing beginning of self-employment. In general, there are two fundamental approaches that elucidate the inclination towards self-employment: firstly, the aspiration to validate one's capabilities, exploit existing opportunities, and realize one's potential; and secondly, the less-than-optimal conditions prevailing in the labor market, which necessitate self-employment for the provision of resources for oneself and one's family. Using a modified international methodology that examines entrepreneurial potential (GEM), we monitored a group of traditional and so-called dependent self-employed persons whose activities can be described as forced ones. For both groups, we investigated self-employment motives, which the research methodology divides into opportunity motives and necessity motives.

The conducted research confirmed the fact that necessity prevails as the basic motivational factor to start a self-employment in the case of dependent self-employed persons compared to traditional ones. However, our research was conducted as a one-time study on a relatively small sample of respondents. Nevertheless, as there are no official statistical data on dependent self-employed persons in Slovakia, we consider our results to be exceptional and useful, not only for self-employed persons themselves but also for the decision-making sphere. However, it is necessary to at least periodically repeat the survey among self-employed persons, or to expand the research so that only dependent self-employed persons can be clearly identified and to focus specifically on this group. The results are inconsistent in several areas with the results of the GEM (2018) surveys, whose modified methodology was also used in our research. Therefore, we find it necessary to repeat the research using the same methodology to confirm or reject our previous results.

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Cointegration Analysis of Stock Indices and Money Supply M2 in Selected Countries

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Abstract

This paper focuses on the examination of the long-run relationship between money supply and selected national and global stock indices. Detailed knowledge of this relationship can be used by analysts, investors and monetary policy makers. Analysis of the relationship was performed using a 2-stage Engle-Granger cointegration. First, the stationarity of the time series was tested, then both the long-term OLS model and the short-term EC model were estimated. Time series were always tested on the longest period for which data were available. The long-term dependence of stock indices on the respective M2 was confirmed for the BOVESPA, FTSE100, S&P/BMV IPC, S&P BSE500, TSX and The 5000 Wilshire Small Cap Price Return indices. In contrast, the dependence between world money supply indicator GlobalM2, the stock index FTSEALL World, and the S&P500 index was not demonstrated. Additionally, no dependence was identified between the respective M2 and the DAX, PX, Nikkei225, KOSPI, SMI, SPCITIC300, Eurostoxx50, Willshire5000PR and ATX indices. Backward dependence of M2 on the stock index was found only for the Chinese SPCITIC300 index.[3]

Keywords	***DOI***	***JEL code***
Money supply, stock index, interest rate, Engle-Granger test, EC model	*https://doi.org/10.54694/stat.2024.7*	*G12, G17*

INTRODUCTION

Movement of stock price is determined by numerous global, macroeconomic and microeconomic factors, whose influence on stock prices is examined in detail by fundamental stock analysis. Among the factors affecting stock prices belongs money supply. In financial theory, the prevailing opinion is that there is

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a positive causal relationship between money supply and stock prices. This view is supported across a number of studies by the likes of Rogalski and Vinso (1977), Bernanke and Kuttner (2005), or Maskay (2007). Assuming the existence of the aforementioned relationship between money supply and stock prices, changes in the money supply can be reflected in the development of stock markets, since changes in the money supply can affect the wealth of investors and, consequently, their investments and consumption.

The positive causal relationship between money supply and stock prices is supported by the negative causality between the money supply and interest rates, as well as the negative causality between interest rates and stock prices (Keran, 1971). It therefore means that there is not necessarily a causal relationship between money supply and stock prices.

The considered negative relationship between money supply and interest rates, which assumes that an increase in the money supply will lead to a decrease in nominal interest rates, can be explained using the liquidity effect. With the growth of money supply excess monetary liquidity is released into circulation and the money supply increases, which, assuming an unchanged price level, can lead to a decrease in nominal interest rates, i.e. a decrease in the price of money, since the demand for money is a decreasing function of nominal interest rates. However, if, as a result of the increase in money supply, there was an increase in price level or real output, the effect of a decrease in interest rates would not occur. Rather, on the contrary, there could be an increase or no change in interest rates. The demand for money would shift to the right in this case. When considering these two scenarios, it is important to keep in mind that an increase in money supply may or may not necessarily be followed by a decrease in nominal interest rates.

Several interrelated explanations can be used to account for the negative relationship between the movement of interest rates and stock prices. The correct price of a stock, i.e. its intrinsic value, is calculated as the present value of future cash flows from the stock. The discount interest rate for discounting future cash flows when determining the intrinsic value of a stock is derived from the level of interest rates. As interest rates fall, analysts, with other factors being constant, set higher intrinsic values for stocks, which investors in the stock market react to. A decrease in interest rates will reduce the borrowing costs of companies, which can, under certain conditions, contribute to higher profits, to which stock prices respond by rising. However, despite a decrease in the borrowing costs of firms, profits may not increase if the demand for the firms' products and their sales decline. In this case, stock prices would rather react to a decline in company sales and profits by falling. The positive effect of the decrease in borrowing costs can also be eliminated by the increase in the price of production inputs, as a result of which the total company outlay may not decrease at all. Given that, in addition to the stock market, the bond market also functions as a competitive market where the most important determinant of the movement of bond prices is the interest rate. When interest rates move, it is also necessary to consider the possible reactions of investors to changes in interest rates and the movement of investors between the two markets with regard to the movement of stock and bond prices, along with rates of return from both instruments, as the value of different types of debt and equity instruments is not equally sensitive to interest rate movements.

From the above, it is clear that the expected positive relationship between money supply and stock prices may not necessarily be fulfilled under the influence of various factors and circumstances, just as the considered negative relationships between money supply and interest rates and interest rates and stock prices may not be maintained. However, the movement of macroeconomic variables is a significant determinant of the movement of stock prices. Therefore, for the successful implementation of an investment strategy, and for taking a suitable investment position, the nature of the impact of macroeconomic quantities on stock prices must be investigated.

The aim of this paper is to determine whether there is a long-run relationship between the development of money supply and stock prices represented by national and global stock indices. The purpose of this investigation is to assess the nature and intensity of the relationship between the money supply

and stock prices, with the resulting understanding of this relationship being a potential aid in forecasting the development of stock prices by fundamental analysts or as information to be taken into account when assessing the effects of monetary policy on stock markets.

1 LITERATURE REVIEW

The relationship between money supply and stock prices has been a subject of interest to many economists for more than 60 years. Some studies, such as Rogalski and Vinso (1977), confirm the existence of a positive relationship between money stock and stock price, while others, i.e. Kraft and Kraft (1977), do not. Some studies – Pearce and Roley (1985), for example – even point to a negative relationship between money stock and stock prices.

B. Sprinkel had already stated in her 1964 study that money supply precedes the onset of a bear stock market by fifteen months and at the same time precedes the bull stock market by two months. This author examined the turning points of money supply and stock indices for the period 1918–1960 in data from the USA.

Homa and Jaffe (1971) concluded that the average level of stock price is positively related to money supply. These authors state that stock prices are affected by the dividend growth rate, the risk-free rate of return and the risk premium, with the risk-free rate being a function of the money supply. The authors point out that the relationships between these variables can serve as a forecasting tool when implementing investment strategies.

Based on his analysis using the US market data from 1956–1970, Keran (1971) expressed the view that changes in the nominal money supply have only a weak positive direct impact on stock prices. According to Keran, stock prices are strongly influenced by inflation, interest rates and expected corporate profits. Keran also points to the strong effect of changes in the money supply on interest rates, as well as the strong effect of changes in interest rates on stock prices.

According to a study by Gupta (1974), turning points in the money supply can be used to forecast the stock price movements. The aforementioned author states that 59% of stock price peaks can be accurately predicted using the turning point in the money supply. In this study, monthly data over a period of 23 years was used.

The long-run positive relationship between M2 monetary aggregate and stock prices represented by general and sectoral indices in Pakistan was confirmed by Husain and Mahmood (1999) using the cointegration analysis for the time period June 1991–June 1999. This long run relationship between the variables analysed in the model used, indicates unidirectional causality running from M2 to stock prices. However, the model used also provided evidence of short-term effects of M2 on stock prices.

Kulhánek and Matuszek (2006) investigated the existence of a long-run relationship between money supply and stock prices in the Czech Republic, Slovak Republic, Poland, the USA, UK, Switzerland and EMU using a parametric Johansen cointegration test for different time periods. The research has shown the existence of a long-run equilibrium link between money supply and stock market in all countries studied.

In contrast, Alatiqi and Fazel (2008), using the Engle-Granger cointegration test, Granger causality test and monthly US market data from 1965–2005, did not identify a significant long-run relationship between the money supply represented by the M1 aggregate and stock prices represented by the S&P500 index. The two authors explain the result of their research by the absence of a stable negative causal relationship between money supply and interest rates and, also, by the absence of a relationship between interest rates and stock prices.

Ariff, Chung and Mohamad (2013) examined the relationship between money supply, liquidity and stock prices in Canada, the US and the UK over the period 1968–2012. The results of the study supported the existence of the Friedman effect of liquidity. In all three monitored countries, the money

supply had a significant positive effect on stock prices through its creation of liquidity. The study confirmed the endogenity of the money supply and the existence of bidirectional causality from money to the interest rate in accordance with the post-Keynesian endogenous money theory.

The positive effect of changes in money supply on stock prices is also pointed out by Pícha (2017), who used the Johansen's cointegration methodology and data from the US market for a relatively long time period spanning 1952–2015. The results of his study show that money supply significantly affects the S&P 500 index in both the short and long run. At the same time, according to the results of this research, the money supply acts as a leading indicator, when compared to the stock index, by 6 months.

Qing and Kusairi (2019) made a study about performance of stock market in Malaysia. The study employed monthly data, from January 1997 to August 2018. Method analysis is the autoregressive distributed lag (ARDL) and GARCH model. The findings stated that the money supply, real effective exchange rate and interest rate spread, had a long-run effect on the performance of the stock market. Money supply and the real effective exchange rate had a positive effect on the stock market performance in the short run.

John and Ezeabasili (2020) investigated the effect of money supply on stock market performance in Nigeria, South Africa and Ghana using data from 1986 to 2018. Apart from the preliminary tests, Johansen cointegration test, error correction model and Granger causality test were applied in the study. The findings of the study revealed that money supply had a long-run relationship with stock market performance in Nigeria, South Africa and Ghana. Also, causal relationships were established in the three economies; running from stock market indexes of the three economies to money supply of the economies respectively. It meant that stock prices were not influenced by the money supply but the opposite was true.

Sahu and Pandey (2020) dealt with the relationship between the money supply and stock prices in India in the period 1996–2016 using time-varying parameter models with vector autoregressive specification. Using the Johansen cointegration test, the authors identified a significantly positive long-term co-movement between the money supply and stock prices, however, using the vector error correction model they failed to demonstrate a significant relationship in the short-term. Furthermore, the aforementioned authors point out the unidirectional causality of the money supply to stock prices.

Conrad (2021) focused on the impact of expansionary monetary policy and changes in interest rates on the behaviour of investors in the stock market. The research was carried out in the winter semester 2019/20 at the University of Applied Science HTW at Saarbrücken in Germany, and 56 + 43 participants took part in it. The result of this research was the finding that an increase in the money supply and a decrease in interest rates directly positively affects stock prices. The author points out that an extremely expansionary monetary policy with low, zero or even negative interest rates supports the emergence of financial bubbles on the stock market, and therefore central banks should change interest rates very slowly.

McMillan (2022) turned his attention to the relationship between stock returns and three variables in the form of the rate of return on long-term government bonds, inflation and money supply for the period 1959–2020. The method used was correlation analysis, which was applied to data from the US market. The study found negative relationships between government bond returns and stock returns, as well as between inflation and stock returns before the Dotcom bubble and the financial crisis in 2008. After the mentioned events, both relationships turned positive. Regarding the relationship between money supply and stock returns before 2000 it was measured as positive and after 2000 mostly as negative. The authors point out that change in correlation occurred in the period of 2008 financial crisis.

Tsai, Chang and Tzang (2022) focused on the relationship between money supply and stock returns before and after the quantitative easing (QE) policy of the United States. The authors examined data from the US and Taiwanese markets for the period 1998–2019 using a vector autoregressive model. The positive relationship between money supply and stock returns was insignificant in Taiwan before QE, but became significant after QE. The relationship between money supply and stock returns in the USA

was insignificant before and after QE. In the USA, a study identified a causal relationship between stock returns and money supply before and after QE. In Taiwan, a causal connection between stock returns and money supply was discovered before QE, but not after QE. A causal relationship between Taiwanese stock returns and US stock returns has been demonstrated before and after QE.

2 DATA AND METHODOLOGY

In an attempt to test the analysed time series for cointegration over the longest possible period, the longest time series available will always be selected and used in the following analysis.

2.1 Exogenous variables

M2 monetary aggregates from selected countries were chosen as the exogenous variable. M2 for the US is defined as the aggregate that includes M1 (currency and coins held by the non-bank public, cheque deposits and travellers' cheques) plus savings deposits (including money market deposit accounts), small term deposits of up to $100 000 and shares in retail money market mutual funds. The methodology for other countries may vary slightly and even for the US there have been changes in the calculation methodology (FRED, 2023).

Monthly data were available. The observation period then, was set as the longest possible given the data at hand and Trading Economics was used as the main data source. In addition, Bloomberg's GlobalMoneySupply USD aggregate (hereafter referred to as GlobalM2) was also used, being composed of the total M2 money supply from the US, China, Eurozone, Japan, South Korea, Australia, Canada, Brazil, Switzerland, Russia, Taiwan and Mexico.

2.2 Endogenous variables

The following stock indices from major global financial markets were considered as dependent variables. Both investing.com and finance.yahoo.com were used as data sources. Countries were chosen according to countries with largest stock markets worldwide ranked by share of total world equity market value. Our objective was to analyse world markets in aggregate with the majority of worldwide market capitalization – in our case it was more than 85% (Statista, 2024). If a market capitalization-weighted index was available for a given market, it was preferred over a price-weighted index which is more prone to distortion of its value. The major indices with the largest total capitalization, and best representing the performance of a given market, were preferred. As the most important stock market, for the US several indices were chosen, namely the S&P500, which covers approximately 80% of US market capitalization, and the Wilshire5000PR index, having a very broad base containing all publicly traded companies in the US market. The Wilshire Small Cap index was also used, which represents the market performance of small market capitalisation companies, along with the NASDAQ Composite, whose base contains a significant portion of the IT sector and growth companies.

In addition, the global index The FTSE All World containing stock titles from global stock exchanges was selected for the GlobalM2 time series analysis.

Following indices were analysed:

- the Wilshire 5000 Price Return Index: similar to The Wilshire Total Market Index, except that this index does not include dividend reinvestment and is an index weighted by the market capitalization of all U.S.-traded stocks. As of September 30, 2021, it contained 3 641 companies (Wilshire Advisors, 2021);
- the Wilshire US Small Cap Price Return Index: an index of smaller companies traded in the US market with the average market capitalization of these firms amounting to $6.457 billion. This index is weighted by market capitalization and as of 1/31/2023 its base contained 1 272 companies (Wilshire Advisors, 2022);

- the S&P 500: includes the top 500 publicly traded companies in the U.S. which represents approximately 80% of the market capitalization of the U.S. stock market (S&P Global, S&P 500, 2023);
- the NASDAQ Composite: a market capitalization-weighted stock index that includes nearly all stocks listed on the NASDAQ exchange. Together with the price-weighted Dow Jones Industrial Average and the market-cap-weighted S&P 500, it is one of the three most followed stock indices in the US. The composition of the NASDAQ Composite is heavily focused on companies in the information technology sector (NASDAQ, 2020);
- the DAX (Deutscher Aktien Index): a German market capitalization-weighted stock index composed of 40 selected German blue chip stocks traded on the Frankfurt Stock Exchange. This is an index that takes into account both the share price and the dividend paid (Qontigo, 2023);
- the ATX (Austrian Traded Index): a market capitalisation-weighted index composed of the most liquid stocks listed on the Vienna Stock Exchange and consisting of 20 titles (Wiener Boerse, 2023);
- the BOVESPA: a market capitalisation weighted index, this is the main stock index of the B3 stock exchange in Sao Paulo, Brazil (B3, 2023);
- the PX index: the main index of the Prague Stock Exchange, this is a market capitalization-weighted index based on the most liquid stocks traded on the Prague Stock Exchange (Prague Stock Exchange, 2023);
- the FTSE100: the main market capitalisation-weighted index of the London Stock Exchange and based on the 100 largest companies traded on the Exchange (London Stock Exchange, 2023);
- the Nikkei 225: a price-weighted stock index calculated from 225 stocks traded on the main market of the Tokyo Stock Exchange (Nikkei 225 Official Site, 2023);
- the S&P/BMV IPC: the main index of the Bolsa Mexicana de Valores weighted by modified market capitalization. Its base includes the 35 largest and most liquid stocks listed on the Bolsa Mexicana de Valores (S&P Dow Jones Indices, 2023);
- the KOSPI (Korean Composite Stock Price Index): the main index of the South Korean Stock Exchange. The KOSPI index consists of the 200 largest companies and their most liquid stocks on the Korean Exchange. The KOSPI index is market capitalization weighted (Morningstar Office, 2023);
- the S&P BSE500: a broad proxy of the Indian market, its base contains 500 stocks of the largest companies. The S&P BSE AllCap covers all major industries of the Indian economy and is weighted by market capitalization (S&P Dow Jones Indices, 2023);
- the SMI (Swiss Market Index) index: the most important stock index of the SIX Swiss Exchange, its base comprises the 20 stocks of the largest companies, equivalent to approximately 80% of the total capitalization of the Swiss stock market. The weights of the individual stocks in the index are limited so that no stock exceeds a weight of 20% (Six, 2023);
- the S&P China A 300 index: contains more than 2 500 Chinese A-shares traded on the Shenzhen or Shanghai stock exchanges. The index includes the 300 largest and most liquid stocks of companies from 24 Global Industry Classification Standard (GICS®) industry groups, selected to represent all sectors of the broad market (S&P Dow Jones Indices, 2023);
- the TSX S&P/TSX Composite: the main index of the Canadian stock market and weighted by market capitalization. As of January 31, 2023, the index contained 236 stock titles (S&P Dow Jones Indices, 2023);
- the TA-125 Index: the most important index of the Tel-Aviv Stock Exchange (TASE) and considered the benchmark index of the Israeli market. The index base includes 125 stocks with the highest market capitalization included in the TA-35 and TA-90 indices. The TA-125 Index was launched as the TA-100 Index and, as of February 9, 2017, was expanded to TA-125 (Tradingeconomics, 2024);
- the EuroStoxx50: a global stock index for the Eurozone with its base including the 50 stocks of the largest companies in terms of market capitalization from the 20 super sectors in the Euro area.

The index is part of the STOXX blue-chip index family and captures approximately 60% of the tradable market capitalisation of the EURO STOXX Total Market Index (TMI) (Stoxx, 2023);

– the FTSE All World: a market capitalization-weighted index comprising large, mid-size and small cap stocks traded worldwide. The index base covers developed and emerging markets (FTSE Russell, 2023).

Table 1 Analysed variables

Variable	Period	T	End of period [Index beginning = 1]	Growth p.a. [%]	Variable	Period	T	End of period [Index beginning = 1]	Growth p.a. [%]
USA M2	1959:01–2023:06	774	72.89	6.88	SP500	1959:01–2023:08	776	82.76	7.07
					NASDAQ	1971:03–2023:06	629	135.38	9.81
					WILL5000PR	1971:01–2023:06	631	53.18	7.85
					WILLSMLCAPPR	1992:02–2023:06	379	12.62	8.36
Canada M2	1979:07–2023:06	528	94.51	8.55	TSX	1979:07–2023:06	530	13.24	6.02
Brazil M2	1998:01–2023:06	420	38 546 765	64.72	BOVESPA	1993:05–2023:06	365	3 494.07	30.77
Czechia M2	2002:01–2023:06	258	4.66	7.42	PX50	2002:01–2023:06	359	3.01	3.75
EURO M2	1992:12–2023:06	354	14.12	6.28	ATX	1992:12–2023:06	369	4.34	4.89
					7.42	2001:02–2023:06	428	17.57	8.37
					EuroStoxx50	2003:09–2023:06	240	1.87	3.17
China M2	2000:02–2023:06	281	49.19	13.16	SPCITIC300	2000:02–2023:06	283	2.8	4.46
Israel M2	1992:11–2023:06	368	102 895.95	31.48	TA125	1992:11–2023:06	370	10.24	7.84
India M2	2003:03–2023:06	244	51.72	13.2	SPBSE500	2003:03–2023:06	246	25.26	17.06
Japan M2	1984:03–2023:06	472	1.83	0.1	Nikkei225	1984:03–2023:06	474	3.04	2.85
Mexico M2	1987:02–2023:06	437	828.65	19.58	SPBMVIPC	1987:02–2023:06	439	686.78	19.55
South Korea M2	1970:01–2023:06	644	6 382.64	17.73	KOSPI	1981:05–2023:06	508	20.84	7.44
Switzerland M2	1988:02–2023:06	425	4.74	4.11	SMI	1988:02–2023:06	427	7.81	5.94
United Kingdom M2	2001:02–2023:06	269	18.2	8.25	FTSE100	2001:02–2023:06	271	1.27	1.07
Global M2	2003:05–2023:06	234	4.19	7.33	FTSEAllWorld	2005:11–2023:08	214	2.39	5.00

Source: Own computation, bloomberg.com, investing.com, finance.yahoo.com

World M2 growth, as measured by the GlobalM2 variable, has reached 7.33% p.a. over the last 20 years. Comparing M2 growth (Table 1) for developed market countries, we can generally observe growth around this value up to about 10% p.a. The exception is the South Korea, which is, however, influenced by the high M2 growth of the 1970s and 80s.

Conversely, for emerging countries, long-term growth above 10% p.a. is evident (India, Mexico, China), something often associated with higher growth in the respective stock index. It is important to note that this growth is nominal and those countries that have shown such M2 growth in the past have also often suffered from higher inflation than developed countries. As a result, the real growth of their markets has been lower. Table 1 contains variables with different lengths of T (number of observations) by time series as were available. Such a comparison may, therefore, produce inaccuracies.

2.3 Time series cointegration

As the time series used are non-stationary, classical regression cannot be used. Since the dependence of non-stationary time series cannot be tested by an ordinary OLS model, their cointegration was tested, which examines long-run dependence and equilibrium (Verbeek, 2008). Engle-Granger cointegration of time series was used, where the cointegration relationship was always tested for two time series.

The variables were exponential according to Figures 1 and 2 in the Appendix. Furthermore, according to Tables 11 and 12, the variables also had skewness and were therefore logarithmized. This also linearized them and reduced their skewness (see Tables 13 and 14).

Heteroskedasticity was often present in both the short- and long-run relationship equations. Logarithmization is also one possible way to remove or at least mitigate it (Brooks, 2002). We denote new variables with a 'l' before their name to make it clear that they are logarithmic variables.

2.4 Stationarity

To test for cointegration, it is necessary that the time series be integrated in the same order. The next step, therefore, was to check the stationarity of the variables. According to Enders (2014), if the time series of the variables are not stationary, the classical regression according to Formula (2) cannot be used except when cointegration is present.

A stationary time series is one in which the mean, variance and covariance of the residuals do not change with time (Verbeek, 2008).

The stationary process AR(1) has the following properties:

1) $E(Yt) = 0$, i.e., the unconditional mean is zero,
2) $D(Yt) = \sigma 1^2/(1 - \rho^2)$, i.e. the unconditional variance is constant,
3) $\rho k = \rho^k$, $k \geq 0$, i.e., the autocorrelation function does not depend on time t and its values decrease with increasing displacement k; the process has temporary memory,
4) the expected time to cross zero is finite (Arlt, 1997).

All log-transformed variables were tested with the ADF test, suitable for long time series with more than 250 observations (Arltová and Fedorová, 2016).

Three variants of the ADF were tested: without constant, with constant, and with constant and trend. In the case of a time series that exhibits stable exponential growth (each observation period by the same rate) and converted to a logarithmic time series, the model with a constant would be the best fit. Or, alternatively, if growth varies over time, then the model with a constant and trend would be the best fit.

The maximum lag was according to Akaike's information criterion and also not exceeding the maximum lag $p_{max} = 12(T/100)^{1/4}$ according to Schwert (1989). With a small lag, if p is too low, the test will be affected by autocorrelation. On the other hand, if p is too large, the power of the test will be lower.

In order to perform a test for cointegration, it is necessary to always have a reading from both time series for a given number of observations T during the same time period. The shorter time series always represents the limit. Some time series have been tested more than once, for example the SP500 against the US money supply, but also against the world money supply (Global M2). Global M2 is only available from 2003, whereas US M2 has been available since 1959, so the stationarity of the SP500 has been tested for both the period 2003–2023 and the period 1959–2023.

If one only applied the test to the longest available period of the time series and then made a statement about its (non-)stationarity, then used the time series in a variant with fewer observations T, it might exhibit a different characteristic.

2.5 Engle-Granger test

Time series that were integrated by the same order, in our case I(1), were used for the Engle-Granger cointegration test. The stock index was chosen as the dependent variable and one of the money supply time series M2 as the independent variable. US stock index-US l_M2, Brazilian stock index-Brazilian l_M2 were used, and for the German DAX and Austrian ATX series the EURO l_M2 series, with 1 January 1999 as the start of testing when both countries adopted the Euro.

The lag order was chosen according to the result of the Akaike information criterion with a maximum lag of 12, the model being tested with no constant, with constant and with constant and trend.

Asset prices sometimes play a role in setting monetary policy (Czech National Bank, 2010), so the rejection of reverse causality – the situation where stock indices would affect the money supply – was also tested, i.e. the exchange of endogenous and exogenous variables in the Engle-Granger test.

2.6 EC model

In cases where cointegration was found, i.e. a long-run relationship between M2 and the respective stock index, the EC Model (Error Correction Model) was further used to express the short-run relationship between the variables. The ECM model is able to report whether a stock index tends to return to its equilibrium position after a deviation from equilibrium and with what speed. Moreover, this is another confirmation of cointegration because if this short-run relationship were missing – and thus the tendency of the index to return to equilibrium after its deviation was missing – then the long-run relationship (cointegration) according to Engle and Granger (1987) would not be possible. The ECM model can be written by Formula (1). The error correction term was constructed from the residuals from Formula (2) lagged by one period.

$$\Delta yt = \alpha + \beta_1 \Delta x_t + p_1 \hat{u}_{t-1} + \varepsilon_t, \tag{1}$$

where y_t is the first difference of the endogenous variable, β_1 is parameter of variable and Δx_t is the first difference of exogenous variable, ρ_1 is parameter of error correction term, $\hat{u}_{t-1}$ is error correction term estimated from residuals of Formula (2) delayed by one period and εt is error term.

2.7 OLS model

The OLS model was used to estimate the long-run relationship between time series of the form in Formula (2) when the p-value of the Engle-Granger test rejected the null hypothesis.

$$INDt = \alpha + \beta_1 M2_t + \varepsilon t, \tag{2}$$

where α is constant, β_1 parameter of variable, INDt is one of the chosen stock indices, $M2_t$ is money supply M2 in the chosen country and ε_t error term.

3 RESULTS AND DISCUSSION

All logarithmized variables were tested for the Augmented ADF test at the 5% significance level. Only where both or only one of the time series were not integrated by order I(1) are they reported in the notes in Table 8.

To test for cointegration, it is necessary that the time series be integrated by the same order. In our case, the integration shall be by order 1 marked as a I(1), which means that the time series was non-stationary. However, only after first differencing did it become stationary.

Except for the Czech and European (Euro) money supply, the result of the stationarity test of exogenous variables showed that the time series was integrated by order 1, thus being able to be tested for cointegration.

Euro M2 over the period September 2003–June 2023 was neither stationary nor integrated by order 1. Had the logarithmic transformation not been used, however, the I(1) series would have been stationary and integrated. Nevertheless, as the series is exponential in nature, this would not have been a suitable solution from a methodological point of view, so the series was not tested further against Eurostoxx50. Similarly, this was the case for the Japanese M2.

Neither was the time series of the Czech aggregate M2 stationary, but neither was it I(1). In order to be declared I(1) it would have to be tested only at the 10% significance level, which was rejected.

Table 2 Stationarity test of endogenous variables (bold time series I(1))

Variable	Period	T	Model	Variable (level)		Variable 1(d)		Integration
				test statistic	p-value	test statistic	p-value	I(d)
l_Global M2	2003:05–2023:06	234	w/o constant	4.2446	1	–2.89268	0.003719***	I(1)
			with constant	–1.90545	0.3301	–6.18682	4.201e-08***	I(1)
			with constant and trend	–1.60281	0.7923	–6.42626	9.615e-08***	I(1)
l_USA M2	1959:01–2023:06	774	w/o constant	4.04941	1	–2.47238	0.013**	I(1)
			with constant	–1.4277	0.5703	–5.39939	2.898e-06***	I(1)
			with constant and trend	–1.77276	0.7182	–5.51349	1.56e-05***	I(1)
l_USA M2	1971:03–2023:06	626	w/o constant	3.58744	0.9999	–2.50381	0.0119**	I(1)
			with constant	–1.48635	0.5408	–5.24881	6.15e-06***	I(1)
			with constant and trend	–2.6943	0.2389	–5.38281	2.995e-05***	I(1)
l_USA M2	1971:01–2023:06	630	w/o constant	3.5593	0.9999	–2.43017	0.0146**	I(1)
			with constant	–1.60301	0.481	–5.20568	7.601e-06***	I(1)
			with constant and trend	–2.83423	0.1848	–5.36186	3.319e-05***	I(1)
l_USA M2	1992:02–2023:06	377	w/o constant	4.26572	1	–2.10681	0.03377**	I(1)
			with constant	0.733428	0.9929	–5.5029	1.709e-06***	I(1)
			with constant and trend	–3.23171	0.07821*	–5.59157	1.046e-05***	I(1)
l_Canada M2	1979:07–2023:06	528	w/o constant	2.83682	0.999	–2.1728	0.02869**	I(1)
			with constant	–1.08294	0.7248	–3.67717	0.00447***	I(1)
			with constant and trend	–2.9084	0.1597	–3.74624	0.0194**	I(1)
l_Brazil M2	1993:05–2023:06	362	w/o constant	0.289901	0.7698	–3.5973	0.0003179***	I(1)
			with constant	–3.25401	0.0171**	–3.61621	0.005487***	
			with constant and trend	–8.41467	7.64e-14***	–3.48649	0.04077**	
l_Czechia M2	2002:01–2023:06	258	w/o constant	2.11256	0.9922	–0.92927	0.3142	
			with constant	–0.693795	0.8466	–2.62371	0.08811*	
			with constant and trend	–3.1322	0.09873*	–2.64614	0.2596	

Table 2 (continuation)

Variable	Period	T	Model	Variable (level)		Variable 1(d)		Integration
				test statistic	p-value	test statistic	p-value	I(d)
l_EURO M2	2003:09–2023:06	238	w/o constant	1.83656	0.9846	−1.59564	0.1043	
			with constant	−1.52506	0.5211	−2.42148	0.1357	
			with constant and trend	−2.32099	0.4219	−2.61667	0.2727	
l_EURO M2	2001:02–2023:04	234	w/o constant	2.59692	0.998	−1.39767	0.1512	
			with constant	−2.21377	0.2014	−3.12415	0.02485**	I(1)
			with constant and trend	−2.32849	0.4178	−3.50938	0.03831**	I(1)
l_EURO M2	1992:12–2023:06	354	w/o constant	2.85154	0.9991	−1.75208	0.07576*	
			with constant	−1.00492	0.7538	−3.40709	0.01075**	I(1)
			with constant and trend	−1.72204	0.7417	−3.43457	0.04685**	I(1)
l_China M2	2000:02–2023:06	281	w/o constant	3.30726	0.9998	−1.15061	0.2284	
			with constant	−2.81652	0.05592*	−4.18136	0.0007048***	I(1)
			with constant and trend	−0.215768	0.9928	−5.08183	0.0001***	I(1)
l_Israel M2	1992:11–2023:06	368	w/o constant	1.23985	0.9457	−2.00507	0.04309**	I(1)
			with constant	−2.92736	0.04225**	−2.58403	0.09626	
			with constant and trend	−3.72878	0.02044**	−3.35741	0.05726*	
l_India M2	2003:03–2023:06	244	w/o constant	6.42312	1	−2.25725	0.02315**	I(1)
			with constant	−1.73051	0.4158	−8.1016	2.512e-13***	I(1)
			with constant and trend	−2.1096	0.5399	−8.26498	2.504e-13***	I(1)
l_Japan M2	1984:03–2023:06	472	w/o constant	1.15675	0.9368	−1.58851	0.1057	
			with constant	−1.34627	0.6101	−2.26868	0.1823	
			with constant and trend	−4.05418	0.007277	−2.34516	0.4088	
l_Mexico M2	1987:02–2023:06	437	w/o constant	1.61214	0.9744	−3.25719	0.001101***	I(1)
			with constant	−2.68045	0.07741*	−3.59277	0.00593***	I(1)
			with constant and trend	−3.9892	0.00903***	−3.69463	0.02261**	
l_South Korea M2	1981:05–2023:06	506	w/o constant	1.58247	0.9727	−2.43531	0.0144**	I(1)
			with constant	−3.44263	0.009621***	−2.92266	0.04277**	
			with constant and trend	−1.76081	0.7238	−4.10885	0.006046***	I(1)
l_Switzerland M2	1988:02–2023:06	425	w/o constant	1.06048	0.925	−3.51819	0.0004282***	I(1)
			with constant	−1.00314	0.7544	−3.81913	0.00273***	I(1)
			with constant and trend	−4.17284	0.004847***	−3.8199	0.01549**	
l_United Kingdom M2	2001:02–2023:06	269	w/o constant	5.23314	1	−2.43236	0.01452**	I(1)
			with constant	−2.48329	0.1195	−14.3729	2.883e-33***	I(1)
			with constant and trend	−1.11428	0.9253	−14.6553	2.941e-41***	I(1)

Source: Own elaboration

The time series of monetary aggregates was therefore broadly in line with the assumption I(1). The series that was not consistent with the assumption could have been used in a non-logarithmic variant, but this was rejected both to maintain a uniform methodology and also because these variables showed exponential growth over time, which would have impaired their statistical properties when tested.

Table 3 Stationarity test of endogenous variables (bold indices I(1))

Variable	Period	T	Model	Variable (level)		Variable 1(d)		Integration
				test statistic	p-value	test statistic	p-value	I(d)
l_SP500	1959:01–2023:06	774	w/o constant	3.62142	0.999	−10.5819	4.996e-21***	I(1)
			with constant	0.225641	0.9743	−11.1501	6.214e-23***	I(1)
			with constant and trend	−2.39446	0.3824	−11.1732	1.016e-24***	I(1)
l_SP500	2003:05–2023:06	242	w/o constant	3.27259	0.9998	−10.5656	5.534e-21***	I(1)
			with constant	0.262191	0.9764	−11.1344	6.991e-23***	I(1)
			with constant and trend	−2.3867	0.3865	−11.1576	1.189e-24***	I(1)
l_NASDAQ	1971:03–2023:06	628	w/o constant	2.75544	0.9988	−22.3366	1.086e-41***	I(1)
			with constant	−0.0492124	0.9529	−22.6399	5.171e-5***	I(1)
			with constant and trend	−2.89594	0.1637	−22.6336	3.466e-83***	I(1)
l_DAX	2001:02–2023:06	269	w/o constant	0.849735	0.8938	−15.491	3.115e-33***	I(1)
			with constant	−0.479647	0.8928	−15.5038	1.211e-36***	I(1)
			with constant and trend	−3.84158	0.01448**	−15.5404	8.701e-46***	
l_ATX	1992:12–2023:06	367	w/o constant	0.885991	0.8997	−16.4148	4.338e-35***	I(1)
			with constant	−1.98444	0.2939	−16.4465	2.739e-39***	I(1)
			with constant and trend	−2.48391	0.3362	−16.4445	1.691e-50***	I(1)
l_BOVESPA	1993:05–2023:06	362	w/o constant	1.7809	0.9824	−13.1222	1.002e-27***	I(1)
			with constant	−6.57202	4.474e-09***	−13.4579	2.079e-30***	
			with constant and trend	−8.41734	7.479e-14***	−13.8747	2.368e-37***	
l_PX50	2002:01–2023:06	258	w/o constant	0.697543	0.8661	−6.26784	1.088e-09***	I(1)
			with constant	−3.07533	0.02846	−6.31794	1.983e-08***	I(1)
			with constant and trend	−2.90801	0.1598	−6.39103	1.19e-07***	I(1)
l_FTSE100	2001:02–2023:06	269	w/o constant	0.338969	0.7831	−16.3671	5.352e-35***	I(1)
			with constant	−1.49794	0.5349	−16.3483	5.071e-39***	I(1)
			with constant and trend	−3.2677	0.07167*	−16.3328	6.517e-50***	I(1)
l_Nikkel 225	1984:03–2023:06	472	w/o constant	0.821607	0.889	−20.6039	8.322e-41***	I(1)
			with constant	−1.4048	0.5816	−20.6139	1.966e-48***	I(1)
			with constant and trend	−1.38789	0.8648	−20.5975	1.454e-72***	I(1)
l_SPBMVIPC	1987:02–2023:06	437	w/o constant	2.87439	0.9991	−12.8714	4.311e-27***	I(1)
			with constant	−3.73123	0.003715***	−17.4628	6.218e-42***	
			with constant and trend	−3.05071	0.1184	−17.68	4.962e-57***	I(1)
l_KOSPI	1981:05–2023:06	506	w/o constant	1.58048	0.9726	−21.0888	3.804e-41***	I(1)
			with constant	−1.81155	0.3753	−21.1843	2.7e-49***	I(1)
			with constant and trend	−2.21286	0.4818	−21.1835	1.184e-75***	I(1)
l_SPBSE500	2003:03–2023:06	244	w/o constant	2.78637	0.9989	−13.5071	1.107e-28***	I(1)
			with constant	−2.51403	0.112	−13.9294	6.813e-32***	I(1)
			with constant and trend	−4.2238	0.004052***	−13.9997	5.694e-38***	

Table 3 (continuation)

Variable	Period	T	Model	Variable (level)		Variable 1(d)		Integration
				test statistic	p-value	test statistic	p-value	I(d)
l_SP CITIC300	2000:02–2023:06	281	w/o constant	0.298594	0.7722	–6.11998	2.431e-09***	I(1)
			with constant	–1.81666	0.3728	–6.12499	5.959e-08***	I(1)
			with constant and trend	–3.65325	0.02553**	–6.11436	6.064e-07***	
l_TSX	1979:07–2023:06	528	w/o constant	2.06047	0.9911	–20.8524	5.459e-41***	I(1)
			with constant	–1.22792	0.6647	–21.0382	4.388e-49***	I(1)
			with constant and trend	–3.56163	0.03315**	–21.0271	7.862e-75***	
l_WILL5000PR	1971:01–2023:06	630	w/o constant	3.37624	0.9999	–23.5818	9.417e-42***	I(1)
			with constant	–0.114937	0.9461	–23.9818	5.88e-52***	I(1)
			with constant and trend	–2.52253	0.3171	–23.9682	6.346e-90***	I(1)
l_ WILLSMLCAPPR	1992:02–2023:06	377	w/o constant	2.16972	0.9933	–18.0598	6.746e-38***	I(1)
			with constant	–1.05329	0.7361	–18.2794	7.038e-44***	I(1)
			with constant and trend	–3.76468	0.01835**	–18.2616	3.969e-60***	
l_EuroStoxx50	2003:09–2023:06	238	w/o constant	0.747042	0.8756	–8.45359	2.965e-15***	I(1)
			with constant	–2.28176	0.178	–11.5542	2.976e-24***	I(1)
			with constant and trend	–2.52943	0.3137	–11.5326	2.642e-26***	I(1)
l_TA125	1992:11–2023:06	368	w/o constant	1.71618	0.9796	–9.38762	8.948e-18***	I(1)
			with constant	–1.17904	0.6859	–9.60189	6.181e-18***	I(1)
			with constant and trend	–2.55202	0.3028	–9.60296	3.172e-18***	I(1)
l_MSCIWorld	2003:05–2023:06	234	w/o constant	3.02442	0.9995	–4.27859	2.004e-05***	I(1)
			with constant	–0.0530925	0.9526	–15.2388	7.181e-36***	I(1)
			with constant and trend	–1.67715	0.7616	–15.2215	3.821e-44***	I(1)
l_SMI	1988:02–2023:06	425	w/o constant	1.63375	0.9756	–7.89162	9.106e-14***	I(1)
			with constant	–1.81663	0.3728	–8.1067	2.427e-13***	I(1)
			with constant and trend	–2.03203	0.5831	–8.15821	5.766e-13***	I(1)

Source: Own elaboration

Testing for stationarity of the endogenous variables showed that all time series was integrated of order 1 as expected, i.e., it was non-stationary, but was stationary after first differencing.

Only the BOVESPA index turned out to be I(1) only when using a model without a constant. The time series of money stocks was also overwhelmingly integrated of order 1, providing the opportunity to test for long-run dependence by cointegration, with the exception of the Eurostoxx50 index, the Czech PX and the Japanese Nikkei225, none of which had their money aggregates I(1). The solution would be to use them in a non-logarithmic version or to use another methodology, such as the ADL model, allowing the testing of the dependence of stationary and non-stationary variables simultaneously.

Next, we performed the Engle-Granger test for cointegration, which showed the dependence between the respective money stock and stock index at 5% significance level for the indices l_WILLSMLCAPPR, l_BOVESPA, l_FTSE100, l_S&P/BMV IPC, l_S&P BSE500, l_CITIC300 and l_TSX.

If we were less stringent and chose a 10% significance level, we would be able to prove the dependence of the l_ATX and l_TA125 on the respective money supply as well as l_FTSEAllWorld, l_SP500 and the l_Willshire5000PR index on l_GlobalM2.

Table 4 P-value Engle-Granger cointegration test with stock index and corresponding M2 money supply (bold models significant at 5% significance level)

	Period	Test w/o constant	Test with constant	Test with constant and trend	T
l_SP500	1959:01–2023:06	0.8196	0.6722	0.3677	774
l_Willshire 5000PR	1971:01–2023:06	0.5353	0.2333	0.5286	630
l_WillshireSMLCAPPR	1992:02–2023:06	0.03465**	0.0236**	0.05078	377
l_NASDAQ	1971:03–2023:06	0.8229	0.1304	0.3198	628
l_DAX	1988:01–2023:07	0.1982	0.2211	0.2308	427
l_ATX	1992:12–2023:07	0.08125*	0.216	0.134	368
l_BOVESPA	1993:05–2023:07	0.0004056***	0.1235	0.4171	363
l_PX50	2002:01–2023:06	0.1112	0.1318	0.2535	258
l_FTSE100	2001:02–2023:07	0.01541**	0.09607*	0.1654	270
l_NIKKEI 225	1984:03–2023:07	0.5102	0.7953	0.9524	473
l_S&P/BMV IPC	1987:02–2023:07	0.03142**	0.2653	0.5645	438
l_KOSPI	1981:05–2023:08	0.1189	0.3303	0.5772	508
l_S&P BSE500	2003:03–2023:08	5.13e-05***	0.000874***	0.003709***	246
l_SMI	1988:02–2023:07	0.1264	0.3419	0.7789	426
l_CITIC 300	2000:02–2023:07	0.005709***	0.0114**	0.06679*	282
l_TSX	1979:07–2023:06	0.1559	0.2054	0.02325**	528
l_TA125	1992:11–2023:06	0.2987	0.05093*	0.1971	363
l_FTSEAllWorld	2005:11–2023:07	0.7248	0.4846	0.06348*	213
l_EURO STOXX 50	2003:09–2023:07	0.1019	0.2618	0.4984	239
l_SP500 x l_Global M2	2003:05–2023:07	0.9222	0.7328	0.06025*	243
l_Willshire 5000PR x l_Global M2	2003:05–2023:07	0.8926	0.6934	0.05778*	243

Source: Own elaboration

Where the Engle-Granger test rejected the null hypothesis, the application of the EC model followed to confirm the long-term dependence on the short-term dependence.

In order for the ECM model outputs to be significant, the error correction term must be statistically significant and ρ1 must be negative, as only then does it revert back to its equilibrium value when

deviating from that value. Conversely, if ρ1 were positive, the deviation would increase and the long-run dependence would not be satisfied. Since the models exhibited heteroskedasticity, the HAC model was used.

In general, the outputs of all models were characterized by low R^2 and coefficient of ρ1, implying that the cycles of overvaluation and undervaluation in stock markets are multi-year. This is confirmed by the residuals from the models constructed according to Formula (2) in Figure 3 in the Appendix, which show cycles where the stock index is undervalued or overvalued relative to M2 and takes several years to return to equilibrium. In our case, using monthly data, the low coefficient ρ1 on the error correction term (converted to a 2–8% correction from the deviation from equilibrium over one observation period) makes sense.

If we require a 5% significance level, the short-run relationship and thus confirmation of the long-run relationship (cointegration) can be confirmed for the Wilshire5000CAPR, ATX, BOVESPA, FTSE100, S&P/BMV IPC, S&P BSE500, TSX and the respective money supply.

Table 5 P-value of EC models and parameter of error correction term of stock indices with respective money supply (models significant at 5% significance level, ECT with minus sign and without seral correlation)

Variables				Tests			
Y	**Konst.**	**X**	**ρ_1**	**Breusch-Pagan**	**F-test p-value**	**DW**	**R^2**
d_l_Willshire SMLCAPPR	0.00676980 0.0561*	d_l_USAM2 –0.0323195 0.9582	–0.0506880 0.0062***	0.000000***	0.019779**	1.844060	0.026992
d_l_BOVESPA	5.38420e-05 0.9920	d_l_BrazilM2 0.930885 3.23e-014 ***	–0.0399976 0.0073***	0.000006***	3.59e-14***	1.866717	0.337052
d_l_FTSE100	0.000567137 0.8299	d_l_UnitedKingdomM2 0.0823271 0.6760	–0.0590829 0.0055***	0.000158***	3.37e-14	1.944561	0.337124
d_l_S&P/BMV IPC	0.0124748 0.0055 ***	d_l_MexicoM2 0.184212 0.5948	–0.0308341 0.0353**	0.000000***	0.030147**	1.621680	0.016532
d_l_S&P BSE500	0.0119333 0.0088 ***	d_l_IndiaM2 0.115233 0.4518	–0.0834395 0.0002***	0.257237	0.000830***	1.750507	0.056948
d_l_CITIC 300	0.00528225 0.4593	–0.160238 0.7275	–0.0298864 0.1670	0.000000***	0.334876	1.757747	0.015603
d_l_TSX	0.00344610 0.2611	d_l_CanadaM2 0.244341 0.5976	–0.0229328 0.0494**	0.000006***	0.102755	1.797608	0.011970

Source: Own elaboration

For time series where cointegration was confirmed, an OLS model was applied to estimate the long-run relationship. All estimates resulting from the application of OLS models were characterized by autocorrelation and high R2, and the F-test was conclusive. This may be a symptom of the so-called apparent regression, which is likely if R^2>DW (Granger and Newbold, 1974). Then, the OLS model does not provide relevant information. The only exception may be when there is cointegration between the variables. In this case, the OLS model can be used to capture long-run relationships.

Table 6 OLS model for variables satisfying cointegration (endogenous variables in bold where a long-run relationship has been proved)

Variables			Tests			
Y	**const**	**X**	**Breusch-Pagan**	**F-test p-value**	**DW**	**R^2**
l_WillshireSMLCAPPR	−2.93216 2.30e-059 ***	l_USAM2 1.26021 8.25e-229 ***	0.001035***	8.3e-229***	0.096963	0.938217
l_BOVESPA	−1.70298 6.52e-06 ***	l_BrazilM2 0.884315 3.86e-110 ***	0.006133***	2.0e-216***	0.070388	0.935553
l_FTSE100	3.43847 8.57e-08 ***	l_UnitedKingdomM2 0.364471 1.61e-015 ***	0.000525***	1.62e-47***	0.098300	0.544631
l_S&P/BMV IPC	−16.1409 2.22e-228 ***	l_MexicoM2 1.18000 5.19e-308 ***	0.575080	5.2e-308***	0.070625	0.960765
l_S&P BSE500	−0.707002 0.1015	l_IndiaM2 0.987092 3.96e-064 ***	0.000000***	0.000830***	0.140309	0.925736
l_TSX	−2.95844 9.76e-064 ***	l_CanadaM2 0.889074 6.20e-290 ***	0.305922	6.2e-290***	0.047140	0.919494

Source: Own elaboration

Table 7 provides the variables for which cointegration, i.e. the long-run dependence of the stock index on the corresponding money supply, has been confirmed.

Table 7 Variables where cointegration was confirmed between them

Cointegration confirmed	
Endogenous variable	Exogenous variable
l_WilshireSMLCAPPR	l_USA M2
l_BOVESPA	l_Brazil M2
l_FTSE100	l_UnitedKingdom M2
l_S&P/BMV IPC	l_Mexico M2
l_S&P BSE500	l_India M2
l_TSX	l_Canada M2

Source: Own elaboration

Table 8 contains pairs of time series for which, conversely, cointegration was not confirmed.

Table 8 Time series where cointegration was not confirmed between them

Cointegration not confirmed		
Endogenous variable	**Exogenous variable**	**Reason of not confirmed cointegration**
l_SP500	l_USA M2	Engle-Granger test
l_NASDAQ	l_USA M2	Engle-Granger test
l_DAX	l_EURO M2	Engle-Granger test
l_PX 50	l_Czechia M2	l_Czechia M2 není I(1)
l_Nikkei225	l_Japan M2	l_Japan M2 není (1)
l_KOSPI	l_Korea M2	Engle-Granger test
l_SMI	l_Switzerland M2	Engle-Granger test
l_SPCITIC300	l_China M2	ECM model
l_Eurostoxx50	l_Euro M2	l_Euro M2 není I(1)
l_Willshire5000PR	l_USA M2	Engle-Granger test
l_SP500	l_GlobalM2	Engle-Granger test
l_ATX	l_EURO M2	Engle-Granger test
l_TA125	l_EURO M2	Engle-Granger test
l_FTSEAllWorld	l_GlobalM2	Engle-Granger test

Source: Own elaboration

According to Keran (1971), the fact that some stock indices have not been found to be dependent on the money supply may be due to the fact that a rising money supply lowers interest rates which affect stock prices. Thus, the relationship between the change in M2 and stock price may not necessarily be causal but may only be mediated, possibly affecting the cointegration test.

Another explanation is also possible: according to Borio, Hofmann et al. (2023), a rising money supply increases (expectations of) inflation in the long run, especially if inflation is already of a higher order. Stock prices are then discounted by a higher nominal required rate of return, leading to a lower intrinsic value or stock fair value. In this case, an increase in the money supply would even affect the stock price negatively.

The fact that the dependence of some stock indices on the cash stock has not been discovered does not necessarily mean that there is no dependence between the variables mentioned. Possible reasons could be as follows:

- Incorrectly chosen monetary aggregate. For our analysis M2 was chosen, however, some authors also mention M0, M1 (Shaoping, 2008), or MZM (Money Zero Maturity) (Sirucek, 2012).
- Inappropriate choice of length or period for the time series used, where, for example, a shorter time series may contain a structural break or otherwise deviate significantly from equilibrium but already miss the period when it returns to equilibrium.
- A missing parameter, such as money velocity, GDP growth or other variables that are necessary to fully explain the relationship being analysed.
- Poorly chosen methodology. Under certain conditions it might be more appropriate to use multiple variables, for instance, together with a Johansen cointegration test.

– Where there may not be a relationship between a country's stock index and the relevant M2 aggregate, but where foreign M2 (especially US M2) may have a greater influence, especially in the case of an economy with a significant foreign investor presence in the local stock market.

According to the specific equations of the long-run relationship constructed according to the general Formula (2) with the results presented in Table 6, it is possible to infer whether stock markets are undervalued or overvalued according to M2. Specifically, the above can be inferred by the residuals from the given equations in Figure 3 in the Appendix, which show that some stock markets are overvalued relative to the dates ending in the period June 2023 (l_WilshireSMLCAPPR, l_TSX). Some stock markets, however, are overvalued only in the period July 2023 (l_BOVESPA, l_FTSE100, l_S&P/BMV IPC) while others only in the period August 2023(l_S&P BSE500). Other indices, namely l_WilshireSMLCAPPR, l_BOVESPA, l_TSX, and l_S&P BSE500, are undervalued at this date.

Equations of long run relationship between stock indices and related money supply

$$l\_WilshireSMLCAPPR = 2.93216 + 1.260211\_USAM2$$

$$l\_BOVESPA = -1.70298 + 0.8843151\_BrazilM2$$

$$l\_FTSE100 = 3.43847 + 0.3644711\_UnitedKingdomM2$$

$$l\_S\&P/BMV\ IPC = -16.1409 + 1.181\_MexicoM2$$

$$l\_Wilshil\_S\&P\ BSE500 = -0.707002 + 0.9870921\_IndiaM2$$

$$l\_TSX = -2.95844 + 0.8890741\_CanadaM2$$

Equations of short run relationship between stock indices and related money supply

$$d\_l\_WilshireSMLCAPPR = 0.0067698 - 0.0323295\, d\_l\_USAM2_t - 0.0506880\, \hat{u}_{t-1}$$

$$d\_l\_BOVESPA = 5.38420e-05 + 0.930399\, d\_l\_BrazilM2 - 0.0399976\, \hat{u}_{t-1}$$

$$d\_l\_FTSE100 = 0.000567137 + 0.0823271\, d\_l\_UnitedKingdomM2 - 0.0590829\, \hat{u}_{t-1}$$

$$d\_l\_S\&P/BMV\ IPC = 0.000567137 + 0.0823271\, d\_l\_MexicoM2 - 0.0590829\, \hat{u}_{t-1}$$

$$d\_l\_S\&P\ BSE500 = 0.0119333 + 0.115233\, d\_l\_IndiaM2 - 0.0590829\, \hat{u}_{t-1}$$

$$d\_l\_TSX = 0.00344610 + 0.244341\, d\_l\_CanadaM2 - 0.0429381\, \hat{u}_{t-1}$$

To test for reverse causality, i.e., a situation where stock indices affect the money supply, time series was again tested and integrated with the same order of magnitude as in Tables 2 and 4. This was followed by the Engle-Granger test for cointegration and then estimation of the ECM model. The two tests conducted showed reverse causality only for the SPCITIC300 index according to Tables 9 and 10, suggesting that the stock index affects the Chinese money supply.

Thus, it seems that China's SPCITIC300 index is not influenced by the country's M2 money supply, but instead the index value influences the amount of money supply. As an explanation for this relationship one can use the reasoning that, as stock prices rise, entities feel wealthier and therefore further increase their investments in the domestic market (property acquisitions, company incorporations, etc.), which then leads to an increase in bank lending activity and thus an increase in the money supply.

Observed reverse causality in China's SPCITIC300 is similar to the results of the aforementioned study of John and Ezeabasili (2020). Explanation can be that developing countries could be prone for reverse causality because capital markets in developing countries positively affect economy growth according to Nordin and Nordin (2016), who proved this link in Malaysia and was also observed in India (Mishra, et al., 2010). Economic growth and increasing output then causes money supply growth.

Table 9 Engle-Granger test for reverse causality (models at 5% significance level bold)

	Period	Test w/o constant	Test with constant	Test with constant and trend	T
l_SP500	1959:01–2023:06	0.7951	0.9764	0.7325	774
l_Willshire 5000PR	1971:01–2023:06	0.5285	0.172	0.5886	630
l_Willshire 5000CAPR	1992:02–2023:06	0.03285	0.04946	0.02271	377
l_NASDAQ	1971:03–2023:06	0.7856	0.04436	0.1637	628
l_DAX	1988:01–2023:07	0.1689	0.39	0.7303	427
l_ATX	1992:12–2023:07	0.9991	0.6756	0.6501	368
l_BOVESPA	1993:05–2023:07	0.000397	0.3338	0.04953	363
l_PX50	2002:01–2023:06	0.1092	0.9863	0.2046	258
l_FTSE100	2001:02–2023:07	0.01724	0.0957	0.9723	270
S&P/BMV IPC	1987:02–2023:07	0.01734	0.193	0.3547	438
KOSPI	1981:05–2023:08	0.1208	0.3652	0.8231	508
S&P BSE500	2003:03–2023:08	4.706e-05	0.02267	0.3636	246
SMI	1988:02–2023:07	0.1155	0.6404	0.02893	426
CITIC 300	2000:02–2023:07	0.006869	0.08005	0.9783	282
TSX	1979:07–2023:06	0.1529	0.2705	0.1834	528
TA125	1992:11–2023:06	0.2957	0.03329	0.05522	363
l_FTSEAllWorld	2005:11–2023:07	0.6736	0.3368	0.08645	213
EURO STOXX 50	2003:09–2023:07	0.1031	0.7567	0.1929	239
SP500 x l_Global M2	2003:05–2023:07	0.8991	0.496	0.115	243
Willshire5000PR x l_Global M2	2003:05–2023:07	0.8659	0.4912	0.3235	243

Source: Own elaboration

Table 10 EC for reverse causality (models at 5% significance level bold)

Variables				Tests			
Y	**Konst.**	**X**	**ρ_1**	**Breusch-Pagan**	**F-test p-value**	**DW**	**R^2**
d_l_USAM2	0.00483465 6.45e-020 ***	d_l_Willshire 5000CAPR –0.000934586 0.8808	0.000254898 p-value 0.9595	0.000000	0.980075	0.784047	0.000108
d_l_USAM2	0.00549950 9.24e-048 ***	d_l_NASDAQ 0.00450994 0.3085	–0.00194293 0.1058	0.000000	0.174257	0.722472	0.009239
d_l_BrazilM2	0.0163790 3.99e-06 ***	d_l_BOVESPA 0.344479 0.0060***	–0.0224829 0.0813*	0.000000	0.022796	0.813553	0.337745
d_l_UnitedKingdomM2	0.00483307 1.68e-010 ***	d_l_FTSE100 0.0120201 0.3894	–0.00289695 0.3654	0.000000	0.459242	1.741808	0.006411
d_l_MexicoM2	0.0133287 2.21e-014 ***	d_l_S&P/BMV IPC 0.0156969 0.5226	–0.0116952 0.1355	0.000000	0.294173	1.347369	0.020948
d_l_IndiaM2	0.0100947 2.89e-09 ***	d_l_S&P BSE500 0.0181095 0.4263	–0.017137 0.0782	0.029960	0.172703	1.767890	0.013706
d_l_ChinaM2	0.00996413 1.81e-054 ***	d_l_CITIC 300 –0.00270171 0.7571	–0.00414605 0.0059***	0.000005	0.019241	2.361229	0.035706
d_l_IsraelM2	0.0101613 1.24e-018 ***	d_l_TA125 0.0273992 0.0290**	–0.00925664 0.0938*	0.001712	0.068292	1.181632	0.050371
d_l_SwitzerlandM2	0.00318796 0.0011 ***	d_l_SMI 0.00503308 0.8010	0.00322105 0.2002	0.008829	0.417633	1.121118	0.005433

Source: Own elaboration

After aforementioned overall results and discussed reasons of not discovered cointegration in some cases we suggest deeper analysis focused on:

- possible higher probability of reverse causality between money supply and stock market in emerging markets,
- cointegration using another monetary aggregates including modifications of existing official ones,
- influence of foreign investors on the domestic markets using capital from abroad, thus interference into link between domestic money supply and domestic stock market.

CONCLUSION

The results of our calculations show the dependence of some of the analysed indices on the respective M2 money supply. The longest time series available were used to investigate the relationship between M2 and stock indices. Notably, the long-run dependence (cointegration) of stock indices on the respective M2 was confirmed for the BOVESPA, FTSE100, S&P/BMV IPC, S&P BSE500 and TSX indices.

In contrast, our analysis did not show a dependence between the proxy global M2 money supply as measured by the GlobalM2 index and the FTSEALLWorld stock index. Furthermore, the dependence between the GlobalM2 variable and the SP500 index was not demonstrated either. Finally, and also not confirmed, was the dependence between the respective M2 and the DAX, PX, Nikkei225, KOSPI, SMI, SPCITIC300, Eurostoxx50, Willshire5000PR and ATX indices.

An especially noteworthy outcome of the analysis performed is that the dependence of the US indices on M2 mentioned by authors such as Parhizgari and Nguyen (2011), or Chung and Ariff (2016) has also not been shown on the highly liquid SP500 and NASDAQ. However, the dependence on M2 has neither been demonstrated in relation to the Wilshire5000 index, the most representative benchmark of the entire US market.

A certain exception among the examined indices from the US market is the 5000 Wilshire Small Cap Price Return index, which showed a long-term dependence on M2, something also demonstrated by the subsequent short-term dependence according to the EC model. This relationship is a rather surprising outcome, as the index's dependence on M2 was rather assumed and expected for larger and more liquid indices whose base contains stocks of companies with larger market capitalisation. This assumption was itself based on the premise that highly liquid stocks of larger capitalization companies would allow investors, both institutional and retail, to frequently adjust positions in light of the changing (and generally steadily increasing) money supply. However, changes in M2 appear to be a significant factor affecting the stock prices of smaller market capitalization companies whose prices are more volatile, more risky and more sensitive to fundamental influences compared to the more stable stocks of large market capitalization companies.

In all cases, the short-term EC model showed a very small coefficient for the error correction term, specifically converted to 2–8% per period. These results are consistent with the fact that monthly data was used. Stock market cycles, however, are generally multi-year, as is evident from the residuals of the long-term OLS model which represent the state of under- or over-valuation of the index.

The small coefficient on the error correction term is also related to the small R^2 in the EC model, where the change in M2 over the period explains the change in the stock index in very limited terms, as stock under/overvaluation cycles take place over a longer time period.

When testing for backward dependence, i.e., the dependence of M2 on stock indices, only the Chinese SPCITIC300 demonstrated this property, meaning the Chinese stock index in turn affects Chinese M2. According to the residuals from the OLS model, it was possible to infer whether the stock market is overvalued or undervalued relative to M2.

In interpreting the results obtained, it is important to note that the existence or absence of a relationship between M2 and the stock index identified from the analysis of past data does not imply that this will be the case in the future, especially if focusing on a shorter period and if the OLS model according to Formula (2) suggests an undervalued or overvalued market. A return to its equilibrium may take a very long time, but in the meantime the movement may still continue to the extreme and pose a possible risk to the investor. The outputs of our analysis are currently applicable to global fundamental equity analysis focusing on the effects of M2 on equity markets in the markets under study, but the relationships between M2 and equity indices need to be monitored further in the future as the nature of these relationships may be subject to change.

Investors and asset allocators are encouraged to take our analysis into consideration in their long term decision making only, since model suggests multiyear cycles. Thus, not appropriate for short-term allocation and speculation. Policy makers should bear in mind, that money supply can also influence stock market and be cautious especially when increased rate of money supply growth is observed due to possible influence on stock market not supported by fundamentals.

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APPENDIX

Table 11 Exogenous variables of monetary aggregates M2 and their statistical characteristics

Variable	Mean	Median	Minimum	Maximum	Standard deviation	Coefficient of variation	Skew-ness	Kurtosis
GlobalM2	5.9636e+013	5.9847e+013	2.4002e+013	1.0380e+014	2.3012e+013	0.38588	0.27675	–0.87680
USAM2	5062.8	3327.2	286.60	21703.	5316.0	1.0500	1.4567	1.4853
BrazilM2	1.2146e+006	5.6974e+005	0.010000	5.4165e+006	1.3446e+006	1.1070	1.1998	0.57498
CanadaM2	6.2552e+005	4.3889e+005	25523.	2.4322e+006	6.1105e+005	0.97686	1.2906	0.87444
CzechiaM2	3.2106e+006	2.8929e+006	1.3268e+006	6.2432e+006	1.3668e+006	0.42572	0.51941	–0.75411
EUROM2	5.9102e+006	4.5438e+006	1.0705e+006	1.5447e+007	4.0231e+006	0.68070	0.71372	–0.60983
ChinaM2	82465.	49614.	5840.1	2.8730e+005	77440.	0.93906	0.92872	–0.32775
IsraelM2	3.3307e+005	2.3435e+005	12.400	1.3990e+006	3.6358e+005	1.0916	1.2182	0.69720
IndiaM2	15917.	9789.4	1127.5	61024.	15753.	0.98970	1.1723	0.38910
JapanM2	4.6662e+005	5.0131e+005	8404.0	1.2390e+006	3.5118e+005	0.75261	0.28741	–1.0441
MexicoM2	3.6767e+009	2.3553e+009	1.5370e+007	1.2737e+010	3.4528e+009	0.93910	0.91503	–0.21875
SouthKoreaM2	8.9359e+005	4.2077e+005	590.60	3.8027e+006	1.0538e+006	1.1793	1.1220	0.19648
SwitzerlandM2	5.5727e+005	4.5359e+005	1.9823e+005	1.0956e+006	2.9518e+005	0.52969	0.53415	–1.2060
UnitedKingdomM2	1.3861e+006	1.1266e+006	1.6734e+005	3.2181e+006	8.5348e+005	0.61575	0.36438	–1.2245

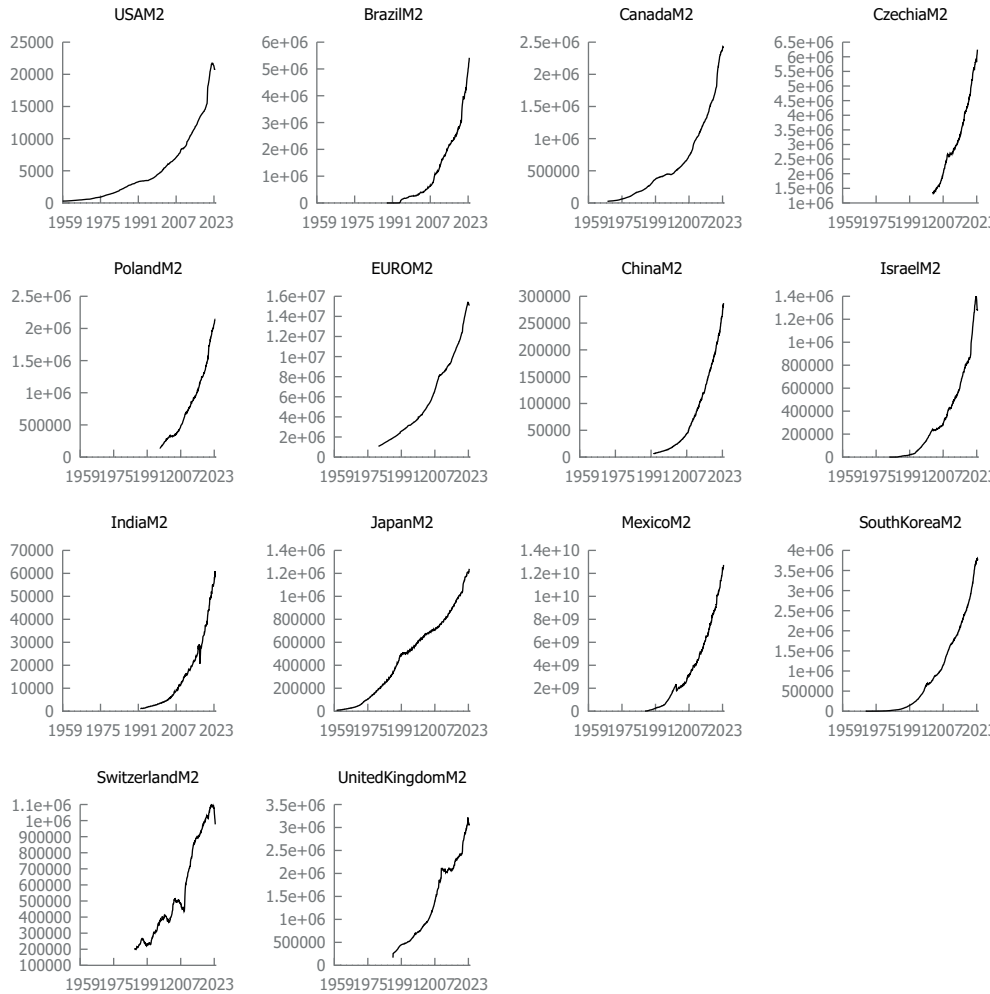
Source: Own elaboration, investing.com, finance.yahoo.com

Table 12 Endogenous variables of stock indices and their statistical characteristics

Variable	Mean	Median	Minimum	Maximum	Standard deviation	Coefficient of variation	Skewness	Kurtosis
SP500	871.33	375.22	53.390	4766.2	1050.4	1.2055	1.6852	2.4700
NASDAQ	2456.9	1314.8	55.670	15645.	3317.7	1.3504	2.0943	4.0385
DAX	6483.6	5738.9	936.00	16447.	4165.1	0.64240	0.60308	–0.70608
ATX	2249.2	2250.2	747.70	4885.4	1019.5	0.45327	0.43822	–0.68783
BOVESPA	40759.	36232.	1.0000	1.2680e+005	36248.	0.88934	0.65986	–0.70810
PX50	919.25	957.86	331.90	1908.3	364.26	0.39626	0.30273	–0.51963
FTSE100	6039.8	6076.6	3567.4	7876.3	1069.7	0.17712	–0.32602	–0.79363
Nikkei225	17886.	17336.	7568.4	38916.	6557.4	0.36662	0.62865	–0.067425
SPBMVIPC	21298.	13486.	79.820	56537.	19063.	0.89505	0.30656	-1.5783
KOSPI	1199.6	909.22	114.57	3296.7	795.14	0.66286	0.46275	–0.88674
SPBSE500	10108.	7687.7	1068.0	27069.	6480.8	0.64117	0.86644	–0.070718
SMI	6370.8	6595.1	1351.0	12876.	2938.4	0.46123	–0.16589	–0.86694
SPCITIC300	2419.3	2418.9	695.14	4750.4	1110.7	0.45910	0.14038	–1.0264
TSX	8727.7	7622.8	1366.8	21890.	5515.5	0.63195	0.44359	–0.99674
WILL5000PR	10540.	7559.4	550.04	48835.	11086.	1.0518	1.4900	1.7442
WILLSMLCAPPR	5436.0	4245.6	989.12	15299.	3807.7	0.70046	0.88546	–0.29423
EuroStoxx50	3264.6	3239.3	1976.2	4512.6	574.44	0.17596	0.20210	–0.61842
TA125	883.68	942.10	145.45	2109.2	524.22	0.59323	0.27831	–0.97020
MSCIWorld	2.4753e+005	1.9266e+005	10000.	1.0032e+006	2.3678e+005	0.95655	1.4401	1.4730
FTSEAllWorld	286.12	268.88	122.52	496.89	86.273	0.30153	0.66293	–0.32437

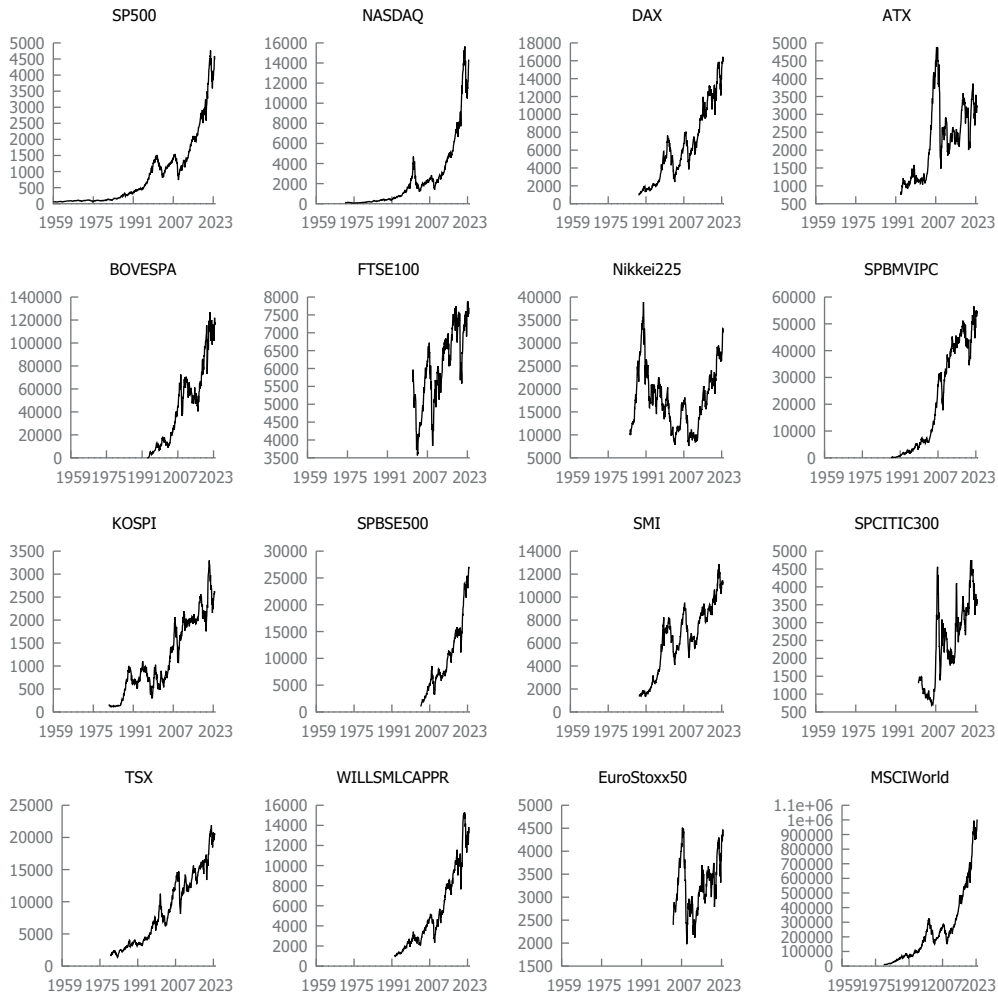
Source: Own elaboration, bloomberg.com, tradingeconomics.com

Figure 1 Exogenous variables in time



Source: Own elaboration, bloomberg.com, tradingeconomics.com

Figure 2 Endogenous variables in time



Source: Own elaboration

Table 13 Exogenous variables of logarithmized data series of M2 and their statistical characteristics

Variable	Mean	Median	Minimum	Maximum	Std. dev.	C.V.	Skewness	Ex. kurtosis
l_USAM2	7.8834	8.0972	5.6619	9.9922	1.2158	0.15423	–0.21016	–1.0596
l_BrazilM2	11.682	13.195	–4.6052	15.403	4.7878	0.40985	–2.0734	3.2326
l_CanadaM2	12.741	12.977	10.147	14.681	1.2113	0.095073	–0.46605	–0.70751
l_CzechiaM2	14.868	14.870	14.098	15.597	0.42849	0.028819	–0.12728	–0.98939
l_EUROM2	15.318	15.312	13.884	16.553	0.74087	0.048366	–0.14575	–1.1416
l_ChinaM2	10.814	10.953	8.6725	12.493	1.1348	0.10495	–0.18922	–1.3204
l_IndiaM2	9.0639	9.1537	7.0277	10.928	1.1395	0.12572	–0.10446	–1.2300
l_JapanM2	12.465	13.121	9.0365	14.008	1.3592	0.10904	–0.98680	–0.24345
l_MexicoM2	21.232	21.571	16.548	23.221	1.5749	0.074175	–1.0077	0.34136
l_RussiaM2	8.4706	9.3469	1.8718	11.250	2.2914	0.27051	–0.82464	–0.28391
l_SouthKoreaM2	12.008	12.901	6.3811	15.149	2.5826	0.21508	–0.67921	–0.84083
l_SwitzerlandM2	13.075	13.018	12.197	13.907	0.54029	0.041323	0.081798	–1.2992
l_UnitedKingdomM2	13.897	13.907	12.028	14.983	0.71010	0.051099	–0.26822	–1.2012

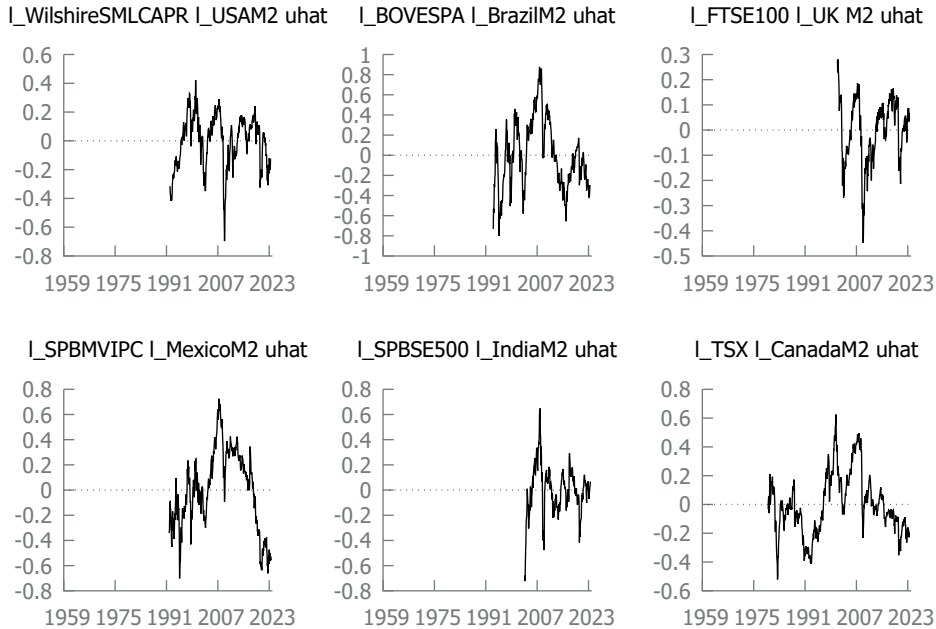
Source: Own elaboration

Table 14 Endogenous variables of logarithmized data series of stock indices

Variable	Mean	Median	Minimum	Std. dev.	C.V.	Skewness	Ex. kurtosis
l_SP500	5.9650	5.9275	3.9776	1.3494	0.22621	0.13584	–1.4348
l_NASDAQ	6.8652	7.1815	4.0194	1.5080	0.21966	–0.080962	–1.1231
l_DAX	8.5325	8.6550	6.8416	0.74599	0.087429	–0.36090	–0.97040
l_ATX	7.6082	7.7188	6.6170	0.48146	0.063282	–0.16766	–1.2406
l_BOVESPA	9.6338	10.498	0.00000	2.3127	0.24006	–2.3059	5.7190
l_PX50	6.7370	6.8647	5.8048	0.43066	0.063924	–0.36570	–0.98624
l_FTSE100	8.6893	8.7122	8.1796	0.18797	0.021633	–0.65143	–0.36310
l_Nikkei225	9.7244	9.7605	8.9317	0.37116	0.038168	–0.093370	–0.78474
l_SPBMVIPC	9.1072	9.5094	4.3798	1.6933	0.18593	–0.84639	–0.24635
l_KOSPI	6.7810	6.8126	4.7412	0.89525	0.13202	–0.83474	–0.094108
l_SPBSE500	8.9935	8.9474	6.9736	0.71999	0.080058	–0.48504	–0.19803
l_SMI	8.6075	8.7941	7.2086	0.61280	0.071194	–0.94720	–0.33844
l_SPCITIC300	7.6646	7.7911	6.5441	0.53326	0.069575	–0.51531	–0.93738
l_TSX	8.8328	8.9389	7.2202	0.73745	0.083490	–0.28362	–1.2122
l_WILL5000PR	8.6197	8.9305	6.3100	1.2409	0.14396	–0.15489	–1.2432
l_EuroStoxx50	8.0753	8.0831	7.5889	0.17813	0.022059	–0.16726	–0.52853
l_TA125	6.5535	6.8481	4.9798	0.73784	0.11259	–0.49802	–1.0721
l_MSCIWorld	11.897	12.169	9.2103	1.1429	0.096068	–0.50480	–0.41146
l_FTSEAllWorld	5.6125	5.5943	4.8083	0.29694	0.052907	0.050827	–0.43045

Source: Own elaboration

Figure 3 Residuals of OLS models where was confirmed cointegration



Source: Own elaboration

Can Conventional Monetary Policy Stimulate Bank Credit? Evidence from a Developing Country

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Abstract

The predominance of bank credit in financing the economies of less developed countries is prompting policymakers to stimulate this mode of financing. This study tests the ability of conventional monetary policy to stimulate the supply of bank credit to the private sector in Morocco. Based on the lending channel as a theoretical framework, an analytical framework to explore the conduct of monetary policy and the preconditions for the functioning of this channel was developed. In addition, a test of the impact of monetary policy on credit supply was conducted using bank-level data from a representative sample of the Moroccan banking sector.

The results show that demand factors and the quality of potential borrowers are the main drivers of bank credit growth. They also show that monetary policy in Morocco directly affects credit growth. However, no evidence that this impact is mediated through credit supply was provided, indicating that the credit channel is not operational in Morocco. The policy implications of these results are discussed.

Keywords	***DOI***	***JEL code***
Monetary policy, lending channel, bank credit, Morocco	*https://doi.org/10.54694/stat.2023.54*	*E4, E5, G2*

INTRODUCTION

Since the 1970s, the emergence of literature regarding the impact of information asymmetries on the smooth functioning of the banking sector and economic activity has led to intense debate on the importance of macro-financial linkages (Levine, 1997). This debate is all the more relevant in the case of developing countries with less efficient financial systems, where the banking sector dominates

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the financing of economic agents. In these countries, the banking sector represents the main source of financing for businesses and households (Nyasha and Odhiambo, 2014). Thus, the empirical results of several studies show that the development of the banking sector promotes economic growth in developing countries (Kchikeche and Mafamane, 2023).

Although the primacy of the price stability objective guides monetary policy (Criste and Lupu, 2014), promoting bank credit by the latter is a decisive lever for supporting economic growth without conflict with its primary objective. The theoretical underpinnings of this link are grounded in the role of bank credit in monetary policy transmission (Bernanke and Gertler, 1995). Moreover, while the stance of monetary policy can be a decisive lever for affecting bank credit, its effectiveness in stimulating banking activity remains dependent on the quality and operationality of this transmission.

Since economic policy considers economic growth to be a decisive goal of economic development (Friedman, 1968) and based on the role of bank credit in promoting economic growth in developing countries, the stimulation of bank credit by an accommodating monetary policy becomes a necessity, particularly in the absence of inflationary pressures, and where bank credit is primordial to monetary policy transmission to real economic activity.

In Morocco, the simultaneous slowdown in economic growth and bank credit over the last decade, against a backdrop of accommodating monetary policy with successive cuts in policy rates from 3.25% to 1.5% and reserve requirements from 16.5% to 0% between 2006 and 2021, suggests the malfunctioning of Bank-Al-Maghrib's monetary policy transmission channels, particularly the lending channel, and prompts us to question the effectiveness of this policy by examining the operationality of this channel. Therefore, this paper assesses the ability of conventional monetary policy to stimulate bank credit to the private sector in Morocco between 2006 and 2021. Looking at the available data, it is reasonable to assume that the monetary policy transmission to bank credit is hindered.

This paper distinguishes itself from the existing literature, which focuses on the restrictive effects of monetary policy on economic activity, by analyzing its effect on bank credit. In addition, an analytical approach defines monetary policy shifts and enables a clearer exploratory analysis of the conduct of monetary policy. Using this analytical framework, the operational framework and conduct of monetary policy are explored to assess their potential impact on bank credit and the prerequisites of the lending channels.

Finally, the study verifies the lending channel's existence in Morocco, employing bank-level data between 2006 and 2021. The empirical specification detects heterogeneity in the response of individual banks to changes in monetary policy stance by measuring the moderating effect of bank-specific characteristics on the response of credit growth to changes in the policy rate. After conducting a battery of statistical tests, fixed effect (FE) and generalized least squares (GLS) estimators are employed to ensure the robustness of the results.

This paper is structured as follows. The first section reviews the theoretical literature on the lending channel of monetary policy transmission before exploring the existing empirical evidence. The second section examines the conduct of monetary policy in Morocco and the preconditions for the functioning of the lending channel. The third section presents the data and empirical methodology used throughout this paper. The fourth section reports the results, and the final section concludes the paper by discussing policy implications.

1 LITERATURE SURVEY

1.1 Monetary policy transmission and the supply of bank credit: theoretical underpinnings

The impact of monetary policy on bank credit hinges on the credit view's validity, a view that opposes the traditional money view, which represents the traditional Keynesian and monetarist interpretation of the monetary policy transmission mechanism (Gertler and Gilchrist, 1993) and emphasizes the functioning

of the interest rate channel. The transmission of monetary policy through this channel depends on the sensitivity of the interbank interest rate to variations in the supply of reserves by the central bank and, ultimately, on the sensitivity of business and household spending to variations in lending rates. This transmission is mainly due to the unique role of commercial banks' liabilities in the money-creation process (Oliner and Rudebusch, 1996).

In contrast, Bernanke and Gertler (1995) argued that in the presence of the effect of informational asymmetries and other frictions, the interest rate channel is limited by its inability to fully explain the magnitude, timing, and composition of aggregate demand response to monetary policy shocks. With these imperfections, the adjustment of interest rates to changes in credit supply remains limited and can lead to credit rationing (Romer et al., 1990).

The credit view of monetary policy transmission provides a way of approaching the impact of monetary policy on bank credit. This view stipulates that monetary policy is transmitted through the assets side of the bank balance sheet, mainly through bank credit supply (Romer et al., 1990). Bernanke and Gertler (1995) reveals that the size of the financing premium reflects various types of imperfections in credit markets that lead to divergences between banks' expected returns and potential borrowers' expected costs. Accordingly, the lending channel, which shows the potential effect of monetary policy shocks on the supply of bank credit, stipulates that the credit supply amplifies the transmission of monetary policy (Loupias et al., 2001). However, the impact of monetary policy on credit supply requires the validity of the lending channel. This channel can work alongside other monetary policy transmission channels (Loupias et al., 2001) and even amplify the interest rate channel (Bernanke and Gertler, 1995).

Two conditions should be met for the lending channel to be operational (Oliner and Rudebusch, 1996). First, banks must be unable to completely isolate their credit supply from variations in their stock of reserves by issuing liabilities that are not subject to reserve requirements or liquidating existing assets. Second, because of the additional costs involved in accessing capital markets, a subset of bank-dependent borrowers who cannot completely isolate their spending from the supply of bank credit should exist. Accordingly, the lending channel is operational in countries with less developed financial markets where banks are the dominant lenders (Bernanke and Gertler, 1995).

1.2 Verifying the operationality of the lending channel: the empirical debate

While explaining the inner workings of the lending channel is relatively straightforward. Proving its operationality and distinguishing it from other channels proved to be a challenging task. While earlier studies relied heavily on aggregate data and vector autoregression, these methods face substantial identification problems, mainly distinguishing changes in credit supply from changes in demand. As a result, new literature using disaggregated data and panel econometric methods emerged by providing new identification strategies to verify the lending channel.

1.2.1 Evidence using aggregated data

Aggregate data methods were first used to settle the debate between the money and the credit view. Some notable works along these lines include Bernanke and Blinder (1988), who emphasized the role of relaxing the assumptions of the substitutability of credit and bonds and that the price fully compensates the bond market and provided evidence that the monetary policy is transmitted through bank assets.

This argument was countered by Romer et al. (1990), who argued that, in the absence of reserve requirements on certificates of deposit, bank lending loses its role in transmitting monetary policy. Therefore, the substitutability between securities issued inside and outside the banking system implies that monetary policy shocks do not impact the supply of bank credit. On the other hand, Bernanke and Blinder (1992) support both channels' coexistence.

For Morocco, most studies used VAR techniques to verify the existence of a lending channel in Morocco and provided evidence for the coexistence of the two monetary policy transmission channels (Bennouna et al., 2016; Boughrara, 2009; García-Ortíz and Pizarro-Barceló, 2010; Ouchchikh, 2018).

Overall, studies using aggregate data and impulse response functions to analyze correlations between money, credit, and output or the lead-lag relationship between these variables suffer from significant identification problems relating to the nature of the data used and the econometric methods employed. These methods fail to consider the endogeneity problem (Kashyap et al., 1993), as money and credit can also be contemporaneously affected by changes in output (Bernanke and Gertler, 1995). This problem stems mainly from the possible counter-cyclicality of credit demand, as firms and households often increase their demand for credit to counteract falling incomes. Thus, a variation in credit demand caused by changes in activity can explain the variation in aggregate credit in response to a monetary policy shock (Kashyap et al., 1993). Also, Abuka et al. (2019) argue that these empirical studies cannot distinguish between changes in credit supply and demand. Hence, the reaction of bank credit to a monetary policy shock does not reflect whether this change results from a change in credit supply or demand (Oliner and Rudebusch, 1996).

1.2.2 Evidence using disaggregated data

Based on the criticism above of aggregate data evidence, studies using disaggregated data provided more elaborate identification strategies to verify the existence of the lending channel. For instance, several studies used disaggregated data to identify the heterogeneity of banks' responses with dissimilar characteristics (size, liquidity, and capitalization) to monetary policy shocks. Most notably, Kakes and Sturm (2002), Kashyap and Stein (1995, 2000), and Loupias et al. (2001) revealed a differentiated response of banks' credit and securities portfolios to monetary policy shocks. They argued that capital market imperfections cause a disproportionate response of small banks constrained in their ability to finance themselves on capital markets to monetary policy shocks.

Nevertheless, Frühwirth-Schnatter and Kaufmann (2006) show that the widely used bank-specific characteristics do not explain differences in bank reactions to monetary shocks and developed an alternative identification approach using Bayesian estimation methods. Similarly, Hussain and Bashir (2019) argued that the lending channel in China operates primarily through other sparkly considered bank-specific characteristics such as market structure and competition. In particular, High market concentration harms monetary policy transmission through the lending channel. Furthermore, by affecting banks' access to alternative sources of funds, the market's structure can moderate the lending channel's quality.

The operationality of this channel is also affected by external structural factors. Boukhatem and Djelassi (2022) argue that the lending channel is more efficient in developing countries where banks are the source of financing. However, financial frictions and structural rigidities that constrain banks in these countries limit this efficiency (Modugu and Dempere, 2022) and weaken the transmission of monetary policy (Abuka et al., 2019; Modugu and Dempere, 2022). Studies on developing countries support these observations. In particular, Amidu (2006) shows the significant impact of bank size and liquidity on bank credit and the functioning of the lending channel in Ghana. Similarly, Shokr et al. (2014) support the operationality of the lending channel of monetary policy in Egypt and that small banks are more affected by monetary policy shocks than large ones.

In Morocco, the only empirical study mobilizing bank-level data was conducted by Boughrara and Ghazouani (2010), who examined the lending channel during the period 1989–2007 in the case of four MENA countries, including Morocco, demonstrating the operationality of the lending channel.

In light of this review and the aggregate data limitations, the present study empirically identifies the impact of monetary policy on credit supply using a mix of microeconomic and macroeconomic data spanning from 2006 to 2021. Based on a representative sample of the Moroccan banking sector,

we estimate two panel data econometric models. The present work provides updated and more comprehensive evidence for a period characterized by bank credit slowdown and accommodative monetary policy stance.

2 MONETARY POLICY IN MOROCCO AND THE OPERATION OF THE LENDING CHANNEL

2.1 Monetary policy in Morocco: the operational farmwork and implications for the lending channel

Against a backdrop of financial liberalization, monetary policy in Morocco has undergone a series of operational and institutional reforms over the last few decades, setting price stability as the central bank's ultimate objective while reinforcing its independence. With the abandonment of direct monetary policy instruments, these reforms have consolidated the actions of the Moroccan central bank on the money market to regulate the latter through liquidity injections or withdrawals. This intervention aims to steer the interbank rate to align with the primary policy (the rate on weekly advances) rate while eventually remaining within a corridor set at plus or minus 100 basis points of this rate (Akaaboune, 2017). Currently, BAM's operational framework relies on its interventions in the money market to maintain the interbank rate at a level compatible with the monetary policy stance (Mafamane and Qachar, 2018). As a result, the interbank market interest rate constitutes the operational objective of Morocco's monetary policy (Daoui, 2020).

The analysis of conventional monetary policy starts by exploring its effectiveness in achieving its stated operational objective. This analysis shows that, over the study period, the interbank market rate was close to the primary policy rate in most quarters while remaining within the aforementioned corridor, as shown in the upper panel of Figure A1 (in the Annex). In addition, to evaluate the misalignment of the interbank market rate with the policy rate, the difference between the policy rate and the interbank market rate relative to the policy rate is used to measure the extent of this misalignment.

Overall, the second panel of Figure A1 shows that the interbank market rate aligned well with the policy rate over the study period. Furthermore, the value of the misalignment index is within the interval [–0.05; +0.05] (i.e., the absolute value of the misalignment is less than 5% of the policy rate) for most of the study period. Accordingly, the gap between the declared objective and the actual results remains marginal, suggesting that Morocco's monetary policy effectively achieves its operational objective. Moreover, to measure Moroccan banks' liquidity needs and their level of dependence on the central bank refinancing, the structural position of bank liquidity, which measures the structural surplus or deficit of bank liquidity, reflecting the net effect of autonomous monetary policy factors on bank reserves, reveals a quasi-structural liquidity deficit that has grown in recent years, as shown in the first panel of Figure A2 (in the Annex). This deficit reveals Moroccan banks' expenditure of liquidity from BAM's liquidity injections on the money market. Furthermore, the second panel of Figure A2 shows that the Moroccan central bank has provided Moroccan banks with all the demanded liquidity.

To dive deeper into the conduct of monetary policy in Morocco during the study period, multiple subperiods where the stance of monetary policy in Morocco changed are defined. Each sub-period starts as the quarter in which the Bank Al-Maghrib Board decided to change the primary policy rate. In addition, each period subperiod ends with the quarter preceding the following change in the primary policy rate. Quarterly data is used for simplicity, as Bank Al-Maghrib's Board of Directors meets regularly in the first month of each quarter. The analysis of primary change data revealed seven periods when the primary key rate changed.

Table 1 presents a deeper exploration of monetary policy conduct in Morocco by focusing on interpreting the indicators that play crucial roles in the transmission of monetary policy to bank credit. These figures show a strong downward trend in the policy rate, with a drop of over 175 basis points between 2006 and 2021, backed by reasonable control of BAM's operational target, with a very marginal deviation from the policy rate. However, with such an accommodating stance and the movement of the interbank

market and lending rates, the growth of bank credit to the private sector in Morocco did not follow the same trend. This observation shed doubt on the operationality of lending channel over the last decade.

Table 1 Changes in monetary policy indicators and bank lending conditions between 2006 and 2021

Sub-periods	Policy rate	Interbank rate	Lending rate	Growth of bank credit to the private sector
2006Q1–2008Q2	3.25	2.90	6.49	16.00
2008Q3–2009Q1	3.50	3.46	6.30	18.97
2009Q2–2012Q1	3.25	3.28	6.40	9.43
2012Q2–2014Q3	3.00	3.06	6.16	2.65
2014Q4–2016Q1	2.50	2.52	5.75	–0.56
2016Q2–2020Q1	2.25	2.26	5.19	2.37
2020Q2–2021Q4	1.50	1.50	4.37	2.67

Source: Compiled by the authors based on Bank Al-Maghrib's data

The above descriptive analysis can in no way be inferential, and its main objective is to explore the existence or absence of simultaneous movements in the indicators of interest to justify the interpretation of the results. Thus, the existence of confounding variables is likely to influence the evolution of these indicators, which would bias any causal interpretation derived from the simple descriptive analysis of these figures.

2.2 The conditions of the validity of the lending channel in Morocco

For Oliner and Rudebusch (1996), the functioning of the lending channel hinges on the existence of a set of borrowers that are dependent on bank credit and the inability of banks to raise alternative funds to central bank refinancing without additional cost. Therefore, the evolution of these two conditions is examined to assess the strengthening or weakening of the prerequisites for the functioning of the lending channel in Morocco.

2.2.1 Analysis of borrowers' dependency on bank credit in Morocco

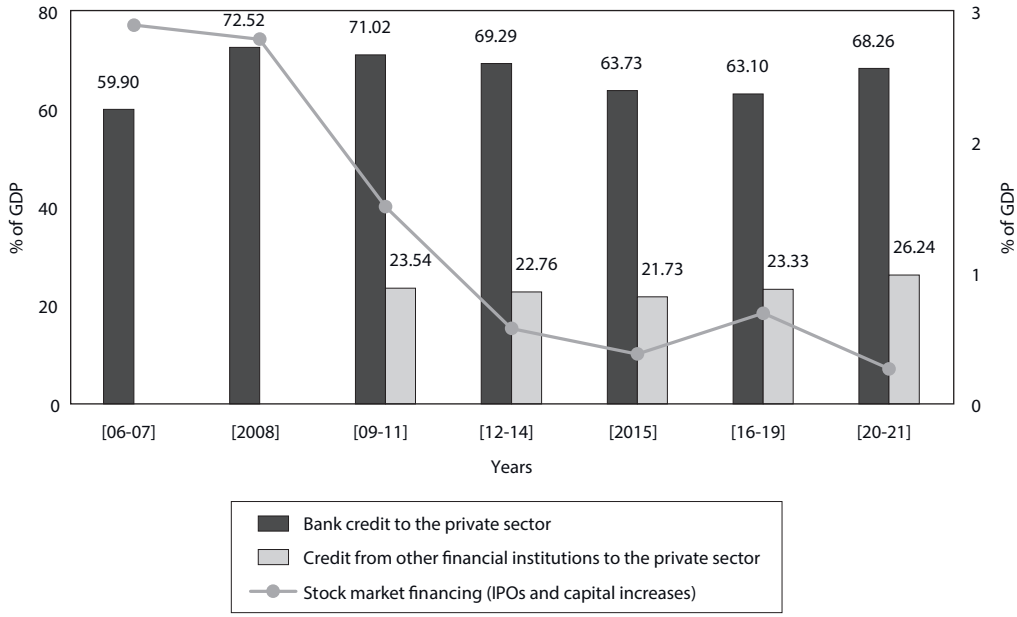
The existence of a set of borrowers that are unable to substitute bank credit with alternative sources of financing without additional costs is an expression of their inability to completely isolate their demand for financing from monetary policy shocks, given that bank credit and other types of financing are not perfect substitutes for these borrowers. Theoretically, the transmission of monetary policy through lending channels should be strengthened with the reliance of a higher proportion of borrowers on bank credit.[2]

Figure 1 shows the predominance of bank credit in private sector financing in Morocco, compared with stock market financing and financing from other financial institutions. This figure illustrates that bank credit to the private sector is more than three times greater than the credit granted by other financial institutions. All other things being equal, strengthening the lending channel's functioning is likely correlated with a higher role of bank credit in financing the private sector in Morocco. Therefore, even with the gradual decline in bank credit (as % of GDP) between 2009 and 2019, the first condition for

[2] If the policy rate and the interest rates on bank credit substitutes, such as credit by non-bank financial intermediaries and securities, are correlated, the transmission of monetary policy shocks could also go through these debt instruments. However, this is outside the scope of our paper as we are only interested in monetary policy transmission through credit supply.

the functioning of the lending channel seems to have been met during the study period, as the other sources of financing did have either slightly improved (in the case of credit from other financial institutions) or declined (in the case of stock market financing) during the study's period.

Figure 1 Evolution of financing indicators for the Moroccan economy by financial sector segment (as % of GDP) between 2006 and 2021



Source: Elaborated by the authors based on data compiled from the World Bank's Global Financial Development database and Casablanca Stock Exchange's statistics reports

Two additional indicators may be helpful for the analysis of borrowers' dependency on bank credit in Morocco. The first indicator that we present in Table 2 describes the relative role of bank credit in financing the Moroccan economy by contrasting it with financing through securities. The high proportion of bank loans (as % of total claims on the economy) shows the high preference of borrowers for bank credit and, therefore, indicates the dependence of a large proportion of firms and households on bank credit in Morocco.

Table 2 Evolution of the claims on the Moroccan economy by type of instrument between 2006 and 2021

	Loans (as % of total claims)	Securities (as % of total claims)
2006Q1–2008Q2	92.80	7.14
2008Q3–2009Q1	92.88	7.12
2009Q2–2012Q1	91.53	8.47
2012Q2–2014Q3	90.33	9.67
2014Q4–2016Q1	90.26	9.74
2016Q2–2020Q1	88.78	11.22
2020Q2–2021Q4	88.11	11.89

Source: Compiled by the authors based on Bank Al-Maghrib's data

The second indicator of borrowers' reliance on bank credit measures Moroccan firms' recourse to commercial paper as a short-term financing source. Table 3 shows the evolution of issuances and holdings of commercial paper during the study period. These figures reveal that commercial paper holdings and emissions remain low and insignificant, at less than 10% over most of the study period, showing Moroccan firms' dependence on banks.

Table 3 Evolution of commercial paper issuance and holdings in Morocco between 2006 and 2021

	Commercial paper (as % of negotiable debt instruments holdings)	Commercial paper (% of total emissions of private negotiable debt securities)
2006Q1–2008Q2	11.88	16.50
2008Q3–2009Q1	6.80	19.70
2009Q2–2012Q1	5.02	13.30
2012Q2–2014Q3	5.06	13.30
2014Q4–2016Q1	5.11	27.20
2016Q2–2020Q1	2.85	6.00
2020Q2–2021Q4	2.24	4.60

Source: Compiled by the authors based on Bank Al-Maghrib's data

Overall, these figures show the supremacy of bank credit as the primary source of financing for Moroccan firms and households.

2.2.2 Analysis of banks's access to alternative sources of financing

The second condition for the functioning of the lending channel requires the inability of banks to isolate their credit supply from monetary policy shocks completely. For this to be true, refinancing through the open market and the issuance and/or sale of bank-owned securities should not be perfect substitutes.

To illustrate this condition, Table 4 shows a fall in the banking sector's securities holdings (as % of total assets) by around four percentage points and a rise in issued securities and CDs (as % of bank liabilities) from 1.75% before the crisis to around 4% after the 2008 monetary policy shock, indicating a liquidation of some securities holdings and the issuance of new debt. These changes can, therefore, be interpreted as an insulation of credit supply from restrictive monetary policy effects. However, this trend changed with Morocco's monetary policy shifting towards an accommodating stance in the third quarter of 2008. Banks no longer had any incentive to liquidate their asset holdings or issue a new debt instrument, which resulted in a rebound of securities holding to around 18% and a stagnation of securities issuance at around 4.5% during the rest of the study period.

Table 4 Evolution of the holdings and emissions of securities and CDs by Moroccan banks between 2006 and 2021

	Securities held (as % of bank assets)	Securities and CDs issued (% of bank liabilities)	CD holdings (% of PND securities holdings)	CD emissions (% of PND securities emissions)
2006Q1–2008Q2	18.02	1.75	53.70	72.40
2008Q3–2009Q1	13.98	3.64	82.60	76.90
2009Q2–2012Q1	13.95	4.28	75.41	71.60
2012Q2–2014Q3	17.27	4.76	74.96	64.00
2014Q4–2016Q1	17.58	4.11	72.89	37.40
2016Q2–2020Q1	18.22	4.73	71.89	54.20
2020Q2–2021Q4	20.18	4.73	66.37	48.20

Source: Compiled by the authors based on Bank Al-Maghrib's data

Following the tightening of monetary policy in 2008, commercial banks in Morocco significantly increased their issuance of certificates of deposit, rising from an annual average of 9 billion DH between 2006 and 2007 to 30 billion in 2008, an observation that can be interpreted as a weakening of the lending channel. However, this development does not seem to be reversed over the rest of the study period, characterized by an accommodating stance of monetary policy in Morocco. Overall, data from Table 4 showed that, as a response to monetary tightening in the aftermath of the 2008 crisis, the behavior of Moroccan banks is in line with a weak lending channel as banks liquidated a part of held assets and issued more CDs.

Furthermore, Bernanke and Gertler (1995) argue that the lending channel is weakened if certificates of deposits are (i) less liquid, (ii) not protected by deposit insurance, and (iii) not subject to the same reserve requirements as deposits. In Morocco, two of these three conditions are valid; namely, certificates of deposit are less liquid than bank deposits and are subject to reserve requirements while remaining uncovered by the Moroccan Deposits Funds Management Society (Société Marocaine de Gestion des Fonds des Dépôts, n.d.).

Accordingly, it can be argued that the preconditions for the functioning of the lending channel are reasonably verified during the study period; empirical verification of such a finding is required before any conclusions can be drawn.

3 METHODS

To verify the existence of the lending channel in Morocco, panel data models are estimated using a representative sample of Moroccan banks' yearly data from 2006 to 2021, a study period mainly determined by data availability considerations. In the absence of quarterly balance sheet data, changes in annual data may not capture the variations in policy rate changes, raising questions about the central bank's frequency of monetary policy adjustments. However, during the study period, Bank Al-Maghrib did not change its primary policy rate twice in the same year, rendering this issue irrelevant.

3.1 Sample and data

The sample includes eight Moroccan banks listed in Table 5, including their balance sheet size, and the amount of bank loans granted to the private sector in 2021. This table shows the non-proportional contribution of large banks to private-sector financing. In particular, the larger the bank, the smaller its contribution to total private-sector lending.

Table 5 List of banks included in the empirical study sample

Code	Name	Total assets in 2021		Credits to the private sector in 2021	
		in billions	% of total	in billions	% of total
AWF	Attijariwafa Bank	386.73	29	158.97	26.7
BCP	Banque Centrale Populaire	281.11	21.1	70.93	11.9
BMCE	Bank of Africa	227.10	17	99.45	16.7
CAM	Crédit Agricole du Maroc	127.72	9.6	81.96	13.8
SGMB	Société Générale marocaine des Banques	96.73	7.3	58.03	9.7
CIH	Crédit Immobilier et Hôtelier	91.41	6.9	49.90	8.4
BMCI	Banque marocaine pour le Commerce et l'Industrie	64.85	4.9	39.21	6.6
CDM	Crédit du Maroc	58.17	4.4	37.39	6.3
Totals		1333.83	100	595.84	100

Source: Compiled by the authors based on data collected from individual financial statements

Admittedly, the number of banks included in the sample seems limited. However, this sample represents the majority of the Moroccan banking sector. Indeed, the banking sector in Morocco is characterized by a high concentration level. Based on Bank Al-Maghrib (2021) and data collected from the balance sheets of Morocco's eight largest banks, the banks in the sample hold over 90% of banking assets and grant 97.1% of bank loans. Consequently, our sample is representative of the behavior of the Moroccan banking sector.

The data is collected manually from banks' financial statements from three sources. Financial statements from the Bourse de Casablanca's (n.d.) website are used for banks listed on the stock market. For the rest of the banks, the website of the Autorité Marocaine du Marché des Capitaux (n.d.) is the data source. In the absence of financial statements from the first two sources, the annual reports published by the banks on their websites are employed.

3.2 Specification and empirical methodology

The specification captures the determinants of credit growth to understand bank credit dynamics better. Furthermore, the model tests the effect of the monetary policy stance on bank credit growth by identifying the lending channel in Morocco.

This specification is presented in the equation below:

$$\Delta C_{i,t} = \alpha X_{i,t-1} + \beta \Delta i_t + \gamma \Delta Y_{t-1} + \delta Z_{t-1} + \theta \left(\Delta i_t \times X_{i,t-1} \right) + \varepsilon_{i,t}, \quad (1)$$

where $C_{i,t}$ represents the logarithm of credit granted by a bank to the private sector. The first difference of this variable, $\Delta C_{i,t}$ represents a linear approximation of this variable.

Bank credit growth is explained by the monetary policy stance (Δi_t), bank-specific determinants ($X_{i,t-1}$ *and* Z_{t-1} and macroeconomic conditions (ΔY_{t-1}).

The first difference in the policy rate (i_t) is employed to define the monetary policy stance. Thus, β represents the response of a representative bank to shifts in the stance of monetary policy (Boughrara and Ghazouani, 2010). According to Borio and Gambacorta (2017), this indicator is a proxy for the marginal cost of short-term financing. In particular, a positive (negative) value of Δi_t represents a restrictive (accommodative) monetary policy stance by Bank Al-Maghrib. In this sense, a negative value of β represents the banking sector's appropriate response to the monetary policy stance.

$X_{it-1} = \left[Sizee_{i,t-1}, \text{Liq}_{i,t-1}, \text{Cap}_{i,t-1} \right]$ represents size, liquidity, and capitalization; bank-specific variables most widely used in the empirical literature: size, liquidity, and capitalization. According to Boughrara and Ghazouani (2010), bank-specific characteristics affect the growth of credit linearly. Thus, the lagged value of these characteristics is included to account for their correlation with bank credit growth.

A bank's relative size $Size_{it-1}$ is represented by the logarithm of its total assets $A_{i,t-1}$ during t–1 minus the average level of bank assets during the same period.

$$Size_{it-1} = A_{i,t-1} - \frac{1}{\text{N}} \sum_{i=1}^{N} A_{i,t-1}. \quad (2)$$

According to Loupias et al. (2001), bank size represents the cost of external financing due to information asymmetry. Indeed, as discussed, larger banks have more internal resources and can easily access capital markets. On the other hand, in the presence of capital market imperfections, small banks find it comparatively more difficult to access these markets (Kashyap and Stein, 1995).

Bank capitalization is calculated based on the ratio ($kp_{i,t-1} = \frac{K_{i,t-1}}{A_{i,t-1}}$) between a bank's equity and total assets minus its average value over the studied period. Thus, $\text{Cap}_{i,t-1}$ is defined as follows:

$$\text{Cap}_{i,t-1} = kp_{i,t-1} - \frac{\left(\sum_{i=1}^{N} kp_{i,t-1} / N\right)}{T}. \quad (3)$$

In the presence of asymmetric information, raising capital becomes costly for undercapitalized banks (Loupias et al., 2001). Faced with such a situation, undercapitalized banks can only grant low-risk loans or reduce their credit supply altogether to meet the capital adequacy ratio (Watanabe, 2007). The more-capitalized banks have easier access to capital markets.

Liquidity is calculated based on the ratio ($lq_{i,t-1} = \frac{L_{i,t-1}}{A_{i,t-1}}$) between liquid and total assets minus the average per bank
over the period studied. Thus, $\text{Liq}_{i,t-1}$ is defined as follows:

$$\text{Liq}_{i,t-1} = lq_{i,t-1} - \frac{\left(\sum_{i=1}^{N} lq_{i,t-1} / N\right)}{T}. \quad (4)$$

This variable measures each bank's perception of its excess liquidity. In this sense, banks internally assess excess liquidity based on the characteristics of their balance sheet and their perception of risk. Thus, the variable measures each bank's estimated risk of liquidity insufficiency to cope with deposit withdrawals and the risk of insolvency. Indeed, more liquid banks are more capable of liquidating part of their asset holdings to protect themselves from the effects of monetary policy (Loupias et al., 2001).

By defining liquidity and capitalization in this way, bank-specific characteristics capture pure differential effects. For each period, bank-specific variables are equal to zero on average, being negative for banks whose specific characteristics (liquidity and capitalization) are below average (hereafter referred to as small banks or less liquid/capitalized banks) and positive for banks whose specific characteristic is above average (hereafter referred to as large banks or more liquid/capitalized banks). This definition permits interpreting the coefficients of the monetary policy indicators as the effect of monetary policy on bank credit growth (Boughrara and Ghazouani, 2010).

ΔY_{t-1} represents the log difference of the macroeconomic indicators. Thus, $Y_t = \left[GDP_t^{na},\ CPI_t,\ \text{RRPI}_t\right]$ is a vector of macroeconomic indicators that control the effect of credit demand characteristics. The first difference of these variables represents a linear approximation of the non-agricultural economic growth rate, the inflation rate, and the growth in residential real estate asset prices. These variables control cyclical trends in economic activity.

For instance, more favorable economic conditions positively affect bank credit growth (Borio and Gambacorta, 2017). In particular, an increase in the economic growth rate stimulates demand for bank credit by influencing private economic agents' debt and repayment capacity and their expectations about the economic outlook. Agricultural GDP is excluded from the calculation of economic growth as this component of aggregate supply in Morocco is highly volatile as it is mainly affected by the exogenously determined rainfall rate (Kchikeche and Khallouk, 2021). This volatility renders agricultural GDP a poor indicator of endogenous credit demand factors. In fact, credit extended to agriculture and fishing sectors did not exceed 5% during the study period. In addition, the inflation rate measures the impact of price variations on the purchasing power of economic agents. According to Tamini and Petey (2021), this variable harms the demand for bank credit. Moreover, growth in the price index of residential real estate assets indicates both a potential increase in demand for the acquisition of real estate assets and an increase in their net value and the value of collateral when applying for bank financing. Thus, an increase in this variable is positively linked to bank credit.

$Z_t = \left[NIM_{i,t-1},\ \text{NPLR}_{i,t-1} \right]$ contain two variables: interest margin and nonperforming loan ratio. The first represents the profitability of the lending activity. As a measure of profitability, this variable should positively impact credit growth. The second variable represents the risk perception in the lending activity. An increase in NPLR indicates an increase in the level of borrower risk and should adversely affect bank credit growth. In this sense, a higher level of this variable indicates an increase in banks' risk perception and a deterioration in the quality of their loan portfolios.

The vector ($\Delta i_t \times X_{it-1}$) represents the interaction between the monetary policy stance indicator and bank-specific characteristics [size, liquidity, capitalization]. These three bank-specific characteristics interact with the monetary policy stance indicator. Thus, the coefficients $\theta = [\theta_1, \theta_2, \theta_3]$ describe how responses to monetary policy differ according to bank-specific characteristics. These interaction terms test for asymmetries in the effect of monetary policy on individual banks. Consequently, the test for the bank lending channel checks whether the coefficients of the interaction terms are statistically significant. If so, the lending channel can be considered operational (Boughrara and Ghazouani, 2010).

Indeed, the significance of the interaction terms between the monetary policy stance coefficients and the bank-specific characteristics is – la pièce de résistance – of the empirical identification strategy of the lending channel currently employed in the literature using bank-level data. This empirical identification strategy relies mainly on verifying the second prerequisite of the lending channel advanced by Oliner and Rudebusch (1996). This condition is based on the fact that monetary policy mainly works through the supply of reserves by the central banks to the banking sector. Thus, monetary policy transmission through the lending channel is hindered if banks can acquire these reserves by other means.

Banks can acquire reserves independently from the central bank through capital markets by selling their assets or issuing new debt. This way, they could mitigate the effect of monetary policy shocks on their credit supply. So, by empirically detecting that the credit growth of more established banks (bigger, more liquid, and more capitalized banks) that have easier access to capital markets (and thus are less affected by information asymmetry and market imperfections) are less affected by the monetary policy shocks, we establish that the credit growth of less established banks (with less access to capital markets) is comparatively – more affected by monetary policy shocks. Therefore, the lending channel works through these reserve-constrained banks. This is where the significance of the interaction term comes into play; a positive interaction term means bank-specific characteristics moderate the effect of monetary policy on credit growth, i.e., banks with higher-than-average bank-specific characteristics are less affected by monetary policy shocks, and vice versa. Accordingly, the lending channel is operational if the coefficient of the monetary policy stance is negative while the interaction terms' coefficients are positive. Otherwise, the lending channel is not operational.

Fixed-effect ordinary least squares are used as the estimation method. This bank-specific choice of effect type is based on the results of the Hausman test. The use of individual-effect models aims to capture unobservable heterogeneity between individuals. Thus, a fixed-effect model can be represented as follows:

$$Y_{i,t} = a_i + \beta X_{i,t} + \mu_i + e_{it}, \tag{5}$$

where $Y_{i,t}$ is the endogenous variable, α_i is the unknown constant for each individual, $X_{i,t}$ is a vector of exogenous variables, μ_i is the intra-individual error term and e_{it} is the error term. By including individual constants for each bank, the fixed-effect model controls for all time-invariant differences between banks, so the estimated coefficients cannot be biased due to omitting these characteristics (Awdeh, 2016). Finally, to account for period-specific effects, yearly time dummies are employed. Furthermore, to account for serial autocorrelation and groupwise heteroscedasticity. The model is estimated using Kmenta's (1988)

and Parks's (1967) Feasible Generalized Least Squares method. This method allows the estimation of heteroskedastic and correlated errors across panels. This method is appropriate for panels with T>N. The FGLS model can be represented in the following equation:

$$Y_{i,t} = a_i + \beta X_{i,t} + e_{it}. \quad (6)$$

4 RESULTS AND DISCUSSION

4.1 Descriptive statistics and preliminary tests

To examine the descriptive characteristics of the variables, Table 6 presents the descriptive statistics for the studied variables. These figures show that the three bank-specific variables have zero means but different standard deviations. In particular, the sample is characterized by size and capitalization heterogeneity. However, the variability of the level of capitalization remains low. In addition, the mean value of the net interest margin is 3%, with a standard deviation of 0.01 and a range of 0.05. The rate of provisions on customer loans shows moderate heterogeneity. Furthermore, the average of the policy stance indicator representing the monetary policy stance amounts to 0.08, testifying to the accommodating stance of this policy during most of the study period.

Table 6 Descriptive statistics

Variable	Observations	Mean	S.D.	Minimum	Maximum
$Size_{i,t}$	128	0.00	0.28	–0.44	0.50
$Liq_{i,t}$	128	0.00	0.11	–0.16	0.54
$Cap_{i,t}$	128	0.00	0.03	–0.08	0.11
$NIM_{i,t}$	128	0.03	0.01	0.00	0.05
$NPLR_{i,t}$	128	0.11	0.07	0.00	0.55
ΔGDP_t^{na}	128	0.04	0.04	–0.07	0.13
ΔCPI_t	128	0.01	0.01	0.00	0.04
$\Delta RRPI_t$	128	–0.01	0.04	–0.10	0.07
Δi_t	128	–0.08	0.29	–0.52	0.80

Source: Compiled by the authors

The correlation matrix between the variables of interest is reported in Table A1 (in the Annex). These figures show a correlation between bank credit growth and its determinants. In particular, a positive correlation exists between growth in bank credit and liquidity. Indeed, banks holding more liquid assets tend to lend more. However, there is a negative correlation between the growth in bank credit and bank capitalization. In other words, more capitalized banks tend to lend less. This counterintuitive correlation is surprising and requires further analysis.

Furthermore, the correlation coefficient between credit growth and relative bank size is insignificant and does not exceed 0.08. In addition, bank credit growth is negatively correlated with net interest margin and provision rate. The negative correlation between bank growth and NIM is surprising and means that the increase in the intermediation margin is combined with a fall in the growth of bank credit to the private sector. Moreover, the correlation matrix shows that the monetary policy stance indicator positively

correlates with growth in bank credit, which contradicts the expected sign of this relationship. Finally, growth in bank credit is positively correlated with non-agricultural economic growth and the inflation rate but not with the growth rate of the real estate asset price index.

Before turning to the results of the estimations, Table 7 presents the results of the stationarity tests, showing that all the variables are stationary.

Table 7 Unit root test results

Variable	Specification: with constant		Specification: without constant	
	Levin, Lin & Chu	ADF-Fisher	Levin, Lin & Chu	ADF-Fisher
$\Delta C_{i,t}$	–4.235***	27.664**	–7.393***	68.177***
$Size_{i,t}$	–1.661**	27.473**	0.7268	16.537
$Liq_{i,t}$	–6.057***	53.113***	–3.093***	27.010**
$Cap_{i,t}$	–4.189***	31.637**	–3.878***	41.632**
$NIM_{i,t}$	–4.458***	28.165**	–2.193**	26.432**
$NPL_{i,t}$	–7.941***	37.962***	–2.173**	26.193**
ΔGDP_t^{na}	–3.132***	49.394***	–4.299***	32.914***
ΔCPI_t	–1.382*	22.813	–4.155***	31.634**
$\Delta RRPI_t$	–16.404***	159.754**	–4.186***	30.530**
Δi_t	–6.637***	42.663***	–6.637***	42.663***

Note: ***, **, * indicate that the results reject the null hypothesis of the existence of a unit root in the variable at the 1%, 5%, and 10% significance levels, respectively.
Source: Compiled by the authors

Choosing the appropriate estimation method is crucial for the validity of the model. This choice is based on the characteristics of the data and the model's specifications. The fixed effect model is appropriate as a correlation between unobserved individual characteristics (e.g., management characteristics) and the regressors can be reasonably assumed. This choice is validated by conducting Hausman's (1978) specification test. Accordingly, the null hypothesis of this test is rejected. The inappropriateness of the random effect model is further illustrated by conducting the Breusch and Pagan's (1980) LM test. Based on the result of these specification tests, a fixed-effect model is estimated. The results of this model show that the coefficients are jointly significant with an R^2 of 0.58.

Furthermore, since bank credit growth has changed substantially over the study period, a test of whether adding time-fixed effects would improve the model is conducted by examining the joint significance of added yearly time dummies. The result of this test shows that the time dummies improve the model's explanatory power ($R^2 = 0.69$). Next, the Modified Wald test for groupwise heteroscedasticity is conducted. The results of this test indicate the rejection of the null hypothesis of error homoscedasticity. Two more diagnostic tests are conducted to validate the resulting model. The first is Pesaran's (2021) test for cross-sectional dependence, and the second is Woodridge's (2002) test for autocorrelation. The results of the first and second diagnostic tests indicate the inexistence of cross-sectional dependence and first-order autocorrelation, respectively. However, following Pesaran (2015), the results show that the fixed-effect model suffers from serial autocorrelation. Based on these results, the fixed-effect model is estimated using clustered robust standard errors to account for heteroscedasticity and serial correlation. The results of all these tests are summarized in Table 8.

Table 8 Results of diagnostic tests

	Test statistic	P-value
Hasman specification test	23.54	0.001
Breusch & Pagan's LM test	00.00	1.000
Joint significance of time dummies	3.11	0.002
Joint significance of explanatory variables	11.43	0.000
Modified Wald test for groupwise heteroscedasticity	96.02	0.000
Pesaran's test for cross-sectional dependence	2.564	0.153
Woodridge's test for autocorrelation	–1.546	0.122
Pesaran test for serial autocorrelation	48.886	0.009

Source: Compiled by the authors

4.2 Estimation results

The results of the FE and FGLS models are presented in Table 9.

Table 9 Estimation results for Fixed-Effect and Feasible Generalized Least Squares models

	FE	FGLS
$Size_{i,t-1}$	–0.342***	–0.028*
	(0.093)	(0.016)
$Liq_{i,t-1}$	0.292**	0.165**
	(0.089)	(0.076)
$Cap_{i,t-1}$	–0.835	–0.142
	(0.473)	(0.100)
$NIM_{i,t-1}$	5.409	0.604
	(4.372)	(0.734)
$NPL_{i,t-1}$	–0.354**	–0.183**
	(0.141)	(0.072)
ΔGDP_t^{na}	0.007**	0.010***
	(0.003)	(0.001)
ΔCPI_t	–0.022**	–0.017***
	(0.006)	(0.002)
$\Delta RRPI_t$	0.004*	0.006***
	(0.002)	(0.000)
Δi_t	–0.130**	–0.152***
	(0.037)	(0.013)
$Size_{i,t-1} \times \Delta i_t$	0.092	0.052
	(0.124)	(0.081)
$Liq_{i,t-1} \times \Delta i_t$	–0.781	–0.164
	(0.623)	(0.374)
$Cap_{i,t-1} \times \Delta i_t$	3.232	0.790
	(1.652)	(0.574)
C	–0.069	0.012
	(0.087)	(0.013)

Note: Standard deviations are shown in parentheses. ***, **, * indicate that the regression coefficient is significant at the 1%, 5%, and 10% significance levels, respectively.
Source: Compiled by the authors

The results in Table 9 show that our specification captures our models' dynamics reasonably well. Our model includes nine proper explanatory variables, excluding the interaction terms and the intercepts. Our results show that three out of five bank-specific variables and four out of five macroeconomic variables (thus, only two out of five variables are insignificant).

Our results show that two of the three bank-specific variables significantly affect credit growth. In particular, size (liquidity) negatively (positively) affects the growth of credit. Additionally, they show that the nonperforming loan ratio negatively affects bank credit while the net interest margin has no explanatory power. In particular, the slowdown of bank credit can be explained by the rise in nonperforming loans from 6% in 2009 to 8.6% in 2021. These results show that bigger banks lend less to the private sector (which confirms data from Table 5). This surprising result aligns with the findings of Laidroo (2014), who suggests that smaller banks had to aggressively expand their lending to maintain their already low market share. In contrast, bigger banks that expanded aggressively in the pre-2008 crisis period had to disproportionally reduce their lending growth to improve the quality of their loan portfolios, which was worsened by their expansion during the 2006–2008 credit boom. This interpretation is supported by the negative correlation coefficient ($r_{size/nplr} = -0.550$) between bank size and the NPL ratio. Moreover, as expected, more liquid banks lend more. The results also show that capitalization has no impact on their extended loans.

As for the impact of the macroeconomic environment, the findings support the importance of demand-specific factors. Notably, credit growth is positively affected by the growth of non-agricultural GDP and the residential real estate price index and negatively by the inflation rate. Economic growth affects the demand for bank credit by improving economic agents' borrowing and repayment capacity and their anticipation of economic prospects. Similarly, real estate prices positively impact the supply and demand for credit as they indicate a rise in the demand for housing financing and collateral value. Finally, the inflation rate harms the demand for bank credit by negatively affecting purchasing power.

Furthermore, as expected, growth in bank credit is negatively affected by the increase in the monetary policy stance indicator. Indeed, a more restrictive monetary policy stance negatively affects the growth of bank credit. However, this result alone does not allow us to verify the existence of the lending channel in Morocco, as the effect of monetary policy on lending rates may pass through the demand for credit.

In this sense, the terms of interaction between the monetary policy stance and bank-specific characteristics are crucial to understand the role of the lending channel in Morocco. The results show that all interaction terms are insignificant, which indicates that the lending channel is not operational. This result validates the exploratory analysis that shows the disconnection between monetary policy stance and credit growth. Thus, based on the empirical results of Bennouna et al. (2016), Boughrara (2009), and Ouchchikh (2018), providing evidence of the operationality of the interest channel and the lack thereof in the case of the exchange rate and the asset price channels, monetary policy in Morocco is transmitted to the Moroccan economy only through the interest rate channel. Further evidence of the operationality of the interest rate channel in Morocco was also provided by (Boughrara, 2009; García-Ortíz and Pizarro-Barceló, 2010; Moumni and Nahhal, 2016; Ouchchikh, 2018).

CONCLUSION

The aim of this paper is to test the ability of conventional monetary policy to stimulate bank credit to the private sector in Morocco. The explored stylized facts show that the operational framework of conventional monetary policy in Morocco revolves mainly around regulating liquidity on the interbank market by injecting or withdrawing it in the short term, in line with BAM's orientations in achieving its ultimate objective of price stability.

Moreover, this policy is mainly accommodating in the absence of inflationary pressures characterizing the last decade. However, such a policy has not translated into a significant improvement in the pace

of growth of bank credit to the private sector in Morocco. Therefore, the relevant literature on monetary policy transmission is discussed to shape the analytical framework for the empirical study.

To establish an empirical link between the stance of monetary policy and the supply of bank credit in Morocco, microeconomic data is collected from the financial statements of a representative sample of the eight largest Moroccan banks, which account for over 97% of bank credit to the private sector in Morocco. Based on these data, econometric models capable of verifying the functioning of the bank lending channel in Morocco are estimated.

The results show that bank-specific characteristics play a decisive role in explaining the growth of bank credit to the private sector. In particular, while liquidity positively impacts bank lending, the bigger banks lend less. Furthermore, the results show that banks' perception of the risk associated with lending activity negatively affects bank credit growth. These results may be explained by a flight to quality by established banks. Faced with deteriorating borrower quality, banks are reducing the credit supply to preserve their margins and the quality of their loan portfolios.

The findings provide evidence that the illiquidity of certificates of deposits and their non-eligibility to bank deposit insurance is a possible reason for the weakening the lending channel in developing countries, suggesting that monetary policy in Morocco does not influence the supply of bank credit to the Moroccan private sector and calls into question the operationality and functioning of the lending channel. Thus, although the results show that monetary policy directly affects the growth of bank credit in Morocco, there is no empirical evidence that this policy can stimulate growth in the supply of bank credit.

Our results contrast with those of Boughrara and Ghazouani (2010), who suggest the existence of a capitalization-based lending channel. This contrast could be attributed to the weakened functioning of the lending channel. Boughrara (2009) attributed this possible weakening to a deterioration in the capitalization level of banks, an interpretation disproved by the improvement in the capitalization of the Moroccan sector, which rose from 8.4% in 2006 to 9.5% in 2021.

Our results also contradict the aggregate data results of (Bennouna et al., 2016; García-Ortíz and Pizarro-Barceló, 2010; Ouchchikh, 2018), which suggest the operation of the lending channel in Morocco in tandem with the traditional interest rate channel. As mentioned in the literature review, the results in aggregate data do not distinguish the operationality of the credit channel, as its response results from demand shifts.

In light of these results, the observed disconnect between the stance of monetary policy and the growth of bank credit to the private sector can be explained either by the fact that the fall in bank credit is the result of a tightening of credit supply, or by the fact that the impact of monetary policy is insufficient to counter existing depressors of credit demand.

The inoperability of the lending channel in Morocco may be a consequence of the underdeveloped capital market, constraining the ability of banks to hedge against monetary policy action by issuing certificates of deposits. As Moumni and Nahhal (2016) point out, further development and modernization of capital markets, improving the formality of the Moroccan economy, and improving the banking sector's competitiveness would all ameliorate the effectiveness of monetary policy in Morocco through the lending channel.

The weakening of the lending channel could also be attributed to the rise of non-bank institutions during the study period. In fact, the aggregate balance sheet of financing companies and microcredit associations rose by 63.1% and 64.5%, respectively, between 2009Q2 (the start of the observed decline of bank credit to the private sector and the change of Bank Al-Maghrib monetary stance) and 2021Q4. In comparison, the banking sector's balance sheet only rose by 49.4%. In their recently published work, Cafiso and Rivolta (2023), provided evidence that the transmission of monetary policy through the lending channel weakens with the rise in the size of non-bank lenders.

Finally, given these results, while remaining perfectly synchronized with the objective of price stability in the absence of alarming inflationary pressures, and with the predominance of bank credit in the financing of the Moroccan economy and the strong recourse of a large proportion of economic agents to this means of financing, the central bank must ensure that its monetary policy is increasingly geared towards stimulating bank credit. To achieve this, Bank Al-Maghrib may adjust the monetary policy framework to accommodate further private-sector financing. It could also make greater use of its non-conventional instruments, mainly by targeted refinancing operations conditional on improving the credit supply for SMEs and households – the cornerstone of credit demand and economic activity in Morocco.

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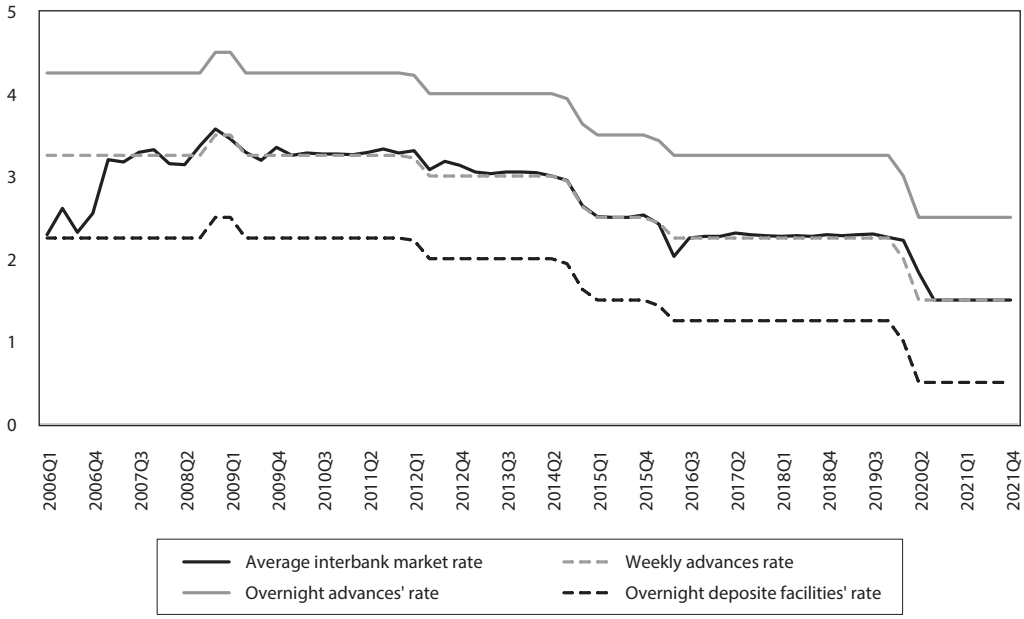
ANNEX

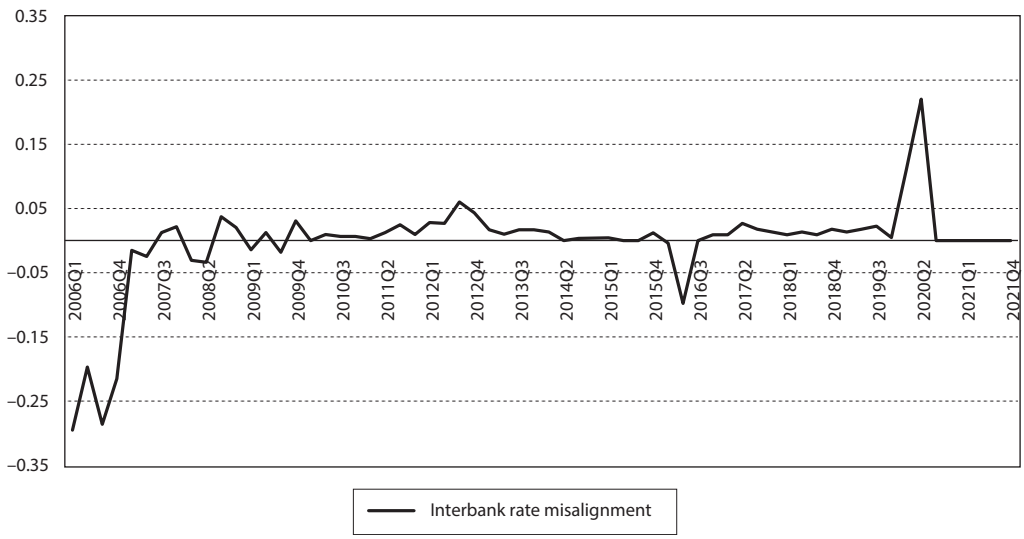
Table A1 Correlation matrix between bank credit to the private sector and its determinants

	$\Delta C_{i,t}$	$Size_{i,t}$	$Liq_{i,t}$	$Cap_{i,t}$	$NPLR_{i,t}$	$NIM_{i,t}$	ΔGDP	$\Delta RRPI_t$	ΔCPI_t	Δi_t
$\Delta C_{i,t}$	1									
$Size_{i,t}$	0.08	1								
$Liq_{i,t}$	0.328***	0.593***	1							
$Cap_{i,t}$	–0.409***	–0.055	–0.246***	1						
$NPLR_{i,t}$	–0.194**	–0.550***	–0.496***	0.380***	1					
$NIM_{i,t}$	–0.183**	–0.694***	–0.826***	0.288***	0.667***	1				
ΔGDP_t^{na}	0.412***	0.000	0.081	–0.159*	0.016	0.096	1			
$\Delta RRPI_t$	0.025	0.000	–0.056	0.037	–0.093	0.019	–0.236***	1		
ΔCPI_t	0.336***	0.000	0.171*	–0.166*	0.131	0.063	0.584***	–0.294***	1	
Δi_t	0.370***	0.000	–0.025	–0.160*	–0.123	0.151***	0.485	0.178**	0.367***	1

Note: *, **, *** mean that the correlation coefficient is significant at the 10%, 5%, and 1% threshold, respectively.
Source: Compiled by the authors

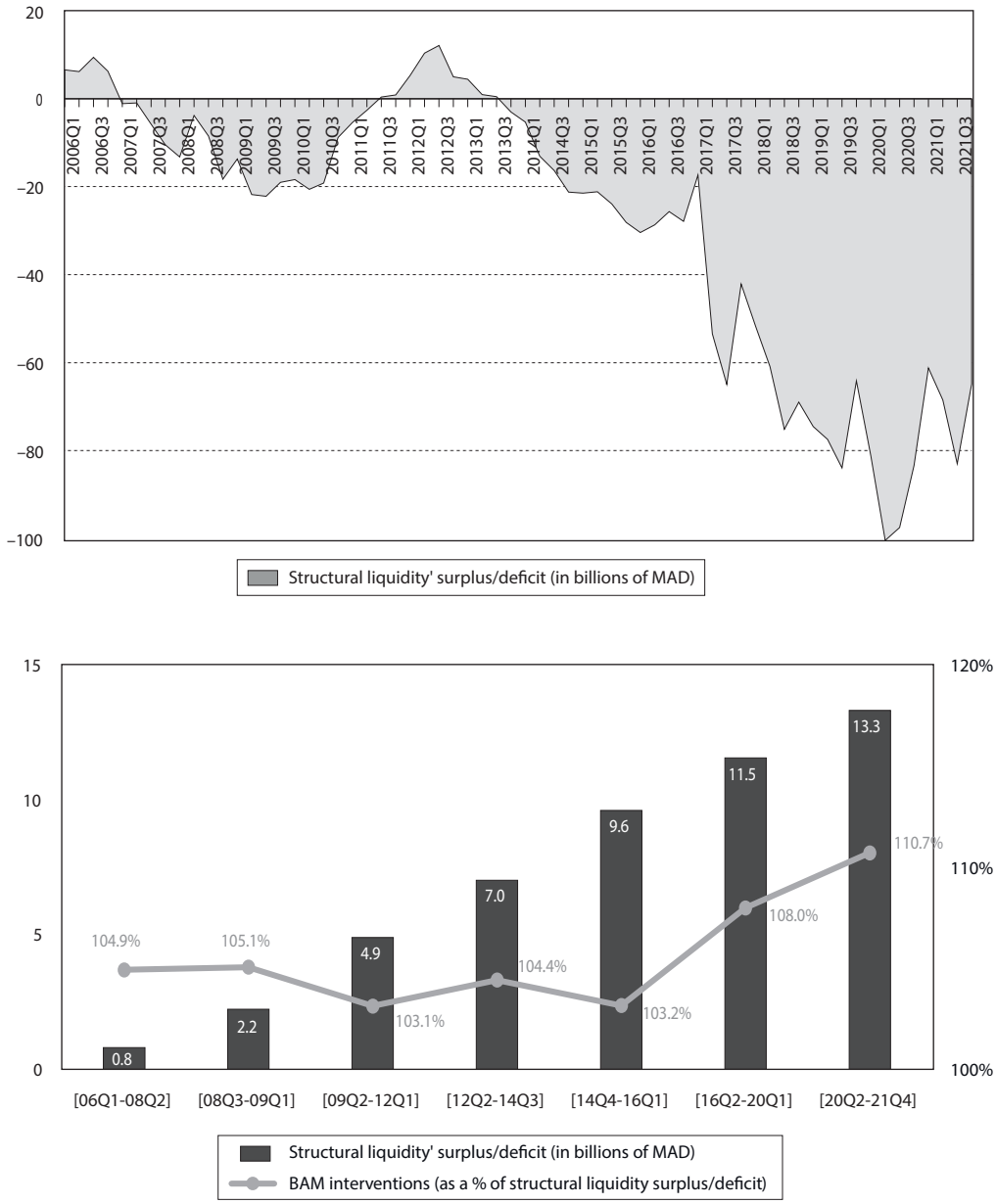
Figure A1 The misalignment of the operational objective of monetary policy in Morocco between 2006 and 2021





Source: Elaborated by the authors based on Bank Al-Maghrib data

Figure A2 Changes in the banking sector's structural liquidity position and BAM's intervention in the Moroccan money market between 2006 and 2021



Source: Elaborated by the authors based on Bank Al-Maghrib data

Identification of Digital Divide across Indonesian Provinces: the Analysis of Key Factors

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Abstract

Despite the economic and societal benefits of digitalisation and digital transformation, it is necessary to map country's digital conditions and identify the digital divide to formulate an effective strategy. The digital divide should be measured periodically to monitor progress and determine continuous improvement. This paper identifies the current digital divide among provinces in Indonesia. The study uses the hierarchical agglomerative clustering method based on The Indonesian Digital Society Index data from the Ministry of Communication and Informatics. It also analyses some key factors of the digital divide based on data from the Indonesian Bureau of Statistics using the multiple linear regression model. The results show three types of the digital divide across Indonesian provinces related to access, usage, and outcomes of information and communication technology. Gross Regional Domestic Product per capita, Wage/Salary, Proportion of Formal Labor, and Size of the Working-Age Population are identified as factors significantly affecting the digital divide.

Keywords	***DOI***	***JEL code***
Digital transformation, digital divide, hierarchical clustering, linear regression model.	*https://doi.org/10.54694/stat.2024.3*	*C38, O39, O53*

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INTRODUCTION

Information and Communication Technology (ICT) offers significant economic benefits and the potential to enhance welfare for individuals throughout their lives (Simamora et al., 2020). Digitalization has created new opportunities for innovation and entrepreneurship (Andita et al., 2022), especially in e-commerce and social media (Bismo et al., 2019). It has also enabled healthcare providers to deliver better and more efficient care through tools like electronic medical records, telemedicine, and remote patient monitoring (Rohmah et al., 2022). Digital technologies have transformed the manner how people learn and access educational resources through tools like online courses, digital textbooks, and educational apps (Block, 2018). Digitalization has helped businesses to automate many tasks, streamline operations, and increase efficiency and productivity (Hartono and Halim, 2020).

Despite these significant benefits, ICT and digital transformation, if not implemented thoughtfully and inclusively, can create a digital divide (Hayre et al., 2021). This divide can manifest in different ways, including disparities in access to computers, smartphones, broadband internet, digital skills, and digital content (Pokrovskaia and Garin, 2022). According to Ferreira et al. (2021) and Jauhiainen et al. (2022) the digital divide has three levels. The first level concerns access to the Internet and various ICTs. The second level relates to differences in digital skills and digital resource use. The third level entails the outcomes of accessing and using technologies.

Indonesia's digital development is essential due to its role as the largest economy in Southeast Asia (Kartiasih et al., 2023) and its strategic geographic position connecting diverse global trade routes. As in other developing countries, some Indonesian regions are much less developed than others, and a digital divide exists between the more developed and less developed regions (Wilantika et al., 2018). Therefore, measuring the digital divide at the regional level in Indonesia is crucial for promoting digital inclusion, economic development, and social equity (Ariansyah et al., 2019). It can help identify areas with limited access to digital technologies and services, the ICT's digital skills and outcomes, and the determinant factors to formulate the most appropriate strategy.

This study aims to determine the digital divide across Indonesian provinces based on the 2022 Indonesian Digital Society Index (Indeks Masyarakat Digital Indonesia, IMDI) published by the Ministry of Communication and Informatics. It applies the hierarchical agglomerative clustering analysis to group provinces based on digital pillar indexes. The groups provide a clearer picture of the digital divide across Indonesian provinces. Then, this study implements the multiple linear regression analysis to analyse the critical factors of the digital divide between the groups using the relevant data sources from the Central Bureau of Statistics of Indonesia (Biro Pusat Statistika, PS).

This paper is unique in its focus on the current differences in digital access, adoption, and usage across provinces in Indonesia. First, instead of using the composite index of digital development to identify the digital divide (Kartiasih et al., 2023; Wilantika et al., 2018; Ariansyah et al., 2019), this study uses the individual IMDI index, namely the Infrastructure Pillar regarding ICT access, the Digital Skills Pillar related to ICT Usage, the Empowerment Pillar, and the Work Pillar related to ICT outcomes. Second, this paper also, for each pillar, highlights the critical factors of disparities of the Indonesian provinces in access to digital technologies and the internet, as well as the digital skills and outcomes of digital technology.

The paper is structured as follows: First, we review the relevant literature, and then we present the methodology used to cluster the Indonesian provinces based on the digitalisation index and the linear regression method to analyse the factors contributing to the digital divide. Next, we present the results and their discussion analysis. Finally, we enclose this paper with conclusions and future research recommendations.

1 LITERATURE REVIEW

The digital divide refers to the gap between individuals, households, businesses, and geographical areas with access and those without access to ICTs and the gap in the efficient use of ICTs. This divide can manifest in different ways, including disparities in access to computers, smartphones, broadband internet, digital skills, and digital content (Pokrovskaia and Garin, 2022). The digital divide has three levels. The first level of the digital divide is the issue of access to the internet and various ICTs. The second level of the digital divide relates to differences in digital skills using digital resources. The third level of the digital divide entails the outcomes of accessing and using ICTs (Ferreira et al., 2021; Jauhiainen et al., 2022).

The digital divide can have significant consequences, as those lacking access to ICTs may be disadvantaged in education (Azubuike et al., 2021), employment, healthcare, civic participation, and social interaction. Moreover, the digital divide can exacerbate existing social and economic inequalities, as it can disproportionately affect disadvantaged groups such as low-income individuals (Singh et al., 2022), rural populations (Zhao et al., 2022), seniors (Yuan and Jia, 2021; Lopez-Ercilla et al., 2021), and people with disabilities (Kolotouchkina et al., 2022).

Identifying the digital divide requires carefully assessing various factors related to the access and use of ICTs. There are some common indicators to measure the digital divide. The first one is internet access (Singh et al., 2022; Arakpogun et al., 2020; Ferreira et al., 2021; Wilantika et al., 2018), which refers to the percentage of households or individuals with internet access to broadband or mobile data.The second one is the ownership of a digital device (Werfhorst et al., 2022). It measures the percentage of households or individuals who own a digital device, such as a computer, smartphone, or tablet. The third one is digital literacy, which measures digital skills and knowledge, such as using digital tools, navigating the internet, and understanding digital content (Ariansyah et al., 2019). The fourth one is the content and services (Pérez-Morote et al., 2020), which measure the availability and quality of digital content and services, such as e-government services, online education, and digital healthcare. Another feature is the geographic location (Sensuse et al., 2019; Zhao et al., 2022). It measures the urban-rural divide and regional differences in access to ICTs.

Measuring the digital divide involves collecting data from surveys (Petrillo et al., 2021), census data (Ferreira et al., 2021), or administrative records (Werfhorst et al., 2022). Then, the data is used to calculate various indicators and assess the level of digital divide across different population groups and geographic regions. Specific methodologies exist for analysing the digitalisation levels and identifying the digital divide. The study by Natalia (2022) used a regression model to determine the digital divide between EU countries during the COVID-19 pandemic. In addition, the study of Morote et al. (2020) used multiple linear regression analysis to identify the relationship between the e-government performance evaluations and citizens' use of e-government and the digital divide. To identify the digital divide among older people, Yuan and Jia (2021) used text mining, the Baidu index, and principal component analysis, while Werfhorst et al. (2022) studied the digital divide in online education using linear regression models.

Many researchers have applied clustering as an effective method for identifying digital divides due to its ability to analyse data and identify patterns within varying population groups (Pick et al., 2015). Some studies applied K-means clustering to group regions based on the digital index data (Kartiasih et al., 2023). Unlike K-means clustering, hierarchical clustering does not require a predetermined number of clusters, which is advantageous in exploring the unknown extent of digital divides (Nishida et al., 2014). Some research used spatial analysis to identify the digital divide by geographically mapping variations in digital access and usage (Pick and Nishida, 2015). It enables the visualisation of disparities in internet connectivity, access to digital devices, and digital literacy across different regions (Pick and Nishida, 2015; Lucendo-Monedero et al., 2019).

This geographical perspective is essential because the digital divide often correlates with spatial factors like urban-rural divides, socio-economic disparities, and infrastructural differences (Song et al., 2020). Spatial analysis thus transforms abstract data about digital access into actionable insights with real-world geographical context, making it an indispensable tool in bridging the digital divide.

Economic development plays a significant role in digital technology transformation; wealthier regions tend to have more resources to invest in digital infrastructure and provide their residents with greater access to technological tools and high-speed internet. Disparities in socio-economic and demographic factors predominantly determine the digital divide between regions within a country (Reddick et al., 2020). Additionally, regions with higher levels of educational attainment usually exhibit a smaller digital divide. Education increases awareness and the ability to use digital technologies and attracts industries and investments that enhance digital infrastructure. In contrast, others need more resources, infrastructure, and educational opportunities. Even though some studies analysed different digital divide factors, some aspects are generally applied in many studies. These factors include income per capita, population size, education, and formal workers (Nishida et al., 2014; Song et al., 2020; Kartiasih et al., 2023). These factors combined create a multifaceted digital divide within a country, where some regions advance rapidly in digital adoption and usage.

Identification of the digital divide between provinces in Indonesia is significant due to the large number of regions and the wide range of the digital divide. Moreover, it is crucial to analyse the critical factors of the divide to determine the most effective strategies to overcome it. Therefore, this study reveals the updated status of the digital divide across Indonesian provinces and analyses the key factors.

2 METHODOLOGY

This study aims to identify the digital divide between Indonesian provinces. Moreover, it also analyses the critical factors behind the divide. First, it clusters the provinces based on the digital development index of each IMDI pillar. Then, it uses the QGIS to visualise the clustering results in a map to show the spatial pattern of the digital divide. Second, it applies the multiple linear regression analysis to determine the dominant factors of the digital divide.

2.1 The data

This study identifies the digital divide across provinces in Indonesia based on the 2022 IMDI data published by The Indonesian Ministry of Communication and Informatics in December 2022 (Badan Litbang SDM Kementrian Kominfo, 2022). IMDI measures several aspects of digital participation, including access to digital infrastructure (such as internet connectivity and mobile phone ownership), digital literacy and skills, and digital entrepreneurship. These aspects are categorised into four pillars, namely: the Infrastructure and Ecosystem Pillar (IMDI1), the Digital Skills Pillar (IMDI2), the Empowerment Pillar (IMDI3) and the Work Pillar (IMDI4). Each pillar has a value between 0 and 100 and is constructed of several sub-pillars, as presented in Table 1.

In addition, this research uses relevant data from the BPS to analyse some key factors of the digital divide. The key factors (explanatory variables) used are Gross Regional Domestic Product (GRDP), Wage/Salary (W), Formal Labor (FL), Working-Age Population (WA), Gender Proportion (GNDR), Literacy Rate (LR), Secondary School Participation Rate (SSR), and Tertiary School Participation Rate (TSR). Table 2 presents the details of these factors. Meanwhile, the target variables of the analysis are all IMDI pillars. Čaplánová et al. (2023) present the data used in this study.

Table 1 The IMDI pillars and sub pillars

Pillar	Detail	Sub pillars
Infrastructure and Ecosystem (IMDI1)	This pillar is critical as it becomes the foundation for creating a quality digital ecosystem, which will improve internal adaptability and meet the industrial demands of the digital era.	1. Access and adoption of digital technology
		a. ICT access and usage data
		b. Implemented technology adoption in the business industry sector
		2. Digital Learning Ecosystem
		a. Schools with internet access
		b. Quality of higher education (number of faculties majoring in ICT)
Digital Skill (IMDI2)	This pillar measures people's ability to access, manage, understand, integrate, evaluate, communicate, and create information safely and appropriately through digital technology for employment, decent work, and entrepreneurship.	1. Complementarity
		a. Communication & collaboration
		b. Critical thinking
		2. Knowledge
		a. ICT knowledge
		b. Data literacy
		3. ICT Security
		a. Device security
		b. Personal security
Empowerment (IMDI3)	This pillar focuses on the ability of consumers/users and sellers/ providers to utilise digital technology developments productively.	1. Consumers/users
		a. Digital financial users
		b. E-commerce consumers
		c. Marketplace users
		2. Vendor/Provider
		a. Digital finance provider
		b. E-commerce seller
		c. Marketplace provider
		d. Social media
		e. E-learning provider
		f. E-learning users
Work (IMDI4)	This pillar focuses on two main elements: the demand for and availability of a digital workforce, which enables us to examine digital skill gaps.	1. Demand
		a. Highly demanded digital skills
		b. Company-provided digital training
		c. Digital skills by occupation
		d. Levels of automation and remote working
		2. Supply
		a. Proportion of workers who use the internet at work
		b. Diverse digital skills
		c. Job-related digital skill level
		d. Digital skills training

Source: IMDI 2022 Report document (Badan Litbang SDM Kementrian Kominfo, 2022)

Table 2 Selected explanatory variables used in the analysis

Category	Variable	Code	Description	Unit
Economic	GRDP per capita	GRDP	Gross regional domestic product per capita	Million Rupiah per year
Economic	Wage/salary	W	The average wage/salary per month	Rupiah per month
Economic	Formal labour	FL	The proportion of labour with formal work	Percentage
Demographic	Working age population	WA	Population 15 years of age and over who are working	Percentage
Demographic	Gender	GNDR	The proportion of male-to-female	Percentage
Education	Literation rate	LR	The literacy rate of the population aged 15–59 years	Percentage
Education	Secondary school participation rate	SSR	The school participation rate of the population aged 16–18 years	Percentage
Education	Tertiary school participation rate	TSR	The school participation rate of the population aged 19–24 years	Percentage

Source: Central Bureau of Statistics of Indonesia

2.2 Cluster analysis

By using the IMDI data, this study identifies three types of the digital divide, i.e., disparities of ICT access, usage, and outcomes (Guo and Wan, 2022; Lythreatis et al., 2022; Song et al., 2020). The IMDI1 regards the ICT access, IMDI2 relates to the ICT usage, while the IMDI3 and IMDI4 relate to the ICT outcomes. This study implements the hierarchical clustering analysis (Pérez-Morote et al., 2020) to categorise the digital gap across Indonesian provinces based on each IMDI pillar. Hierarchical clustering is a clustering algorithm used in machine learning and data analysis that groups similar objects or data points to nested clusters based on their similarity. Unlike the K-means clustering, this method does not need the predetermined cluster number. The feature is essential since there is no information about the number of clusters in the IMDI data. Therefore, the clustering of Indonesian provinces based on the IMDI data produces some clusters, and the distance between clusters indicates the difference, which is a sign of the digital divide between them.

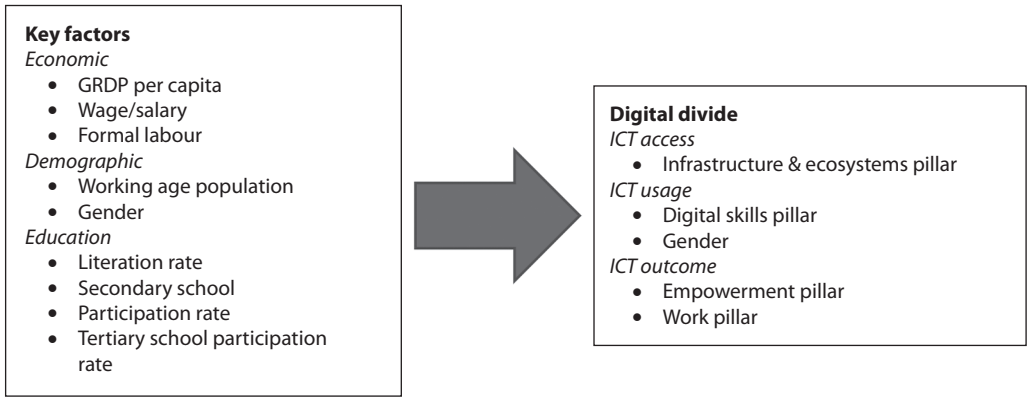
This study uses a hierarchical clustering algorithm, namely agglomerative clustering. This method starts by considering each data point as a separate cluster and then merges the two closest clusters based on a specified distance metric (Van Ruitenbeek et al., 2023). The algorithm continues to merge clusters until all data points are part of a single cluster. The clustering produces a dendrogram, a tree-like diagram showing the hierarchical relationships between the clusters. The dendrogram visualises the clusters, and the algorithm determines the optimal number for further analysis. This research uses Stata software to implement the hierarchical clustering algorithm with Ward's linkage method and Euclidean distance metric. Then, it uses QGIS to visualise maps of the clusters to present the spatial pattern analysis of the digital divide.

2.3 Regression analysis

Furthermore, this study uses statistical methods to analyse several vital factors of the digital divide across provinces in Indonesia. Figure 1 presents the conceptual framework of analysis in this research, which shows the key factors (economic, demographic, and education) and the three types of digital divide. It applies multiple linear regression analysis to determine the relationship between the target variables,

i.e., each of the IMDI pillars defined in Table 1, and the explanatory variables, i.e., key factors, as listed in Table 2. There are four target variables and eight explanatory variables, while the number of observations is thirty-four, which is the number of Indonesian provinces. This study uses the backward elimination method to select the four most significant explanatory variables for each IMDI pillar.

Figure 1 Conceptual framework of digital divide analysis



Source: Own construction

To analyse the critical factors of the digital divide across Indonesian provinces, this study develops the multiple linear regression model:

$$\mathbf{y}_i = \boldsymbol{\beta}_0 + \sum_{k=1}^{q} \boldsymbol{\beta}_k \mathbf{x}_{ik} + \boldsymbol{\varepsilon}_i, \tag{1}$$

where $i = 1, 2, ..., n$; n is observation number; $\mathbf{y}_i$ is i-th observation value of the target variable; $\mathbf{x}_{ik}$ is i-th observation value of k-th explanatory variable; $\boldsymbol{\beta}_0$ is the intercept value of the regression model; $\boldsymbol{\beta}_k$ is k-th regression coefficient; $k = 1, 2, ..., q$; $\boldsymbol{\varepsilon}_i$ is i-th regression error value. The intercept value and regression coefficients are estimated using:

$$\hat{\boldsymbol{\beta}}_k = \left(\mathbf{X}'\mathbf{X}\right)^{-1}\left(\mathbf{X}'\mathbf{y}\right), \tag{2}$$

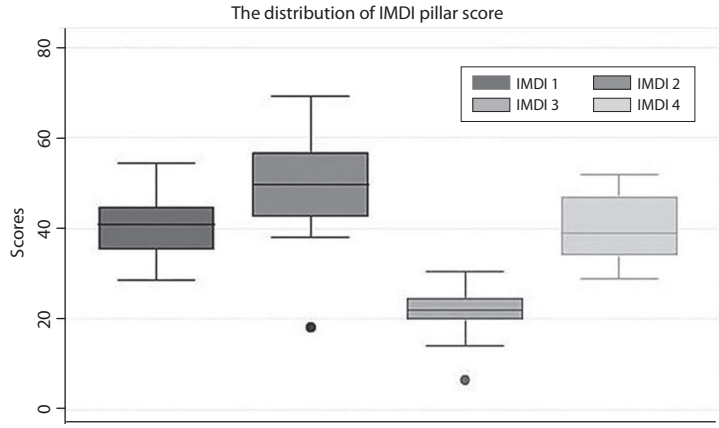
where $k = 0, 1, 2, ..., q$.

This study used Stata software to develop the linear model of each IMDI pillar. Then, it analyses the digital divide's critical factors in each IMDI pillar by identifying the significant coefficients of the linear regression model.

3 RESULTS AND DISCUSSION

This study looks into the variance of the IMDI scores across its four pillars – IMDI1, IMDI2, IMDI3, and IMDI4 – for each Indonesian province, as illustrated in Figure 2. The distribution of data for each pillar within the IMDI highlights substantial differences. Notably, the Digital Skills pillar emerges with the highest median, which indicates that the provinces possess significant potential in terms of human resources equipped with digital skills. In contrast, the Empowerment pillar has the lowest median, which suggests a prevalent shortfall in using ICT productively across most provinces. This discrepancy points to an underutilisation of existing infrastructure and digital competencies. Furthermore, the broader spread observed in the Digital Skills pillar points to a more pronounced disparity in digital skills among the provinces than the variances observed in other pillars.

Figure 2 Data distribution of IMDI pillar score

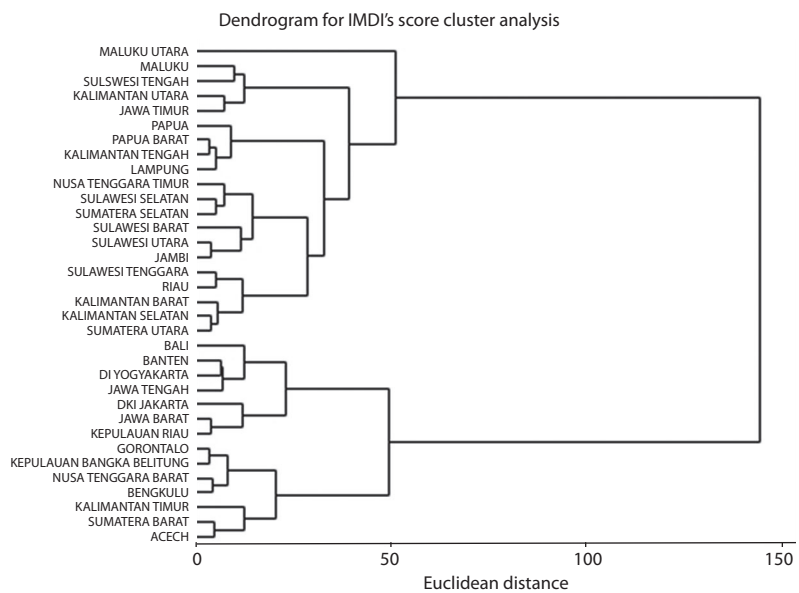


Source: Own construction based on 2022 IMDI data

3.1 Indonesian province clustering regarding the digital divide

This study uses a hierarchical agglomerative clustering approach based on Ward's linkage method and the Euclidean distance to analyse the digital divide and its characteristics among Indonesian provinces. It focuses on the digitalisation scores derived from the four IMDI pillars. The application of this algorithm yields a dendrogram that categorises the provinces into distinct clusters, as depicted in Figure 3. Four main clusters emerge if a dissimilarity threshold is set at fifty, with their respective provincial compositions detailed in Table 3. This classification points to prevalent digital disparities, with only seven provinces (approximately 20.59%) assigned to each cluster 1 and 2.

Figure 3 Dendrogram of Indonesian provinces clustering based on IMDI pillar score



Source: Own construction

Table 3 Clustering of Indonesian provinces based on IMDI pillars

No	Province	Cluster label	Number of provinces in the cluster	Proportion
1	Aceh	1	7	20.59%
2	Bengkulu			
3	Gorontalo			
4	Kalimantan Timur			
5	Kepulauan Bangka Belitung			
6	Nusa Tenggara Barat			
7	Sumatera Barat			
8	Bali	2	7	20.59%
9	Banten			
10	DI Yogyakarta			
11	DKI Jakarta			
12	Jawa Barat			
13	Jawa Tengah			
14	Kepulauan Riau			
15	Jambi	3	19	55.88%
16	Jawa Timur			
17	Kalimantan Barat			
18	Kalimantan Selatan			
19	Kalimantan Tengah			
20	Kalimantan Utara			
21	Lampung			
22	Maluku			
23	Nusa Tenggara Timur			
24	Papua			
25	Papua Barat			
26	Riau			
27	Sulawesi Barat			
28	Sulawesi Selatan			
29	Sulawesi Tengah			
30	Sulawesi Tenggara			
31	Sulawesi Utara			
32	Sumatera Selatan			
33	Sumatera Utara			
34	Maluku Utara	4	1	2.94%

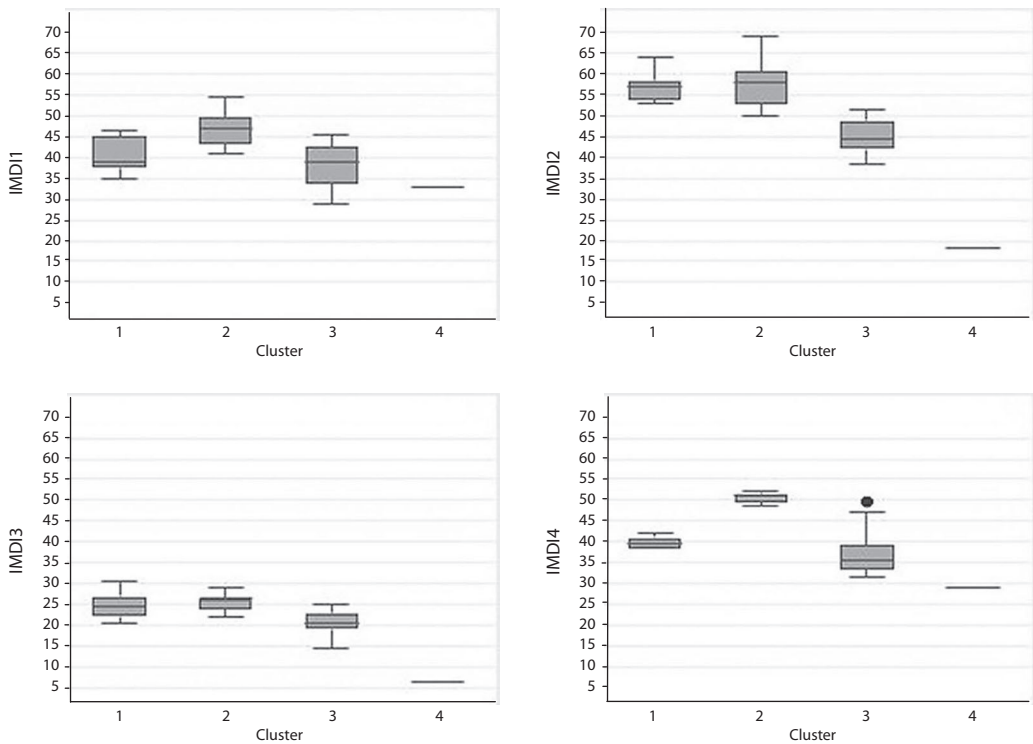
Source: Own construction

Most provinces (nineteen, or 55.88%) are allotted to cluster 3. At the same time, Maluku Utara is the only province in cluster 4, which indicates a pronounced digital divide in this province from the rest due to its unique IMDI scores. Cluster 2, which ranks at the forefront, includes provinces at the forefront of ICT development in Indonesia. This cluster encompasses provinces predominantly in urban areas with robust digital infrastructures, such as Bali, Banten, DI Yogyakarta, DKI Jakarta, Jawa Tengah, Jawa Barat, and Kepulauan Riau. Most of these provinces are strategically located on or near Java Island, close to the nation's capital, except for Bali and Kepulauan Riau. Bali's status as a prime tourist destination has catalysed its ICT advancements, significantly benefiting its tourism sector. Meanwhile, Kepulauan Riau's strategic position near key international maritime routes close to Singapore and Malaysia is vital in its economic and social landscape.

Cluster 1, which holds the second tier in the ranking, is composed of a diverse group of provinces, including four from the Western region – Aceh, Bengkulu, Sumatera Barat, and Kepulauan Bangka Belitung – along with three from the Northern and Eastern territories: Kalimantan Timur, Nusa Tenggara Barat, and Gorontalo. On the other hand, cluster 3, which is positioned third in the hierarchy, encompasses a wide array of provinces across the Indonesian archipelago. This cluster includes four provinces from Sumatera Island, four from Kalimantan Island, six from Sulawesi Island, two from the Papua Islands, and Jawa Timur, Maluku, and Nusa Tenggara Timur. These regions need further development of their ICT infrastructure.

The clustering distinctly points out that Jawa Timur is somewhat behind its counterparts on Java Island. Compared to other Javanese provinces in cluster 2, it falls into cluster 3, the third-ranking group.

Figure 4 The cluster characteristics regarding the mean value of each IMDI pillar



Source: Own construction

This discrepancy indicates the need for focused government and policymaker intervention to propel ICT advancement in Jawa Timur. This could narrow the digital divide between this province and its neighbouring provinces.

Figure 4 depicts the variability in scores for each IMDI pillar across clusters. This highlights the disparate levels of digital maturity among Indonesian provinces. In the Infrastructure and Ecosystem pillar (IMDI1), a significant disparity in median scores can be observed between clusters, which, together with a broad range of scores within each cluster, points to the vast differences in ICT infrastructure across the provinces. A similar pattern can be noted in the Digital Skills pillar (IMDI2), where the differences in median scores are evident between the higher-performing clusters 1 and 2 and the lower-performing clusters 3 and 4. This indicates a pressing need for enhancement in the latter clusters.

On the contrary, the Empowerment pillar (IMDI3) exhibits relatively tiny differences in median scores between and within clusters, suggesting a more uniform distribution of empowerment-related digital capabilities. The Work pillar (IMDI4) shows a considerable variance in median scores between clusters, which points to an uneven distribution of digital workforce opportunities and demands across the provinces. Mainly, Maluku Utara, categorised under cluster 4, requires urgent attention as it has the lowest scores in all IMDI pillars. This indicates a critical need for digital development intervention.

3.2 The type of digital divide in Indonesia

Figure 5 presents the map of Indonesian provinces to reveal the spatial pattern of the digital divide. The figure visualises the digital gap across the Indonesian provinces. Indonesia is a vast country with over 17 000 islands and a population of more than 270 million; like many other developing countries, it faces challenges and needs to reduce the digital divide.

The spatial pattern of the digital divide in Indonesia, as illustrated in Figure 5, highlights significant disparities between urban and rural areas and among the islands. As also stated above, urban centres like Jakarta, Yogyakarta, and Bandung, located mainly on the island of Java, exhibit higher levels of digital connectivity and infrastructure attributed to the concentration of economic activities, educational institutions, and government initiatives. In contrast, remote and rural areas, particularly in regions such as Papua, Maluku, and parts of Kalimantan and Sumatra, suffer from limited internet access and lower digital literacy rates.

Figure 5 Spatial pattern of the digital divide between Indonesian provinces

Source: Own construction

The determinant factors contributing to this divide are multifaceted. Infrastructure development plays a critical role. However, the country's archipelagic nature poses logistical and cost-related challenges in laying fibre-optic cables and establishing reliable internet services. Economic disparities also influence the divide, as individuals in less affluent regions struggle to afford the necessary devices and data plans. Furthermore, educational levels correlate with digital literacy, where areas with lower access to quality education face challenges in effectively adopting and utilising digital technologies. Cultural factors and language barriers further complicate the situation, with a diverse population across thousands of islands with unique cultural and linguistic identities. These complexities necessitate a tailored approach to bridging Indonesia's digital divide and the need to consider each region's unique challenges.

3.2.1 Digital divide in the infrastructure

Internet access and infrastructure stand at the forefront of addressing the digital divide. They are pivotal in establishing a robust digital ecosystem conducive to adapting to and thriving in the digital age. The clustering results reveal a pronounced digital divide across Indonesian provinces. It highlights the advanced infrastructure in Java's provinces and the more modest setup in regions further from Indonesia's current capital, Jakarta. This challenge of insufficient infrastructure is especially acute in remote and rural settings (Nishida et al., 2014), especially in Maluku Utara, an Eastern province formed in 1999 and comprising 1 474 islands, of which only 89 are inhabited. The province's geographical complexity and population density of 41 individuals per square kilometre as of 2021 complicates ICT infrastructure development, leaving many residents with limited or no internet access.

This lack of connectivity hampers the residents' ability to engage with the broader world, access vital information, and partake in the digital economy but also reflects the wider implications of socio-economic constraints on internet access (Reddick et al., 2020). Individuals unable to afford digital devices or internet services are further marginalised, exacerbating the digital divide even in those areas, where infrastructure might be available.

3.2.2 Digital divide in the digital skills

The digital divide also encompasses disparities in internet usage and digital skills (Ariansyah et al., 2019), with the latter referring to individuals' proficiency in utilising digital technologies effectively (Pokrovskaia and Garin, 2022). Internet usage varies by frequency and purpose. It can range from extensive use across work, education, and social interactions to limited activities like checking emails or browsing social media. Digital skills, on the other hand, encompass a range of competencies from online information retrieval and social media navigation to software application usage. Individuals with advanced digital skills can benefit from the full spectrum of digital technologies, while those with limited skills may need to catch up.

Digital skills are influenced by various factors such as age, socio-economic status, education, gender, geographic location, language proficiency, and physical or cognitive disabilities. For instance, older individuals may be less familiar with digital technologies, which affects their ability to acquire new digital skills (Yuan and Jia, 2021). Similarly, people from lower socio-economic backgrounds might have limited access to digital tools, which limits their opportunities to develop such skills (Natalia, 2022). Education level often correlates with digital skill proficiency since higher education provides more chances for formal training (Azmat et al., 2020). Gender disparities also play a role since societal and cultural norms can potentially hinder women's access to digital technology and learning opportunities (Simamora et al., 2020). Also, geographic location significantly impacts access to digital technologies, with rural and remote areas typically facing more significant barriers (Azubuike et al., 2021). Language barriers can further complicate the acquisition of digital skills, which makes using digital technologies more challenging.

People who are not digitally literate may struggle to develop digital skills (Saraeva, 2021; Padhi, 2019). People with disabilities may face physical or cognitive barriers in using digital technologies, which makes it more challenging to develop digital skills (Kolotouchkina et al., 2022).

Based on the clustering results, clusters 3 and 4 reveal a significant gap in digital skills, mainly consisting of provinces in Indonesia's more secluded and rural regions. The geographical challenges in these areas represent substantial obstacles not only for developing essential infrastructure, but also hinder economic growth, social cohesion, and educational advancements. Additionally, the lack of targeted digital literacy programs and inadequate investment in ICT education contribute to the widening digital skills gap. Moreover, socio-economic factors should also be taken into account. Lower-income households in these regions might struggle to afford digital devices and internet services, which limits their opportunities for practice and skill acquisition. Cultural attitudes towards technology and education can also play a role since traditional viewpoints may undervalue the importance of digital skills, particularly among older generations and in more conservative communities. These areas may also experience a brain drain as more digitally skilled individuals move to urban centres for better opportunities. Addressing these multifaceted challenges requires a concentrated effort from governmental and non-governmental organisations to implement inclusive policies and programs.

3.2.3 Digital divide in the outcomes

The third type of digital divide is related to the benefits and outcomes of digitalisation (Song et al., 2020). It refers to the unequal distribution of benefits and opportunities for using digital technologies. It includes differences in access to information, education, employment, healthcare, and civic engagement. For example, people with limited access to digital technologies may have difficulty in accessing online educational resources (Guo and Wan, 2022) or finding job opportunities that require digital skills. They may also have limited access to healthcare resources (Rohmah et al., 2022) as telemedicine and other digital healthcare tools become increasingly important. Additionally, people who cannot fully participate in online civic engagement, such as accessing government services (Andita et al., 2022) or participating in the online political discourse, may be disadvantaged in shaping public policy and public decision-making.

This analysis of IMDI shows that the digital divide in the form of outcomes is linked to the Empowerment (IMDI3) and Work (IMDI4) pillars. The Empowerment pillar evaluates the capacity of both consumers and providers to leverage advancements in digital technology to enhance productivity effectively. The Work pillar concentrates on the demand for digital workforce and availability dynamics. Based on the clustering results, the disparity between clusters 2 and 1 in the Empowerment pillar is relatively modest. Nonetheless, the gap significantly widens when we compare them to clusters 3 and 4. Furthermore, for the Work pillar, the differences here are stark, with cluster 2 leading over its counterparts. This considerable divide stems from the concentration of digital employment opportunities within urban areas, which typically have superior infrastructure and populations with more refined digital skills. Such observations point to a critical need for a holistic approach from the Indonesian government and other stakeholders. There is a pressing need to enhance digital literacy and skills across the population and foster job creation and entrepreneurial ventures that capitalise on these skills. This approach is essential for bridging the digital divide and ensuring equitable access to the benefits of digitalisation across Indonesia's diverse regions.

3.3 Analysis of the key factors of the digital divide

The digital divide highlights the divide between those with access to digital technologies and skills and those without across various dimensions, including individual, household, business, and geographic levels. The literature identifies a range of factors that contribute to the digital divide (Várallyai et al.,

2015; Lythreatis et al., 2022), including socio-economic factors like GDP per capita, education levels, employment status, income, and infrastructure availability; sociodemographic aspects such as age, gender, and urban versus rural dwelling; and personal factors including trust in technology, motivation to use technology, privacy concerns, and risk perceptions.

In this study, we use multiple linear regression analysis to study some factors underlying the digital divide across Indonesian provinces, drawing on the data from the BPS and IMDI data (Čaplánová et al., 2023). We explore the influence of eight explanatory variables (as listed in Table 2) on the digital divide, as indicated by the IMDI scores for each pillar (Table 1). We implement the backward elimination method to select four explanatory variables of each IMDI pillar with the smallest significance values. To confirm the absence of multicollinearity among the explanatory variables, we examine their variance inflation factor (VIF) values, as detailed in Table 4. With the highest VIF value recorded at 2.77, which is significantly below the commonly accepted threshold of 5, it is evident that the explanatory variables maintain their independence, which ensures the reliability and validity of the model's outcomes (Tarjáni, et al., 2023; Pick et al., 2015).

Table 4 The estimated model parameters for each IMDI pillar

Code	Target variables							
	IMDI1		IMDI2		IMDI3		IMDI4	
	Coeff	VIF	Coeff	VIF	Coeff	VIF	Coeff	VIF
GRDP	0.3029*	2.1						
W							0.3980*	2.0
FL	0.5856**	2.8	0.4377*	1.5	0.6581*	1.6	0.2	1.9
WA			0.3	1.1			0.4476*	1.2
GNDR	–0.7043***	1.4			–0.1	1.3		
LR	–0.2686*	1.9	–0.2	1.6	–0.4551*	1.9		
SSR			0.1	1.2	0.1	1.2		
TSR							0.2	1.1
Constant	0		0		0		0	
R-squared	0.7		0.3		0.3		0.5	

Notes: * significant at 0.05, ** significant at 0.01, *** significant at 0.005.
Source: Own construction

Table 4 presents the results of the regression analysis. Its focus on the Infrastructure and Ecosystem pillar reveals the influence of various factors on the development of ICT infrastructure within Indonesian provinces. The Gross Regional Domestic Product (GRDP) per capita is a significant predictor, having a positive relationship with the Infrastructure and Ecosystems pillar at a five per cent significance level. It suggests regions with higher economic output are better positioned to invest in and enhance their ICT facilities and internet connectivity. Furthermore, the positive regression coefficient of the Formal Labor (FL) (significant at a one per cent level) implies that a higher engagement of formal labour within a province contributes positively to establishing and expanding ICT infrastructure. This could be attributed to the formal sector's demand for efficient communication and information systems, which drive improvements in the digital ecosystem.

The Gender Proportion (GNDR) variable, indicating the ratio of males to females, and the Literation Rate (LR) exhibit negative coefficients, which suggests an inverse relationship with the Infrastructure and Ecosystem pillar. These could point to underlying complexities in how gender dynamics and literacy levels impact the development and utilisation of the ICT infrastructure. The negative coefficients might reflect disparities in access and usage of digital technologies between genders and varied literacy levels, requiring a structured approach and targeted interventions to bridge the digital divide in infrastructure and ecosystems.

The analysis of factors influencing the Digital Skills pillar reveals a significant relationship between the proportion of Formal Labour (FL) within a province and its population's level of digital skills. The positive coefficient associated with Formal Labour (significant at the five per cent level) suggests that an increase in formal employment opportunities correlates with enhanced digital competencies among the workforce. This correlation could be attributed to the formal work environment, which often requires and fosters digital skills development through structured training programs or the day-to-day use of digital tools and technologies. Consequently, regions with higher formal employment rates may provide more opportunities for individuals to acquire and refine their digital skills, thus contributing positively to the overall digital literacy and capabilities within those areas.

The analysis of the Empowerment pillar identifies a significant factor: the proportion of Formal Labour (FL) within a province. The presence of a substantial formal labour force is indicative of higher levels of ICT productivity. This correlation may be rooted in the structured nature of formal employment sectors, which often prioritise and invest in the ICT capabilities to enhance operational efficiencies and foster innovation. As a result, regions with a more significant percentage of their workforce engaged in formal employment are likely to witness an uplift in their ICT empowerment, as these environments typically encourage the use of advanced digital tools, promote digital literacy, and facilitate the practical application of digital skills in problem-solving and decision-making processes.

The analysis of the Work pillar highlights the significance of two key variables: Wage (W) and Working-Age Population (WA), both of which exhibit positive coefficients at a five per cent significance level. This suggests that higher wages and a larger working-age population within a province contribute to the dynamics of digital work in terms of supply and demand. Higher salaries can attract and retain talent within the digital sector, incentivise acquiring digital skills, and foster a competitive digital workforce. Similarly, a larger working-age population provides a broader base of potential digital workers and increases the likelihood of a more vibrant digital employment market.

However, the analysis reveals that the Secondary School Participation Rate (SSR) and Tertiary School Participation Rate (TSR) do not significantly affect the IMDI scores across all pillars. This finding suggests that mere participation in secondary and tertiary education may not directly translate into improved digital infrastructure, skills, empowerment, or work outcomes at the provincial level. It could be due to various factors, such as the quality of education, the relevance of educational content to the demands of the digital economy, and the extent to which digital skills are integrated into the curriculum. This highlights the importance of educational attainment and the need for educational systems to evolve and align more closely with the rapidly changing digital landscape to effectively contribute to reducing the digital divide.

CONCLUSIONS

This study provides new perspectives on the digital divide within Indonesian provinces. Using clustering and multiple linear regression analyses and the IMDI 2022 data, the analysis reveals three types of digital divide: infrastructure, digital skills, and outcomes. The infrastructure gap is especially pronounced, with many regions in Indonesia – particularly in rural and remote areas such as Maluku Utara Province – experiencing considerable difficulties stemming from insufficient internet infrastructure. In contrast, provinces located on Java Island have more advanced ICT infrastructure. This characteristic also applies

to Bali due to its closeness to Java and Kepulauan Riau, which gains an advantage from its strategic position close to key international trading pathways such as those near Singapore. However, with less than 21% of provinces having advanced ICT infrastructure, there is a clear imperative for intensified efforts towards infrastructure development. This need is especially relevant for Eastern Indonesia and rural and isolated regions, where enhancing digital infrastructure can be critical for bridging the digital divide and fostering more equitable access to digital opportunities across the archipelago.

The analysis highlights significant disparities in digital skills across its provinces, particularly between more developed urban areas and remote, rural regions. Such factors as socio-economic status, education, geographic location, and cultural attitudes play a crucial role in shaping individuals' access to and proficiency in digital technologies. The digital skills gap in less developed provinces is due to infrastructural deficits, limited internet connectivity, and insufficient ICT education. To effectively bridge this divide, it is imperative to implement inclusive digital literacy programs and infrastructure development initiatives that cater to each province's unique challenges, ensuring equitable digital inclusion and participation across Indonesia.

The analysis also reveals a digital divide centred around the unequal distribution of digitalisation's benefits, which impact access to information, education, employment, healthcare, and civic engagement. This divide, which we examined through the IMDI's Empowerment and Work pillars, shows significant disparities, particularly between urban centres and more rural or remote areas. These findings highlight the critical need for comprehensive strategies by the Indonesian government and stakeholders to enhance digital literacy, expand digital infrastructure, and create inclusive opportunities for digital engagement and employment.

The regression analysis confirmed the multifaceted nature of the digital divide in Indonesia and has shown how economic prosperity, wages, formal labour engagement, gender dynamics, literacy levels, and the size of the working-age population influence the development of digital infrastructure, skills, empowerment, and workforce dynamics across Indonesian provinces. Higher GRDP per capita and formal labour positively affect the advancements in ICT infrastructure. Formal labour also positively affects digital competencies and empowerment. While wage and working-age populations have a positive influence on work. This suggests that economic strength and formal employment are crucial in enhancing digital ecosystems. However, the negative associations of gender proportion and literacy rates with infrastructure development highlight complex underlying factors that may contribute to access and usage disparities. Surprisingly, secondary and tertiary education participation rates did not significantly impact digital outcomes. This finding may indicate a need for education systems to adapt to ICT more effectively.

Even though this study provides valuable insights into the digital divide in Indonesia, it is essential to recognise its limitations for a comprehensive understanding of the problem. The reliance on IMDI data from just one year limits the scope of the analysis. This approach may not fully reflect digital development's dynamic and evolving nature and skew the interpretation of current states and trends. Furthermore, the study's dependence on a limited set of variables available in the BPS data means that other influential factors remain unaccounted for, which could be critical for understanding the nuances of the digital divide. These could include cultural attitudes towards technology, specific policy impacts, or the role of private sector initiatives in ICT development.

Given the limitations highlighted in the current study, future research should focus on broadening the scope of the analysis. It would be beneficial to incorporate longitudinal data that spans multiple years, capturing the dynamic nature of digital development and enabling researchers to identify trends and patterns over time. Additionally, expanding the range of variables, such as cultural attitudes towards technology, the impact of specific governmental and non-governmental policies, and private sector initiatives contributions, could uncover other critical factors influencing the digital divide. Also, the qualitative data obtained from interviews or case studies could enrich the analysis and provide contextual depth to the quantitative findings.

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Effect of Energy Consumption on Green Bond Issuance

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Abstract

Green Bonds are fixed-income securities specifically designed to support climate and environmental projects. The demand for the green bond market is growing every day. Green Bonds are gaining importance as they appeal to environmentally conscious investors and are financial instruments that provide economic benefits. The main motivation of this study is to determine whether energy consumption has an effect on green bond issuance. In this context, the relationship between the green bond issuance amounts of 12 countries, including Australia, Canada, China, France, Germany, Japan, the Netherlands, New Zealand, Norway, Sweden, England and the United States, in the years 2014–2021 and the amount of energy consumption in the same period are analysed by panel data analysis. The findings show that there is a significant relationship between coal, peat and oil shale, oil products, natural gas, renewables and waste, electricity and total energy consumption. In the expected direction there is a linear relationship between sustainable energy resources and the green bond issuance.

Keywords	***DOI***	***JEL code***
Green bond issue, energy consumption, panel data analysis	*https://doi.org/10.54694/stat.2023.18*	*C23, G15, 013*

INTRODUCTION

The industrial revolution and consequent development of production processes based on fossil fuels brought population growth and economic prosperity. It has also raised social and environmental challenges by reducing the availability of previously abundant natural resources. Mass production and consumption emerge as a major factor in the deterioration of climate change and ecological balance through the pollution and depletion of natural resources (Schoenmaker, 2017: 7). The negative effects that have emerged with the rapid development of the global economy have caused environmental awareness to come into prominence more than ever before. As a result of the globalization of the economy, the developments in the financial markets have both technological and structural effects on the environment. Many steps have been taken to protect and improve the green environment, especially through green financing instruments. Therefore, the increase of awareness of sustainability in financial terms has led to the green bond implementation.

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Green bonds are financial instruments issued for the use of financing sustainable green projects related to the environment and climate change. Additionally, green bonds have emerged as a promising way to finance the transition to a lower carbon, flexible economy (Banga, 2019: 17). Although there are different definitions of green bonds, there is a growing consensus on for what purpose they are used (OECD, 2017). Many subjects such as renewable energy, green buildings, clean transportation, sustainable waste management, sustainable land use, biodiversity and clean water, financing of environment or climate-friendly projects can be included in the scope of green bonds (MacAskill, Roca, Liu, Stewart and Sahin, 2021: 2). The growing environmental awareness will cause investors to consider social and environmental values as well as financial values. For this reason, investors are more encouraged to adapt their business models to create not only financial values, but also social and environmental values (Schoenmaker, 2017: 32).

Energy is a special issue as it is a key input in almost all other consumption and production processes. Therefore, energy is a very important parameter that controls growth and determines many aspects of human activity in general (Tukker, Charter, Vezzoli, Stø and Andersen, 2017: 113). Energy is fundamental for economic and social development and improving the quality of life in all countries. Energy is described as the ability to do work and can be found in different forms such as chemical, thermal, electrical, mechanical, gravitation, nuclear, radiation, sound, and motion. Energy can be stored, converted or amplified depending on the implementation. Energy sources can be fossil (oil, coal, petroleum, natural gas, etc.), renewable (biomass, hydro, wind, solar, geothermal, marine, hydrogen, etc.) and nuclear (uranium, thorium). The causal effect of emissions generating from burning fossil fuels on climate change is also important for the provision of energy services. In order to reduce or eliminate the effect of this situation, it is necessary to gravitate toward renewable energy sources and increase the production obtained from these sources. For this reason, the financing of green projects becomes crucial. In this context, the purpose of the study is to analyse the effect of energy consumption on green bond issuance. The literature review, research data set, model, method and analysis findings of the study will be explained in order in the following sections.

1 LITERATURE REVIEW

Green finance has attracted the academicians' attention in the last few years, and the literature on green bonds has been enriched with new contributions. By means of these studies, it is understood that green bonds can contribute to the construction of a more sustainable economy and have an awareness-raising effect (World Bank, 2019). When the studies on green bonds are examined, it became clear that many of them enlighten the theoretical framework (Kandır and Yakar, 2017; Ehlers and Packer, 2017; Banga, 2019; Akdağ and Gözen, 2020; Menteşe, 2021; MacAskill, Roca, Liu, Stewart and Sahin, 2021; Özcan and Durmuşoğlu, 2022). In these studies, the development and implementations of green bond and surveys on green bond was carried out. Additionally, there are studies in which econometric models related to the green bond market are built. Reboredo and Ugolini (2020) examined the price link between green bonds and financial markets using the VAR model. As a result, they confirmed that the green bond market was feebly depending on the stock, energy and high-yield corporate bond markets. Reboredo (2018), on the other hand, explained that green bonds have great benefits in diversification for investors in stock and energy markets. Baulkaran (2019) analysed the stock market reaction to the green bond issuance announcement. He stated that the shareholders saw this version of financing as an increment value and the funds obtained from the issuance of green bonds were considered to undertake the profitable green projects or as a risk reduction tool. Wang, Chen, Li, Yu and Zhong (2020) examined the stock market reaction to green bond issuance in China. Pham and Nguyen (2022), on the other hand searched the effects of changes in stock, oil prices and uncertainty of economic policy on green bond yields. Yağcılar and Yilmaz (2022), also examined the reaction

of the stock market investor to the announcement of green bond issuance. As a result, they could not come to the conclusion that green bond issues in Turkey make a significant contribution to stockholder value.

Besides these studies, there are also studies examining green bond and energy variables in the literature. Taghizadeh-Hesary, Phoumin and Rasoulinezhad (2023) studied the effects of green bonds issued in Japan and volatility in energy prices on the consumption of three types of green energy (wind, solar and hydro). As a result, they stated that the green bonds issued had positive long-term effects. Ye and Rasoulinezhad (2023) investigated the impact of green bonds issued in 15 Asia Pacific countries on the efficiency of natural resource use. They found that issued green bonds had positive and statistically significant effects on renewable natural resource use efficiency in the short and long term. Huang et al. (2023) examined the impact of investor sentiment and green bond issuance on fossil fuel consumption. They conducted an analysis based on data between 2015 and 2022 for the top ten environmentally sensitive countries. Their findings show that a 1% increase in green bond issuance volume results in a 0.12% decrease in crude oil, a 0.49% decrease in coal and a 0.09% decrease in natural gas consumption.

Dong, Li, Gao and Sun (2023) examined the effects of green bond issuance on renewable energy consumption in Southeast Asian countries. The results showed that the issuance of green bonds was an effective green finance tool in the implementation of development policy related to the distribution of renewable energy in countries in the Southeast Asian region. Zhao, Chau, Tran, Sadiq, Xuyen and Phan (2022) investigated the effect of green bond financing on the investment of energy efficiency for green economic recovery. The findings of the study revealed that green bonds were currently the primary source of financing and increasing the economic growth by 4.9%.

2 RESEARCH DATA SET AND METHOD

As energy consumption increases, the dependency on energy sources that will produce the required energy is also increasing. It is possible to come up with the energy problems over time, especially since fossil fuels are resources that are subject to depletion. Indeed, the energy crisis that started in the 3rd quarter of 2022 in Europe has once again revealed the extent of the need for renewable energy resources: The Paris Climate Agreement also emphasized the importance of supporting environmentally friendly, renewable energy sources in terms of financing due to possible energy crises in the future. Accordingly, it is of great importance to provide the energy production need brought by the increasing energy consumption through sustainable energy investments performed by green financing instruments. In this respect, the main motivation of the study is based on research on the effect of energy consumption on the green bond issuance. Here, data on annual energy consumptions for the data set were obtained from www.iea.org website.

In order to meet the growing need for climate-related data, the IMF and international organizations (OECD, World Bank Group, United Nations, European Commission, European Statistical Office – Eurostat, Food and Agriculture Organization – FAO, International Energy Agency – IEA, and National Oceanic and Atmospheric Administration – NOAA) have been concertedly sharing comprehensive statistical indicators on issues such as climate change, greenhouse gas emissions of economic activities and green finance. In this direction, the data set regarding the annual green bond issuances of the countries was obtained from climatedata.imf.org. The World Bank (2015) defines a green bond as "a debt security that is issued to raise capital specifically to support climate-related environmental projects". In other words, green bonds are fixed-income securities specifically designed to support climate and environmental projects. The green bond market has reached an annual growth rate of 50% since its establishment in 2007. In 2014, the total amount of green bond issuance reached 36.6 billion USD, more than three times the previous year (11 billion USD). This new market is a response to investors' growing demand for financial investments that are both environmentally and economically beneficial. As the green

bond market continues to grow, it is important to better understand its risk and return behaviour (Pham, 2016: 263). Therefore, this study investigates the effect of energy consumption on the green bond issuance.

The time range of the data set covers the years 2014–2021. The countries and the years of the relevant data set have been created by considering their continuity. Selected countries comprise 12 countries of Australia, Canada, China, France, Germany, Japan, Netherlands, New Zealand, Norway, Sweden, the United Kingdom and the United States. Green bonds are relatively new financial instruments. The number of countries that regularly issue green bonds every year is limited. For this reason, 12 countries were included in the analysis. The selected countries are those who regularly issue green bonds in the relevant years.

Other explanations of the variables used are shown in Table 1. Detailed explanations on energy variables are presented in the "World Energy Balances Highlights 2023" report prepared by the IEA.

Table 1 Variables

Variables		Scale	Resource
GB	Green Bond	Billion USD (yearly)	climatedata.imf.org
A	Coal, peat and oil shale	Total final consumption (PJ)*	www.iea.org
B	Oil products		
C	Natural gas		
D	Renewables and waste		
E	Electricity		
F	Total		

Note: * Equal to the sum of the consumption in the end-use sectors. Energy used for transformation processes and for own use of the energy producing industries is excluded. Final consumption reflects for the most part deliveries to consumers.
Source: Own elaboration based on Climatedata and IEA

The analysis of panel data is used to test the models that include time- series and cross-section data together. In this context, the research method was carried out with the help of panel regression analysis, as the research dataset includes different countries and different variables belonging to these countries. Panel data analysis was first used in the studies made by Hildreth (1950), and Kuh (1959). However, its real popularity began in the 1990s (Tatoğlu, 2018: 3).

As for the model selection within the scope of the analysis, LR, F and Hausman (1978) tests were performed. According to the results of the relevant tests, it was determined that the fixed effects estimator was appropriate for the model. Finally, the basic assumption tests of the fixed effects model were tested and regression analysis was performed with the Driscoll Kraay resistant estimator.

3 RESEARCH MODEL, ANALYSIS AND FINDINGS

The model fictionalized within the context of research analysis, the performed analysis and findings will be explained respectively below. In this context, first of all, descriptive statistics of the variables are given and the details are shown in Table 2.

Table 2 Descriptive statistics

Variable		Obs.	Mean	Std. dev.	Min	Max
GB	Green Bond	96	11.58	15.992	0.092	74.386
A	Coal, peat and oil shale	96	2 456.862	7 550.586	17.247	32 372.313
B	Oil products	96	6 259.867	9 422.505	254.34	31 739.162
C	Natural gas	96	2 610.074	4 135.022	23.281	16 018.751
D	Renewables and waste	96	940.78	1 570.717	33.07	5 580.397
E	Electricity	96	3 916.359	6 472.156	139.602	27 291.648
F	Total	96	1 6682.2	27 080.182	560.129	96 995.299

Source: Own elaboration based on data from Climatedata and IEA

The model to be used in the analysis is structured as follows:

$$GB_{it} = \alpha_{it} + \beta_1 A_{it} + \beta_2 B_{it} + \beta_3 C_{it} + \beta_4 D_{it} + \beta_5 E_{it} + \beta_6 F_{it} + u_{it}, \quad (1)$$

here: α; represents constant term, "β" the explanatory variable coefficient and "u" the random error term i: units, t: time. Explanations of the variables GB, A, B, C, D, E and F are given in Table 1. After the step of determining the independent variables, the appropriate regression model should be selected. In this context, F test provides an opportunity to make a choice between the classical model and the fixed effects model (Tatoğlu, 2018: 168). The LR test, on the other hand, between the classical model and the random effects model. If the classical model selection is not considered appropriate in terms of the F test and LR rest results, a choice is made between Hausman (1978) test and the fixed effects model or the random effects model.

In this context, the results of the relevant tests are given in Table 3.

Table 3 Determining the appropriate regression model

UNIT EFFECT (Prob>F)	TIME EFFECT (Prob>Chibar2)
Fixed effects (F test)	
Probability value: 0.0000	Probability value: 0.0000
H_0: Unit effects are not significant	H_0: Time effects are not significant
Random effects (LR test)	
Probability value: 0.0000	Probability value: 0.0000
H0: Unit effects are not significant	H0: Time effects are not significant
Hausman test (Prob>Chi2)	
Probability value: 0.0123	

Source: Own elaboration based on data from Climatedata and IEA

When the analysis results in Table 3 are examined, it has been determined that there is a unit and time effect in terms of the results of the F test and LR test, and the classical model is not appropriate. Hausman (1978) test was applied to make a choice between the fixed effects model and the random effects model (Tatoğlu, 2018: 188). According to the results of the two-way Hausman test which considers the unit and time effects together, the probability value was determined as 0.0123. In this case, it has been determined that the use of the fixed effects estimator is appropriate.

The final situation to consider before applying the regression analysis is to perform the basic assumption tests of the model. These assumptions comprise of varying variance, autocorrelation and correlation between units. The test results of the assumptions are shown in Table 4. According to the test results, it was concluded that there was varying variance, autocorrelation and inter-unit correlation for the fixed effects model.

Table 4 Basic assumption tests of Fixed Effects Model

Heteroskedasticity (Wald Test)	Autocorrelation (Durbin-Watson Test)	Inter-Unit Correlation (Pesaran CD Test)
Prob>chi2 = 0. 0000	Durbin-Watson = 1.0550556 Baltagi-Wu LBI = 1.6805674	p-value = 0.0000
H_0: There is no varying variance	If values are less than 2, there is autocorrelation	H_0: There is no correlation between units

Source: Own elaboration based on data from Climatedata and IEA

Wald Test calculates a modified Wald statistic for groupwise heteroskedasticity in the residuals of a fixed effect regression model (Greene, 2000: 598). In respect of the results in Table 4, where the basic assumption tests of the fixed effects model were tested, the Driscoll Kraay resistant estimator should be used for the final regression model. Deviations in basic assumptions are considered with this robust estimator. The results of the regression analysis performed in this context are given in Table 5.

Table 5 The results of regression analysis

	Variable	Coefficients	Std. error	t-value	p-value
A	Coal, peat and oil shale	–0.118	0.027	–4.360	0.003*
B	Oil products	–0.096	0.022	–4.390	0.003*
C	Natural gas	–0.115	0.030	–3.800	0.007*
D	Renewables and waste	0.102	0.048	2.140	0.069***
E	Electricity	–0.129	0.031	–4.110	0.005*
F	Total	0.090	0.022	4.100	0.005*
_cons		113.486	19.032	5.960	0.001*
Number of observations(N)		96			
R^2 value		0.4417			
Prob>F		0.0000			

Note: *** %10, ** %5, and * %1 represent the significance.
Source: Own elaboration based on Climatedata and IEA

When the regression analysis results in Table 5 are examined, the probability value of Prob>F (0.0000) figures the statistical significance at the 1% level of significance. The explanatory power of the model was determined as R^2 value of 0.4417 (44.17%). This value indicates the explanatory power of the independent variables on the dependent variable.

Additionally, it was determined that green bond issuance has a significant relationship (GB) with the coal, peat and oil shale (A) (p = 0.003), oil products (B) (p = 0.003), natural gas (C) (p = 0.007), renewables and waste (D) (p = 0.069), electricity (E) (p = 0.005), total (F) (p = 0.005). In addition, a positive relationship was detected between green bond issuance (GB) and Renewables and waste, and a negative relationship was found with other variables.

CONCLUSION AND RECOMMENDATIONS

The use of renewable energy sources as an alternative to fossil fuels has gained importance day by day in supplying the increasing energy needs. The energy provided from renewable energy sources requires new investments in related production tools. Therefore, green bonds emerging to be used in the financing of renewable energy investments are considered as an opportunity. Green bonds are financial instruments issued to finance projects related to environmental sustainability and climate change. It is generally used to support environmental projects such as energy efficiency, renewable energy and waste reduction. These bonds both provide an opportunity for investors to create environmental impact and contribute to the green economy by supporting sustainability efforts in the energy sector. Environmentally friendly investments are of great importance in reducing the negative effects of climate change and resource use. It also encourages companies to adopt more responsible practices, promote innovation in clean technologies, and create a positive impact on the environment. It is thought that the accompanying increase in environmental awareness will increase the demand for green bonds. In this context, the relationship between energy consumption and green bond was examined in the study.

In the study, energy consumption data of countries that regularly issue green bonds were taken into account. For this reason, 12 countries could be included in the scope of the study. The widest time period covering all these countries was reached between 2014 and 2021. The variables are Green Bond issuances by country and total final consumptions for energy variables. The findings reveal the existence of a significant relationship between green bond issuances (coal, peat and oil shale, oil products, natural gas, renewables and waste, electricity, total consumptions for energy) and the energy consumptions examined. These results are showing similarities with the studies of Ye and Rasoulinezhad (2023), Huang et al. (2023).

The relationship between renewable energy consumption and green bonds often reflects the purpose of these bonds to fund energy projects. By providing financial support to renewable energy projects through green bonds, investors invest in projects that reduce carbon emissions and promote environmental sustainability. In this context, projects financed with green bonds may include efforts to use renewable energy sources and make energy consumption more sustainable, such as wind power plants, solar energy projects, hydroelectric facilities and energy efficiency improvement projects. Research results revealed a positive relationship between renewables and waste energy consumption and green bonds issuance.

Other results obtained within the scope of the research show a negative relationship between coal, peat and oil shale, oil products, natural gas, electricity and total energy consumption and green bonds. Green bonds generally aim to finance projects aligned with environmental sustainability. Coal is one of the oldest and most widely used fossil fuels. However, burning coal causes greenhouse gases to be released into the atmosphere and contributes to climate change. Therefore, reducing coal use can contribute to increasing the use of sustainable energy sources and investing in green energy projects.

The electrical energy sector is one of the largest sources of greenhouse gas emissions worldwide. The largest sectoral increase in emissions in 2022 came from electricity and heat production (IEA, 2022: 3).

The production of electricity through green bonds by environmentally friendly production facilities can have a restrictive effect on greenhouse gas emissions.

Petroleum products and natural gas generally refer to products derived from fossil fuels and used in various industries. The use of these products also causes environmental impacts and climate change problems. Therefore, considering that green bonds are financial instruments that aim to invest into environmentally friendly projects, the projects supported by green bonds may lead to a decrease in the dependence on these energy resources. In this context, energy obtained from coal, peat and oil shale, oil products, natural gas is generally incompatible with green bond criteria. Therefore, it is acceptable to have a negative relationship between them, as obtained in the research results.

The governments agreed to meet the increasing energy needs with renewable energy sources with the growing environmental awareness especially after the Paris Climate Conference, and also many countries even put forward incentive packages for investments in renewable energy sources. Financial institutions and markets are not indifferent to these incentives, and they provide green financing support to companies that operate using environmentally friendly technologies and contribute to sustainable life, with many environmentally friendly green financing instruments they have developed. Green bonds have emerged as one of these financial instruments. The amount of energy obtained from renewable energy sources will also increase with the increase in the issuance of green bonds. In fact, the International Energy Agency has also made statements that approximately 30% of the energy need will be met by renewable energy sources until 2030. Accordingly, the use of renewable energy rather than fossil fuels in energy consumption will be effective in reducing the environmental problems.

In this study, only green bonds from green financing instruments were examined. However, it should not be ignored that investments in renewable energy resources are financed with other green financing instruments. However, since green financing instruments have emerged recently, there may be difficulties in collecting data on them. In the future, it can be predicted that the demand for green financing instruments will increase and their use will become widespread due to reasons such as increasing environmental awareness and focusing on projects that protect nature. This may inspire a new research by providing easier access to large data sets.

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Analyzing Determinants of Spatial Patterns in Total and Industrial Electricity Consumption in Turkey

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Abstract

This research investigates the spatial correlation among per capita electricity consumption, per capita industrial electricity consumption, and economic growth by employing various regression models, including linear regression, geographically weighted regression, and multi-stage geographically weighted regression. The primary goal is to illustrate the presence of spatial effects in the connection between electricity consumption and economic growth. In this context, this study made for Turkey distinguishes itself from previous research by utilizing the multi-stage spatially weighted regression model to examine this relationship. The findings reveal that the multi-scale spatial regression model is the most effective in explaining the relation between economic growth at the provincial level and per capita electricity consumption and per capita industrial electricity consumption. Moreover, the study emphasizes that per capita Gross Domestic Product emerges as the most influential regional economic indicator when assessing its impact on per capita electricity consumption and per capita industrial electricity consumption.

Keywords	***DOI***	***JEL code***
Geographically weighted regression, multi-scale geographically weighted regression, spatial analysis	*https://doi.org/10.54694/stat.2024.2*	*C10, C19*

INTRODUCTION

The relationship between electricity consumption and economic growth is a complex issue. This relationship can vary depending on various factors and is often shaped by factors such as the country's economic structure, energy policies, technological developments, and energy efficiency. Firstly, the positive relationship between electricity consumption and economic growth is generally associated with industrialization and the development process. Economic growth often comes with increased production and industrial activities. Turkey has experienced significant developments in the energy sector in recent years and has strengthened its strategies for energy production in line with its economic growth objectives.

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In this context, electricity production plays a critical role in Turkey's energy independence and sustainable development goals. The relationship between electricity production and growth provides an important perspective for understanding both economic dynamics and changes in the energy sector. Turkey's economic growth objectives, along with expansion in industry, trade, and service sectors, result in an increased energy demand. This rise in demand increases the need for energy production, consequently raising the country's electricity consumption. Electricity production holds strategic importance in responding to this increased demand and ensuring energy supply security. Moreover, the increase in electricity production can positively impact employment in the energy sector, thus contributing to economic growth. Investments in renewable energy sources, sustainable energy policies, and energy efficiency measures provide a balance between environmental sustainability and economic growth. However, sustainability and environmental effects in the energy sector should be considered alongside this growth. The increase in electricity production should focus on factors such as the effective and efficient use of energy resources, the adoption of environmentally friendly technologies, and the reduction of carbon emissions.

Turkey places a significant importance on the industrial sector to achieve its economic development goals and maintain a competitive advantage. In this context, industrial electricity consumption plays a key role in Turkey's economic growth dynamics by increasing production capacity and supporting industrial activities. The relationship between industrial electricity demand and economic growth offers a crucial perspective for the country's industrial transformation and sustainable development goals. The industrial sector can be described as the locomotive of the Turkish economy, and the energy needs of this sector increase proportionally with economic growth. The expansion of production capacities, new investments, and the adoption of technological advancements are fundamental reasons for the increasing electricity demand. The presence of energy-intensive industries significantly contributes to the rise in industrial electricity consumption. The relationship between industrial electricity consumption and economic growth emphasizes the importance of enhancing efficiency in production processes, increasing competitiveness, and creating employment, while also strengthening the country's industrial infrastructure. However, it is crucial to consider this increase in energy demand from a sustainability perspective. Energy efficiency, a shift to renewable energy sources, and the reduction of environmental impacts are vital elements to maintain a balance between industrial electricity consumption and economic growth.

In this study, the linkage between electricity consumption, industrial electricity consumption, and economic growth in Turkey for the year 2021 is spatially examined. By incorporating spatial dependence in energy consumption using spatial data, the aim is to reveal the relationship between energy consumption among Turkish provinces and regional growth.

1 LITERATURE REVIEW

There is a vast literature examining the relationship between electricity consumption and economic growth, with numerous studies published in recent years addressing these topics. Cui et al. (2021) conducted a spatio-temporal analysis across prefecture-level cities in China from 1999 to 2014, revealing a positive correlation between industrial electricity consumption and economic growth. Their study emphasizes the significant role of energy-intensive industries in driving urban economic expansion. Li et al. (2023) explored the effects of urban sprawl on electricity consumption in 283 prefecture-level cities in China, providing empirical evidence of the impact of urban development on energy usage patterns. Chen and Fang (2018) examined the relationship between human capital investment, industrial electricity consumption, and economic growth in Chinese cities, highlighting the importance of education and skills training in fostering sustainable development. Shakouri et al. (2020) investigated the impact of financial development on urban electricity consumption through spatial and heterogeneity analysis, revealing insights into the interconnectedness of financial systems and energy usage patterns. Qi et al. (2023) explored the allometric growth relationship between electricity consumption and economics

in China, offering insights into the evolving patterns of energy usage and economic development. Chica-Olmo et al. (2020) conducted a spatial analysis of the relationship between economic growth and renewable energy consumption in European countries, contributing to the understanding of renewable energy transitions and their economic implications. Yang and Cui (2022) examined the effect of energy consumption on China's regional economic growth from a spatial spillover perspective, highlighting the importance of considering spatial interdependencies in energy and economic systems. Zhao et al. (2021) modeled the spatial correlations among energy consumption, economic growth, and the ecological environment, providing insights into the complex interactions between energy usage, economic activity, and environmental sustainability. Radmehr et al. (2021) analyzed the nexus between renewable energy consumption, CO2 emissions, and economic growth in EU countries using simultaneity spatial modeling techniques, contributing to the understanding of renewable energy transitions and climate change mitigation efforts. Formánek (2020) explored semiparametric spatio-temporal analysis of regional GDP growth with respect to renewable energy consumption levels, providing valuable insights for policy formulation and sustainable development strategies.

Electricity consumption and its relationship with economic growth have been extensively examined both globally and specifically within the Turkish context. However, there is a limited body of research directly exploring the correlation between electricity consumption in the industrial sector and the size of the industrial sector in Turkey, with due consideration to spatial effects. A summary of recent literature on the subject in Turkey is provided below: In a study by Karaca and Karacan (2016), the data influencing electricity consumption and production in Turkey were evaluated using the multiple regression method. The analysis revealed a significant relation between electricity consumption and gross domestic product (GDP), indicating that changes in GDP positively impact electricity consumption. Güvenoğlu and Aydın (2018) examined the relationship between electricity consumption and economic growth at the provincial level in Turkey. Their study covering the years 2007–2014 identified a mutual causality relationship between the two variables. Öz and Togay (2018) investigated the effects of structural reforms in the electricity sector on economic growth in Turkey from 1980 to 2015. The study established cointegration and a long-term relationship between the two variables, with causality tests confirming a causal relationship from GDP to electricity consumption. Yıldırım and Dağdemir (2018) analyzed the relationship between electricity consumption and economic growth in Turkey for the period 1999–2015, revealing a unidirectional causal relationship from electricity consumption to GDP.

Turkan and Ozel (2019) conducted a study that examined the predictors of electricity consumption utilizing a panel data approach for NUTS2 regions. Ayol (2020) conducted a study testing the relationship between electricity consumption and economic growth using panel cointegration tests at the NUTS 2 level. The analysis showed that electricity consumption had a long-term impact on economic growth. Akarsu and Berke (2020) investigated the presence of absolute and conditional beta convergence of per capita total electricity consumption across the provinces of Turkey between 1986 and 2013. Türkmen et al. (2022) explored the regional level of per capita total and industrial electricity consumption convergence (divergence) with spatial panel data for the period 2007–2017. The analyses revealed both absolute and conditional convergence mechanisms in terms of both total and industrial consumption values among the provinces in Turkey. Eralp (2023) examined the structural relationship and potential inverted U-shape relationship between industrial sector electricity consumption and the size of the industrial sector using panel time series analyses covering 81 provinces at the NUTS 3 level for the period 2004-2019. The study suggested that, under total spatial effects, the scale effect of the industrial sector size is expected to dominate up to 280 billion US dollars, followed by the dominance of composition and technical effects. Kurkcuoglu (2023) delved into the concept of energy justice within the framework of natural gas distribution. Their research, based on an analysis of 356 neighborhoods in the Izmir Metropolitan Area, employed various regression models including linear regression (LR), geographically weighted regression (GWR),

and multiscale geographically weighted regression (MGWR). The results indicated that population, income, employment, and areas identified as disadvantaged play crucial roles as determinants influencing natural gas investments.

2 METHODOLOGY OF ANALYSIS AND DATA DESCRIPTION

The research was primarily conducted by initially describing spatial data and subsequently estimating empirical models to draw inferences (Aral and Bakır, 2022). In the process of describing spatial data, the summary statistics were computed and global spatial autocorrelation was utilized. Additionally, the spatial relationship between electricity consumption and economic growth was analyzed using both the GWR model and the MGWR model.

2.1 Exploratory spatial data analysis

Before applying GWR, calculating global Moran's I index is a common practice to assess the presence of spatial autocorrelation in the data. Moran's I, proposed by Moran (1950), is an indicator of whether there is spatial clustering, dispersion, or randomness in the data. The formula for Moran's I is as follows:

$$I = \frac{n}{\sum_{i=1}^{n}\sum_{j=1}^{n}\omega_{i,j}} \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\omega_{i,j}(x_i-\overline{x})(x_j-\overline{x})}{\sum_{i=1}^{n}(x_i-\overline{x})^2}, \quad (1)$$

where n is the number of the regions, x_i is the observed value of the region i, $\omega_{i,j}$ are the spatial weights that denote the spatial proximity between regions i and j. Various methods exist for determining spatial weights. In this study, queen contiguity, based on shared borders, is utilized to establish interactions among the examined provinces in Turkey. The adjacency binary matrix for this study is:

$$\omega_{i,j} = \begin{cases} 1, & i \text{ is adjacent to } j \\ 0, & \text{otherwise} \end{cases} \quad i \neq j$$

$\omega_{i,i}$ is assumed to be zero ($\omega_{i,i} = 0$).

The p-value associated with the standardized Moran's I statistics, $Z = \frac{I - E(I)}{\sqrt{V(I)}}$ where $E(I) = \frac{-1}{n-1}$ and $V(I) = E(I^2) - E(I)^2$, if statistically significant, indicates the presence of a spatial effect. Furthermore, in this study, Moran's I value has been computed for the residuals to assess the existence of spatial dependence in the regression model. A positive Moran's I value detected during regression analysis might suggest the presence of spatial autocorrelation within the model, underscoring the significance of acknowledging such spatial dependency. Conversely, a negative Moran's I value could indicate a breach of the assumption of spatial independence within the model.

2.2 Geographically Weighted Regression

The linear regression (LR) model is written as follows:

$$y_i = \beta_0 + \sum_{k=1}^{p}\beta_k x_{ik} + \varepsilon_i; \quad i = 1,\ldots,n \quad k=1,\ldots,p. \quad (2)$$

The LR model in (2) is rewritten in vector-matrix form as:

$$\mathbf{y} = \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\varepsilon}, \tag{3}$$

where $\mathbf{y}$ is the nx1 vector of reponses, $\mathbf{X}$ is the nxp matrix of explanatory variables, $\boldsymbol{\beta}$ is the px1 vector of unknown parameters and $\boldsymbol{\varepsilon}$ is the nx1 vector of error with $\mathbf{E}(\boldsymbol{\varepsilon})=\mathbf{0}$ and $V(\boldsymbol{\varepsilon}) = \sigma^2\mathbf{I}_n$, $\boldsymbol{\varepsilon} \sim N(\mathbf{0}, \sigma^2\mathbf{I}_n)$. The $\hat{\boldsymbol{\beta}} = (\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{y}$ is the estimation of $\boldsymbol{\beta}$ and $\hat{\mathbf{y}} = \mathbf{X}\hat{\boldsymbol{\beta}}$ is the fitted vector of $\mathbf{y}$. The estimation of σ^2 is $s^2 = (\mathbf{y}-\hat{\mathbf{y}})'(\mathbf{y}-\hat{\mathbf{y}})/(n-p) = \mathbf{e}'\mathbf{e}/(n-p)$.

In practical applications, the relationships between variables can exhibit spatial variations. Unlike LR model, GWR model allows for local variations in the estimation of coefficients (Gwarda, 2018; Millo and Piras, 2012). The GWR model can be expressed as follow:

$$y_i = \beta_{0(u_i,v_i)} + \sum_{k=1}^{p} \beta_{k(u_i,v_i)} x_{ik} + \varepsilon_i, \tag{4}$$

where (u_i, v_i) is the coordinate location of i. The estimator for each location is defined as:

$$\hat{\boldsymbol{\beta}}^{GWR} = \left[\mathbf{X}'\mathbf{W}_{(u_i,v_i)}\mathbf{X}\right]^{-1}\mathbf{X}'\mathbf{W}_{(u_i,v_i)}\mathbf{y}, \tag{5}$$

where $\mathbf{W}_{(u_i,v_i)} = \mathrm{diag}\left[w_{1(u_i,v_i)},\ldots,w_{n(u_i,v_i)}\right]$ is the nxn diagonal weight matrix represents the geographical weighting of each observed data for regression point i at location (ui , vi). This weighting is determined by a kernel function. The weight matrix is obtained from a kernel function that assigns weight to observations closer to the location i. One commonly used kernel function is the bi-square nearest neighbor function:

$$w_{j(u_i,v_i)} = \begin{cases} \left(1-\left(\dfrac{d_{ij}}{b}\right)^2\right), & \text{if } j \notin \{N_i\}, \\ 0, & \text{if } j \notin \{N_i\} \end{cases}$$

where the distance between location i and location j denoted as d_{ij}, and b represents the distance to the Nth nearest neighbor. Bi-square kernel exhibits similar discontinuity by assigning null weights to observations with a distance greater than b. They assign weights that decrease as the distance between observation points increases, up to the distance b. Therefore, these kernels are considered as distance-decay weighting kernels, similar to Gaussian and exponential kernels (Wheeler, 2007; Wheeler, 2009).

The outcomes of GWR model are influenced by the choice of bandwidth for the weighting function. Therefore, selecting the most appropriate bandwidth value is a crucial aspect of GWR model. To determine the optimal bandwidth, the Cross-Validation (CV) approach proposed by Cleveland (1979) is employed. This approach involves:

$$CV = \sum_{i=1}^{n} (y_i - \hat{y}_{-i}(b))^2, \tag{6}$$

where $\hat{y}_{-i}(b)$ is the fitted value of y_i with the *ith* observation omitted from the data. The b that minimizes CV is the optimal b value (Fotheringham et al., 2002; Wheeler, 2007). The optimal kernel bandwidth

for GWR can be determined by minimizing certain model fit diagnostics. These diagnostics may include a leave-one-out cross-validation (CV) score (Bowman 1984), which focuses solely on model prediction accuracy, or the Akaike Information Criterion (AIC; Akaike 1973), which takes into account model parsimony.

2.3 Multiscale Geographically Weighted Regression (MGWR)

A recent improvement in GWR, known as Multiscale GWR (MGWR), eliminates the single bandwidth assumption and enables the optimization of covariate-specific bandwidths (Fotheringham et al., 2017). This allows each parameter surface to have a distinct degree of spatial variation, capturing variations across covariate-specific processes. Consequently, MGWR can discern local, regional, and global processes by optimizing a different bandwidth for each covariate. Furthermore, in MGWR, bandwidths serve as explicit indicators of the scale of various processes that are in operation. The transition from a single-scale local model (GWR) to a multiscale local model (MGWR) introduces flexibility and improves model fit, albeit at the expense of increased computational complexity. This increased complexity is a result of multiscale models having more parameters to be estimated compared to their single-scale counterparts.

MGWR builds upon geographically weighted regression (GWR). It is a local regression model that allows the coefficients of the explanatory variables to vary across space. Each explanatory variable may operate at a different spatial scale. GWR does not account for this, but MGWR does by allowing a different neighborhood (bandwidth) for each explanatory variable. The neighborhood (bandwidth) of an explanatory variable determines the features that are used to estimate the coefficient of that explanatory variable in the linear regression model that is fit for a target feature. MGWR methods are expanded by investigating linkage at different spatial scales using varying bandwidths, as opposed to relying on a single, constant bandwidth. This flexibility in utilizing different bandwidths allows MGWR to model a broader spectrum of geographic phenomena compared to other regression models.The MGWR is expressed as:

$$y_i = \beta_{0(u_i,v_i)} + \sum_{k=1}^{n} \beta_{bwk(u_i,v_i)} x_{ik} + \varepsilon_i, \tag{7}$$

where $\beta_{bwk(u_i,v_i)}$ is the estimated coefficient of k-th explanatory variable for the i-th with the b_w bandwidth. The optimal bandwidth was determined by the CV verification method.

2.4 Data description

In this study, indicators of electricity consumption and economic growth at the 81 provincial level for the year 2021 were examined. Upon reviewing the literature, Gross Domestic Product (GDP) has commonly been used as an indicator of economic growth. The study analyzed data on per capita total electricity consumption (PEC) and per capita industrial electricity consumption (PIEC). Per capita residential building area (PRBA), per capita industrial building area (PIBA) and per capita GDP (PGDP) were also considered as indicators of economic growth. LR, GWR, and MGWR model results were obtained and compared for two types of electricity consumption. The data is obtained from TURKSTAT. The variables used in the analysis were determined based on the previous studies. The variables, variable abbreviations and institutions from which the variables were obtained are given in Table 1. The descriptive statistics for all variables are provided in Table 2.

The border neighborhoods were extensively examined using the Moran's I test. The map in Figure 1, it is created to delineate the border neighborhoods of the provinces for calculation.

Table 1 Variables, variable abbreviations and sources of data

Dependent variables	Variable abbreviations	Source of data
Per capita electricity consumption (kWh)	PEC	TURKSTAT
Per capita industrial electricity consumption (kWh)	PIEC	TURKSTAT
Independent variables		TURKSTAT
Per capita residential building area (m^2)	PRBA	TURKSTAT
Per capita industrial building area (m^2)	PIBA	TURKSTAT
Per capita gross domestic product (TL)	PGDP	TURKSTAT

Source: Author's own construction

Table 2 Descriptive statistics of variables

Variables	Min.	Q1	Mean	Median	Q3	Max.
PEC	0.9435	2.9596	3.9576	3.5521	4.9829	11.0044
PIEC	0.0075	0.5093	1.9110	1.3750	2.6066	9.5827
PRBA	0.5737	1.1341	1.4948	1.4889	1.8572	4.9268
PIBA	0.0006	0.1054	0.1528	0.1474	0.1852	0.5044
PGDP	26.0500	63.1900	81.6500	80.0200	88.9400	151.8100

Source: Author's own calculation

Figure 1 Neighborhood boundaries map

Source: Author's own construction

The gobal Moran's I statistics and the p values related to standardized Moran's I statistics is obtained as in Table 3. Moran's I statistics given in Table 3 validate spatial autocorrelation with a significant p-value for all dependent variables (He et al., 2021).

Table 3 Values of global Moran's I statistics

Dependent variables	Moran's statistic I	p value
PEC	0.0875	0.0000**
PIEC	0.1106	0.0371*

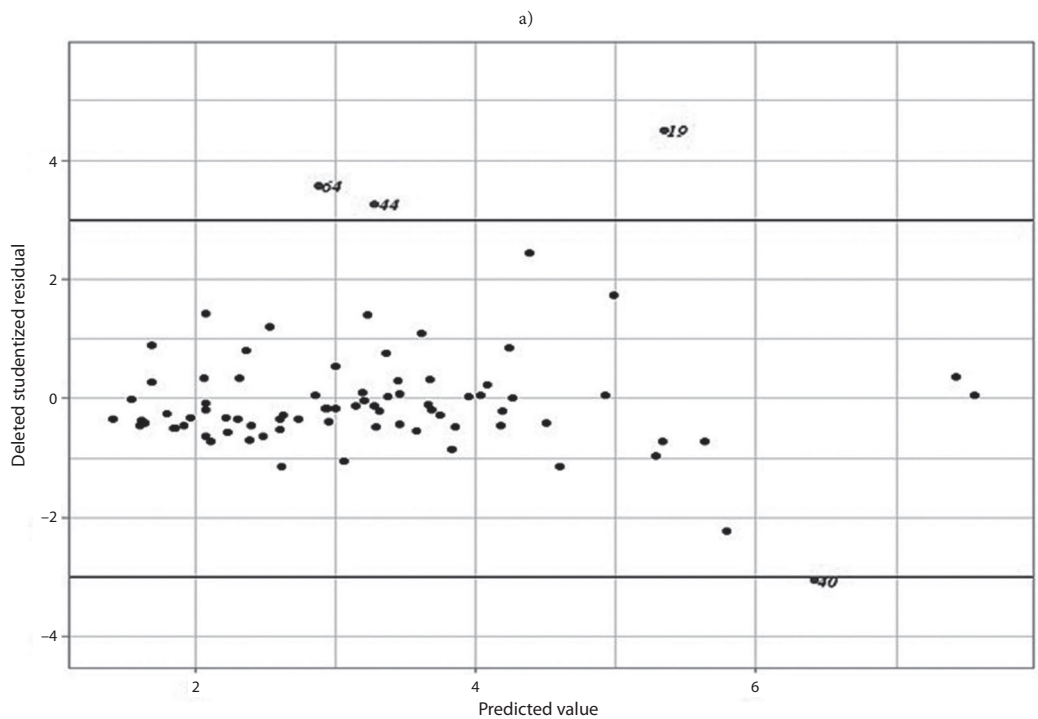
Note: ** significiant level 0.01, * significiant level 0.05.
Source: Author's own calculation

3 EMPIRICAL RESULTS

Initially, the LR model was employed to identify the relationships between PEC and PIEC with PRBA, PIBA, and PGDP. It is evident from the VIF values presented in Table 4 that there is no issue of multicollinearity among PRBA, PIBA, and PGDP. However, upon examination the Breusch-Pagan statistics in Table 4 and the scatter plots depicted in Figure 2, it becomes apparent that there exists a problem of heteroscedasticity.

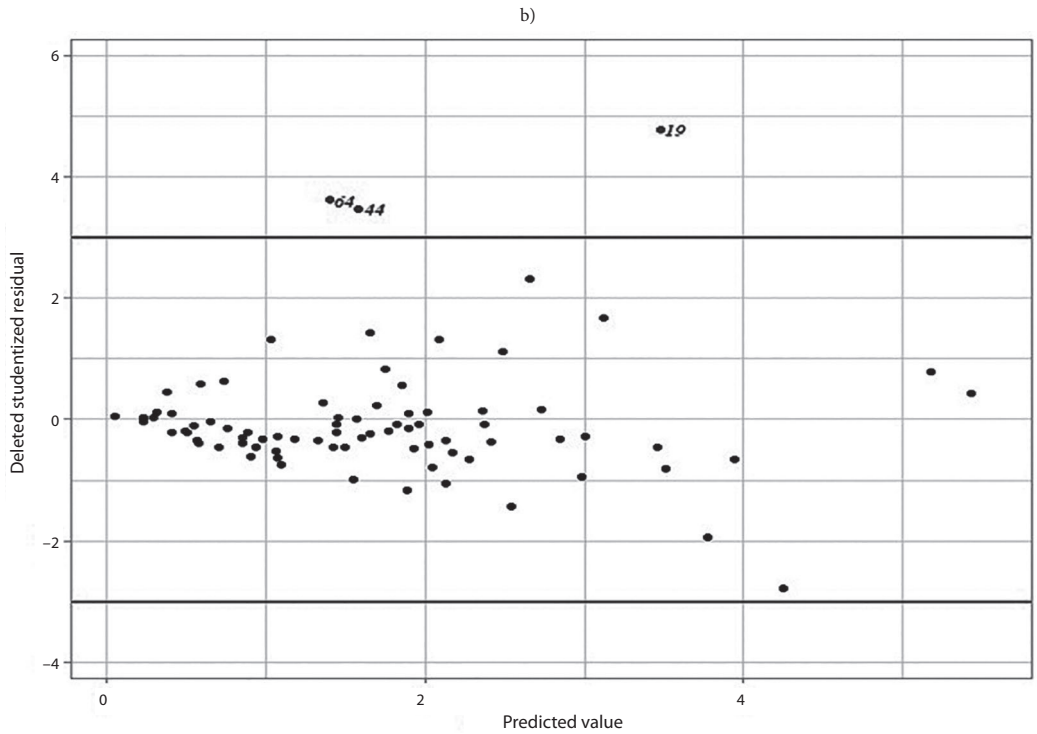
The significance of the Breusch-Pagan test indicates changing variance statistically. Additionally, the scatter plot of residuals against predictions indicates non-randomness, hence confirming the presence of changing variance. Furthermore, upon examining Figure 2, the red dots represent the outliers in the dataset. In such cases, the standard errors for the regression coefficients become unreliable. To address these issues, robust standard errors, which provide more accurate estimates of the standard error values, have been calculated.

Figure 2 The scatterplot of predicted values and deleted studentized residuals: a) PEC, b) PIEC



Source: Author's own construction

Figure 2 (continuation)



Source: Author's own construction

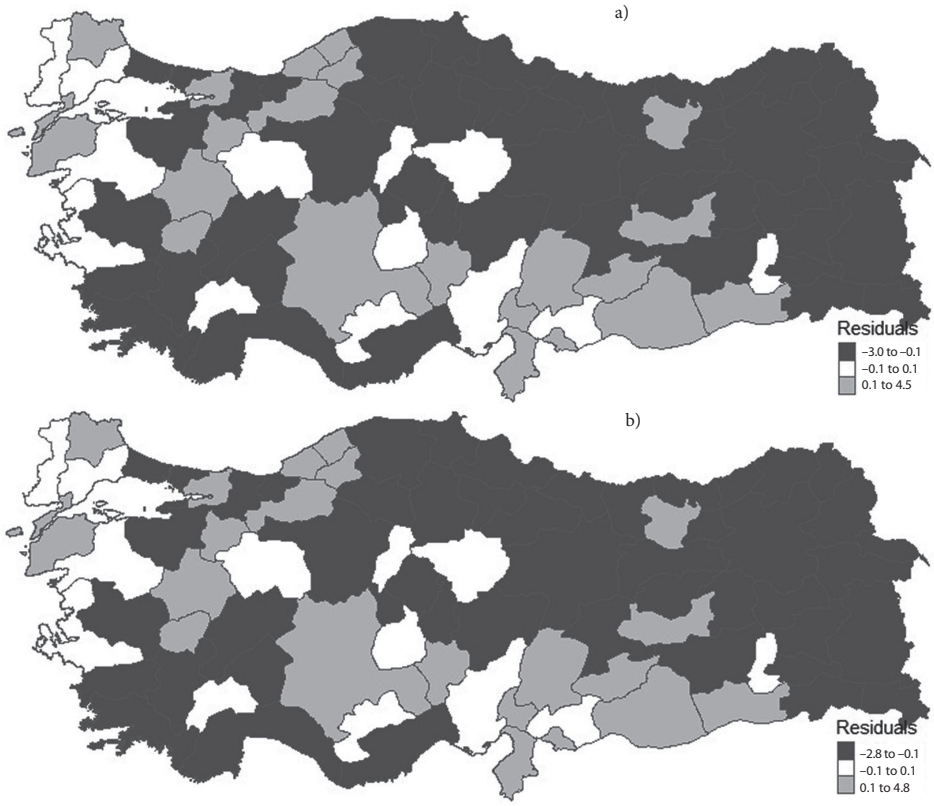
Table 4 Summary of the LR model via robust standard errors

	Coefficient	Std. error	t value	VIF	p value
PEC					
Intercept	0.3211	0.5041	0.6372	–	0.5259
PRBA	−0.1425	0.1971	−0.7228	1.0208	0.4720
PIBA	4.3093	1.5371	2.8036	1.3947	0.0063**
PGDP	0.0403	0.0104	3.8596	1.3773	0.0002**
Breusch-Pagan test statistics: 8.413; p value = 0.0381* Morans'I for residuals: 0.4693, p value = 0.0000**					
PIEC					
Intercept	−0.9415	0.4897	−1.9224	–	0.0582
PIBA	4.0247	1.6087	2.5018	1.3769	0.0144*
PGDP	0.0330	0.0104	3.1669	1.3769	0.0021**
Breusch-Pagan test statistics: 7.172; p value is 0.0276* Morans'I for residuals:0.3834, p value = 0.0000**					

Note: ** significiant level 0.01, * significiant level 0.05.
Source: Author's own calculation

By considering the residual distribution maps in Figure 3 a–b, it can be inferred that the clustered patterns might arise from random chance, indicating notable spatial autocorrelation and spatial heterogeneity. The residuals indicate the presence of numerous cities exhibiting either high or low standard residuals, with their distributions appearing somewhat uneven and clustered. Moran's I statistics is calculated for residuals whether there is no spatial autocorrelation during linear regression analysis. The Moran's I values of 0.4693 for PEC and 0.3834 for PIEC suggest a moderate level of positive spatial autocorrelation in the estimated LR model. These values indicate a tendency for observations to cluster in regions where similar values are close to each other geographically.

Figure 3 The spatial distribution of residuals of a) PEC, b) PIEC



Source: Author's own construction

After conducting the Moran's I tests and examining the spatial distribution of residuals, spatial dependence has been observed in the data. Therefore, spatial regression techniques, namely GWR and MGWR, are used to more accurately capture the spatial nuances within the data. The results obtained from GWR and MGWR models presented in Tables 5–6.

According to results in Table 4, PIBA and PGDP display statistically significant influences on both PEC and PIEC. Particularly, the variables PIBA and PGDP exhibit a positive correlation with PEC and PIEC in the LR model. At the median level, MGWR produces similar estimations for the variables PIBA and PGDP concerning PEC and PIEC when compared to GWR results in Table 5-6. The local impact of PIBA and PGDP on both PEC and PIEC is generally positive.

Table 5 Summary of GWR model

	Min.	Q1	Median	Mean	Q3	Max.
PEC						
Intercept	–0.022	0.2310	1.3172	1.0432	1.6915	1.7784
PRBA	–0.5472	–0.4769	–0.3418	–0.2669	–0.0145	0.0577
PIBA	1.8724	2.5353	3.2190	4.1149	6.2400	6.3845
PGDP	0.0258	0.0328	0.0346	0.0340	0.0358	0.0374
PIEC						
Intercept	–0.8853	–0.8365	–0.6324	–0.6947	–0.5942	–0.4702
PIBA	2.3875	2.7443	2.9320	3.6146	4.8114	5.1908
PGDP	0.0271	0.0283	0.0316	0.0306	0.0326	0.0334

Source: Author's own calculation

Table 6 Summary of MGWR model

	Bandwidth	Min.	Q1	Median	Mean	Q3	Max.
PEC							
Intercept	37	0.0221	0.5595	2.1023	1.6404	2.4442	2.7492
PRBA	64	–0.6972	–0.4905	–0.2693	–0.2581	0.0141	0.0719
PIBA	78	1.4694	2.0272	2.3026	2.3559	2.8066	3.1457
PGDP	74	0.0169	0.0256	0.0277	0.0268	0.0285	0.0291
PIEC							
Intercept	37	–0.7752	–0.5173	–0.0113	–0.0761	0.3440	0.5872
PIBA	78	1.4361	2.0200	2.2864	2.2627	2.6071	2.8557
PGDP	78	0.0201	0.0221	0.0225	0.0231	0.0246	0.0254

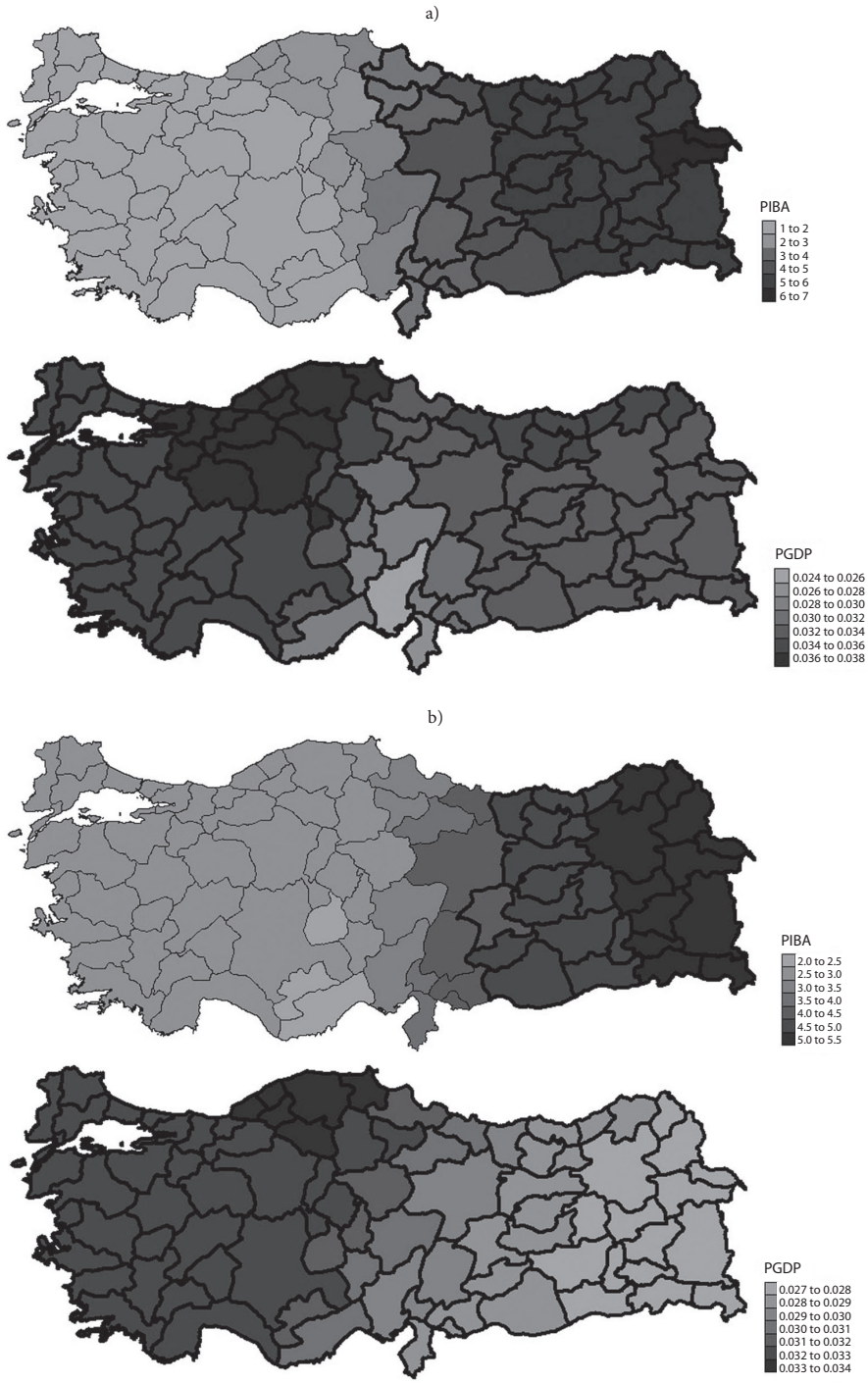
Source: Author's own calculation

In addition to comparing the model fit, the maps are generated and compared for GWR and MGWR results in Figures 4–5. These maps illustrate local variation and the local statistical significance of coefficients. In Figures 4–5, the highlighted provinces within the red frame indicate the regions where the parameter is statistically significant.

Maps are used to illustrate whether GWR and MGWR yield similar or disparate estimates for each variable and their geographic distribution. In the GWR model, the PRBA variable is found to be insignificant in all observations, while in the MGWR model, it is insignificant in 38% of the observations (refer to Figure 5 a). The coefficient values of PRBA were found to be statistically insignificant for the eastern regions of Turkey. Additionally, they demonstrate lower magnitudes and a negative effect in the central and western regions on PIEC (refer to Figure 5 a).

The PIBA variable is insignificant in in 59% of the observations in the GWR model and is insignificant in 51% of the observations in the MGWR model for PEC (refer to Figure 4 a, Figure 5 a). The coefficients of the PIBA variable derived from the GWR model were statistically significant for Turkey's eastern

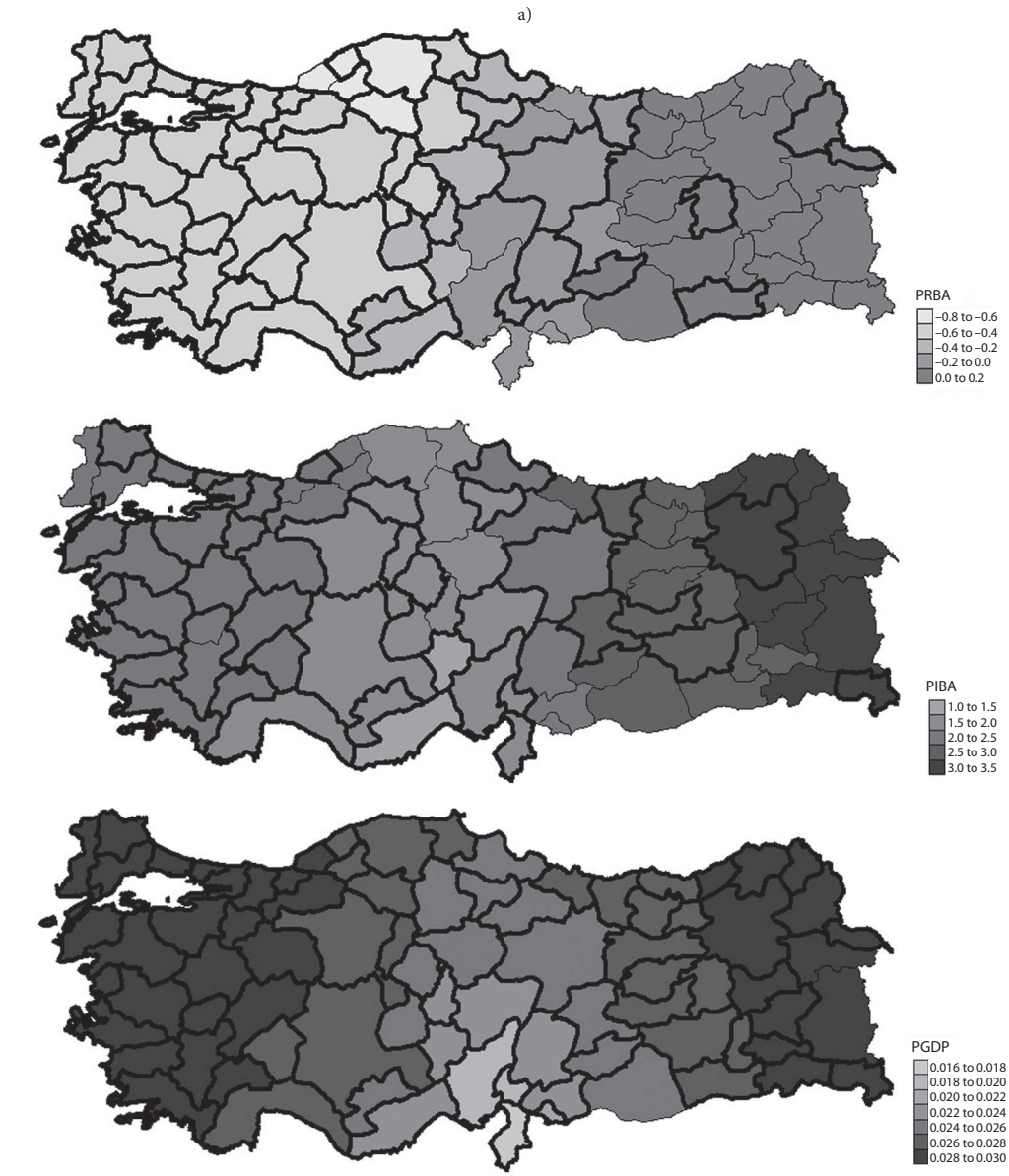
Figure 4 Spatial distribution of the parameters of the GWR model for a) PEC and b) PIEC



Source: Author's own construction

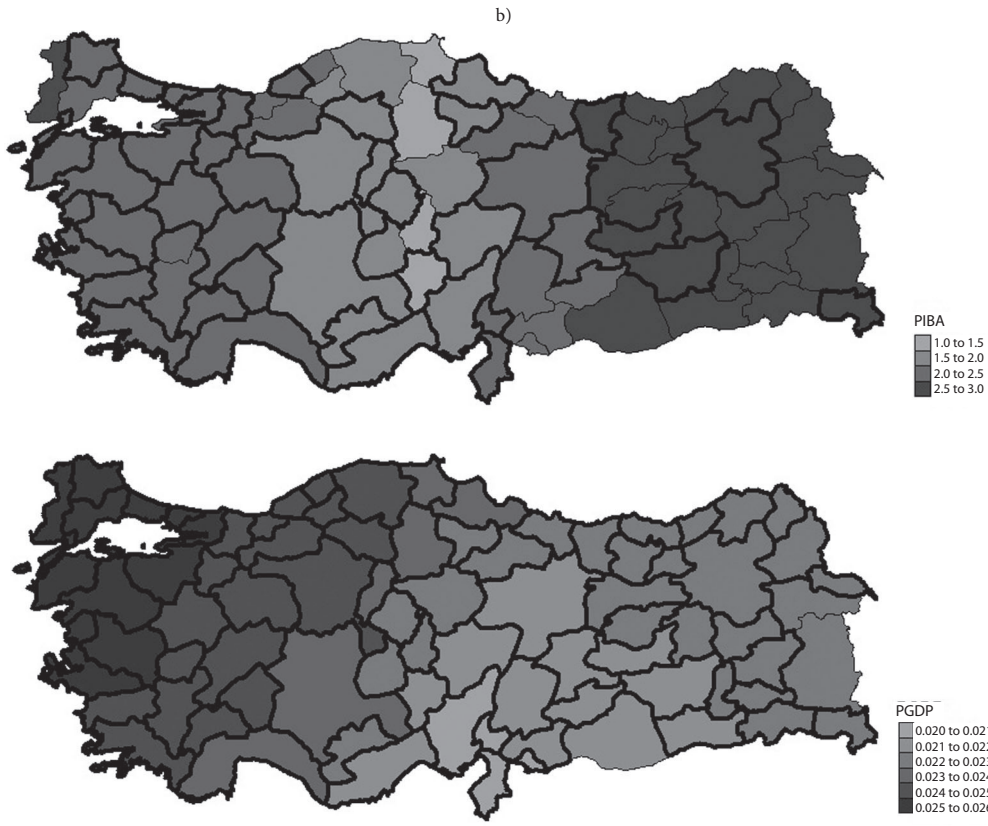
regions, while those obtained from the MGWR model were statistically significant except for the eastern regions. The associated coefficient values are lower in the central and western parts both GWR and MGWR (see Figure 4 a, Figure 5 a). When examining the model results obtained for PIEC, it is observed that the PIBA variable is deemed insignificant in 67% of the neighborhoods in the GWR model and 51% of the observations in the MGWR model (refer to Figure 4 b, Figure 5 b). The coefficient values obtained from the GWR model are statistically significant for Turkey's eastern regions (see Figure 4 b), while those

Figure 5 Spatial distribution of the parameters of MGWR model for a) PEC and b) PIEC



Source: Author's own construction

Figure 5 (continuation)



Source: Author's own construction

obtained from the MGWR model are statistically significant except for most provinces in Turkey's eastern and northeastern regions (see Figure 5 b). Additionally, it is observed that the coefficient values of PIBA are lower in the regions where they are statistically significant.

When examining the PGDP indicator, it is observed that it is significant in all locations in the estimated GWR model for both PEC and PIEC (see Figure 4 a–b). Additionally, the coefficients of PGDP are higher in the western regions where industrial areas are predominantly located. Upon inspection of the MGWR model results, it is observed that the PGDP variable is significant in nearly all regions for both PEC and PIEC, with coefficients notably higher in the western regions compared to other areas (refer to Figure 5 a–b). The disparity between the two models becomes evident, especially concerning statistically significant neighborhoods, particularly for the PRBA and PIBA variables.

Table 7 presents the model performance criteria of LR, GWR, and MGWR models. R-squared assesses the model fit, where elevated values signify a greater explanation of variability in the dependent variable. AIC, AICc and BIC offer a more precise diagnostic for model fit, with lower values indicating a superior fit. The results demonstrate that the MGWR model outperforms the others, exhibiting lower values for AIC and AICc along with higher R-squared for modeling on PEC and PIEC.

Table 7 Model performance criteria for LR, GWR and MGWR

	LR	GWR	MGWR
PEC			
R2	0.4606	0.5090	0.5826
AIC	294.3731	283.2820	273.9483
AICC	295.1731	293.5915	290.3986
BIC	247.3176	224.4637	228.1130
PIEC			
R2	0.3681	0.3881	0.4635
AIC	297.9660	292.3253	284.9482
AICC	298.4923	300.4186	297.876
BIC	244.1216	228.1936	231.9474

Source: Author's own calculation

CONCLUSION

This study investigates the relationship between electricity consumption and economic growth using spatial regression models. LR, GWR, and MGWR models were employed for this analysis. Detecting the presence of spatial effects, the study compares the results of GWR and MGWR models, with MGWR being identified as superior in terms of performance. When examining the MGWR model results for the PEC and PIEC variables, it was found that PRBA and PIBA were generally statistically significant except for the eastern regions, while PGDP is statistically significant for all regions. PRBA values have a negative impact on PEC in the western regions (Figure 5 a). In the western regions of Turkey, there is an inverse relationship observed between per capita residential building area and per capita electricity consumption. This phenomenon is likely due to more widespread energy efficiency measures in these regions, which typically have higher income levels and more modern infrastructure. Additionally, the presence of densely populated cities and smaller average household sizes in the western regions may contribute to lower per capita electricity consumption. However, it should be noted that economic, social, and environmental policies may also play a role in shaping this inverse relationship. These findings provide valuable insight into understanding the differences in residential building structures and energy consumption patterns across different regions of Turkey and can inform the development of energy policies.

According to the MGWR model results, it is observed that the PIBA variable has a positive effect on both PEC and PIEC. The coefficients of the PIBA variable have a consistent regional effect on PEC and PIEC. The PIBA variable is generally statistically significant in affecting both PEC and PIEC, except for the eastern regions of Turkey, and the coefficient values in the western regions are lower compared to the eastern regions. The reasons for the lower PIBA in western regions affecting PEC and PIEC (Figure 5 a–b) are based on various factors. These regions generally have higher income levels and more advanced infrastructure. Therefore, industrial facilities may use more modern equipment and more effective energy efficiency measures. Additionally, western regions may be more focused on the service sector, and industrial facilities may be less intensive or smaller in scale. In areas with higher population density, industrial facilities are likely to have less space compared to residential areas. The combination of these factors may contribute to the lower per capita industrial building variable in western regions affecting PEC and PIEC.

In MGWR models, a positive and statistically relationship was observed between PGDP and PEC as well as PIEC in all regions. According to the results of the MGWR model, the effect of PGDP on PEC showed similar trends in both eastern and western regions of Turkey (Figure 5 a). One reason for its higher significance in western regions is that these areas generally possess more advanced economic infrastructure and industrial activities. Higher income levels and economic growth in these regions may lead to increased electricity consumption. Additionally, the population density in western regions is usually higher, which is associated with higher electricity consumption. In cities with high population density, electricity consumption tends to be higher, thereby enhancing the impact of PGDP on per capita total electricity consumption. Consequently, the higher coefficient values of PGDP on per capita total electricity consumption in western regions may be attributed to the advanced economic structure, high population density, and presence of modern industrial facilities in these areas. The combination of these factors may contribute to a more pronounced effect of PGDP on electricity consumption in western regions. The main reason for the higher impact of PGDP on electricity consumption in eastern regions compared to the interior regions is likely due to the infrastructure being older and less developed. Older and less developed industrial facilities generally tend to be less efficient and consume more energy. This can result in an increase in per capita total electricity consumption. The PGDP has a positive effect on PIEC, with this effect being higher in the western regions (Figure 5 b). There are several possible reasons for this phenomenon. Firstly, western regions generally have more advanced industrial infrastructure and technology. Industrial facilities and factories in these regions typically utilize modern equipment and more efficient production processes, which can enhance the impact of PGDP on industrial electricity consumption. Secondly, industrial activities in western regions are often more intensive and diversified. These regions may have a larger share in production, manufacturing, and other industrial activities, making the effect of PGDP on industrial electricity consumption more pronounced. Thirdly, economic growth and income levels are typically higher in western regions. Higher income levels may lead to increased electricity consumption by both consumers and industries, further amplifying the impact of PGDP on industrial electricity consumption.

The findings of this study emphasize the complexity of the spatial relationship between electricity consumption and economic growth, highlighting the significant role of geographical factors in this relationship. Furthermore, the multiscale geographically weighted regression model was found to more effectively explain this complex relationship. In conclusion, economic activities and industrial zones have a decisive impact on electricity demand. These findings can provide valuable insights for energy planning, economic development, and sustainability strategies.

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Statistics on Income and Living Conditions (SILC) Survey in the Czech Republic: Methodology and History

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Abstract

EU-SILC is a survey focused mainly on mapping income and living conditions of households. In the Czech Republic, the survey has been conducted annualy since 2005 under the name "Životní podmínky" (Living Conditions). Each year, approximately 10 thousand households are surveyed – around one quarter of these households for the first time, while the rest repeatedly as part of the four-year rotating panel. As the EU-SILC has a uniform methodology for all participating countries, the results for the Czech Republic can be compared with other European countries or with the EU average. The Living Conditions survey was introduced in the context of the Czech Republic´s integration into the EU. However, similar surveys focused on households and their current living situation have been conducted regularly in the former Czechoslovakia since 1956. This article focuses primarily on methodology of SILC, but also offers a brief overview of the living conditions surveys in former Czechoslovakia and in present-day Czech Republic.

Keywords	***DOI***	***JEL code***
EU-SILC, living conditions, household income, household survey, income poverty	*https://doi.org/10.54694/stat.2023.43*	*C81, D31, G50, H24*

INTRODUCTION

EU-SILC is a household survey, which has been conducted in the Czech Republic annual by the Czech Statistical Office since 2005. A similar survey is launched in all 27 member countries of the European Union, as well as in Great Britain, Norway, Switzerland, Macedonia, Serbia, Turkey and Iceland.

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The aim of the survey is to map the current living situation of households in the Czech Republic and to gather representative and comparable data on the income distribution of individual household types, on the type, quality and financial character of housing, on the furnishings of the households, and on the working, material and health conditions of adults living in households.

The living conditions of households and their members reflect the general socio-economic situation of the country. In addition to other important macroeconomic indicators, especially gross domestic product, the survey results form the background for assessing the economic development of the state. At the national level, the findings serve as a basis for setting the social policy of the state and analysing the impact of this policy on the living conditions of households, especially in relation to the level of exposure to income poverty. An equally important goal of the survey is to obtain data that provide useful information for the direction of state policy regarding pensions, benefits and taxation, as well as for the evaluation of the impact of individual measures. Thanks to the aforementioned uniform methodology, it is possible to compare the results of the survey for the Czech Republic with other European countries or with the EU average.

This article presents a summary of EU-SILC´s methodology and some of its possible challenges. Secondly, it offers a brief overview of living conditions survey history in Czechia (and former Czechoslovakia), while discussing socio-economic context of each year EU-SILC was carried out. Finally, the article briefly discusses the challenges of conducting a household survey during a world-wide pandemic.

1 LEGAL BASIS OF THE EU-SILC SURVEY

The Czech Republic conducts annual EU-SILC (European Union – Statistics on Income and Living Conditions) surveys as a consequence of Czech membership in the European Union and in order to comply with EU legislation, namely the 1177/2003 framework Regulation and implementing regulations of the Commission. The national version of the survey (Životní podmínky) is carried out by the Czech Statistical Office (CZSO) in accordance with Act No. 89/1995 regarding the state statistics service and with Act No. 101/2000 on individual data protection (CZSO, 2023a).

More recently, in October 2019, a new Regulation (EU) No. 2019/1700 was adopted, together with implementing acts (Commission Implemeting Regulations (EU) No. 2019/2180, No. 2019/2181 and No. 2019/2242). Starting in 2021, this new legislation brought about several changes in the EU-SILC methodology and data collection. Each national statistical institute (including CZSO) was obligated to implement changes together with other surveys under IESS (Integrated European Social Statistics). Additionally, each year a list of annual modules is announced. For instance, for the 2024 survey, in accordance with Commission Implementing Regulation (EU) No. 2022/2498, a 6-yearly module on access to services is covered, as well as a 3-yearly module on children health, access to health care (for children) and children specific deprivation, under the Commission Implementing Regulation (EU) 2019/2242 (European Commission 2023: 16–17).

2 METHODOLOGY

The fieldwork is conducted annually, usually from February to June, by specially trained interviewers. The survey is carried out in a sample design, on a random sample of about one quarter of one percent of the population living in dwellings, i. e. approximately 11 000 households. The following methodological delineation is based primarily on the methodological chapter which is contained in the annual Publication of the EU-SILC results (CZSO, 2023a).

2.1 Sampling and units of survey

The sampling unit is a dwelling. The sample is obtained by a two-stage probability sampling in each of the 14 administrative regions (NUTS3 regions) independently. In the first stage, census districts

are randomly selected from the Register of Census Districts, which are the smallest existing territorial units in the Czech Republic. In the second stage, 10 flats are randomly selected from each census district so selected, which are uniquely identified by address, number or order of the flat in the house. All regions are included in the sample so that the survey covers the entire territory of the Czech Republic. The size of the sample in each region depends on the population of the region (CZSO, 2023a).

The survey units are households, which consist of persons usually living in the selected dwelling. The survey is intended as a four-year rotating panel. This means that households partake in the survey for a total of four years. Approximately a quarter of the sample is rotated each year, with households that have completed the four-year follow-up cycle being replaced by households from newly selected dwellings. Longer-term follow-up of the selected households allows to monitor changes and developments in their living situation (CZSO, 2023a).

Private household stands for a person or a group of people who live together who also provide themselves with the essentials for living (European Commission, 2023).

2.2 Fieldwork and survey content

The survey is carried out face to face. Respondents' answers are recorded in the questionnaires right in the household. Some of the selected households are still interviewed using paper questionnaires (PAPI), the rest is interviewed using electronic ones (CAPI).

The content of the survey is divided into four questionnaires with different units of reference. The survey consists of three stable parts (dwelling, household and personal questionnaires) and a part that changes from year to year (a module). The paper questionnaires are colour coded in order to facilitate interviewers´ work with PAPI questionnaires when collecting data in the field.

Questionnaire A (dwelling unit questionnaire): contains a list of all persons with usual residence in the selected dwelling, their basic demographic characteristics, information on sharing of expenses to determine household units and relationship of each person to the main user of the dwelling and to the head of household.

Questionnaire B (household questionnaire): is filled in for each household. This questionaire contains information on housing, consumer durables, financial situation of the household, consumption of the household's own production (i.e. small scale farming and similar activities), inter-household transfers paid and received, family social benefits, rental income, paid regular taxes on wealth (buildings and land) and childcare.

Questionnaire C (personal questionnaire): is filled in by each household member aged 16 years or over as of 31 December of the previous year. This questionnaire contains information on labour status and employment, personal income (from employment, private enterprise and social security schemes), participation in private pension plans, selected biographical information and health.

Module: is a regular, but varying part of the EU-SILC survey. Most of the times, the module elaborates one of the areas of the survey and gets detailed information on material deprivation, social participation, housing conditions, over-indebtedness or financial exclusion (CZSO, 2023a). Table 1 below contains a list of module topics that were included in the previous surveys.

Table 1 A list of annual ad-hoc modules in EU-SILC survey, 2005–2024

2005	Intergenerational transmission of poverty
2006	Social participation
2007	Housing conditions
2008	Over-indebtedness and financial exclusion

Table 1 (continuation)

2009	Material deprivation
2010	Intra-household sharing of resources
2011	Intergenerational transmission of disadvantages
2012	Housing conditions
2013	Well-being
2014	Material deprivation
2015	Social and cultural participation
2016	Access to services
2017	Health and children's health; Over-indebtedness of households
2018	Well-being
2019	Intergenerational transmission of poverty
2020	Over-indebtedness, consumption and wealth
2021	Health and access to health of the children, Children material deprivation, Living arrangements and conditions of children
2022	Health and quality of life
2023	Labour market and housing; Intergenerational transmission of disadvantages
2024	Health and access to health of the children, Children specific deprivation; Access to services

Source: Czech Statistical Office (CZSO)

Electronical questionnaires for Computer Assisted Personal Interview (CAPI) in notebooks used by interviewers for data collections in the field were developed in software environment Blaise 4.8. Compared to PAPI, CAPI has the advantage of including automatic filtering, logical checks, continuity between topics, contextual help with explanations or methodological instructions, and pre-populated longitudinal data. Since 2023, interviewers for all CZSO household surveys data collection use tablets with CAPI developed in software environment Survey Solutions. Compared to laptops, tablets are lighter, more economical and should make it easier for interviewers to work in the field. The Case Management System (CMS) for all household surveys was developed by the CZSO internal team and is connected to Survey Solutions. The planned Computer Assisted Web Interview (CAWI) for selected household surveys from 2025 is also currently being developed in the Survey Solutions environment. These developments are supported by the EU grants.

2.3 Processing of the questionnaires and collected data

Regional survey coordinators are responsible for collecting the PAPI questionnaires from interviewers and also for entering the data into electronic CAPI questionnaire. Regional coordinators then merge all the CAPI data from interviewers and send the results to the CZSO central database for further processing. All data are transmitted electronically by the regions to the headquarters. Methodologists at CZSO headquarters then perform final super-controls and central processing of the complete questionnaire data files and produce clean data files (CZSO, 2023a).

Household survey data are processed at the CZSO headquarters. Data from the field are exported to database, where microdata are stored and displeyed. OUDot application, which was developed internaly at the CZSO, is used for processing tables and for calculating derived variables and variables in final microdata files. The main purpose of the OUDot application is to have all definitions and structures of individual output tables, as well as definitions and calculations of derived variables in output tables in one place.

2.4 Response rate

One of the disadvantages of sample surveys is the relatively high non-response rate, which affects the results significantly. This non-response is not random, but is instead characteristic of some population groups. The Living Conditions survey shows the highest proportion of non-responding households during the wave one. The overall response rate is approximately 80% (CZSO, 2023a).

Table 2 Response rates in Czech SILC survey, 2018–2022

Year	Response rate (%)				Households in survey	Response count	Response rate (%)
	1st wave	2nd wave	3rd wave	4th wave			
2018	54.8	92.0	93.5	98.1	10 943	8 634	78.9
2019	56.2	94.5	94.6	97.4	10 892	8 707	79.9
2020	55.7	94.5	95.9	97.6	10 767	8 618	80.0
2021	57.0	95.6	95.5	98.4	10 750	8 677	80.7
2022	54.9	92.1	95.9	98.1	10 860	8 605	79.2

Source: CZSO

Participation in the sample survey is voluntary; unlike the census, households are not obliged to provide any information. A selected household must be informed about the content and purpose of the survey. Whether or not a household responds is left to its own consideration. The main reasons for refusal are privacy (objections to providing personal information and fear of misuse of personal data), fear of contact with strangers or inability to participate in the survey (due to health reasons, old age, language barrier etc.). There is a significant group of persons who refuse to give any information as a matter of principle (CZSO, 2023a).

2.4.1 How to increase response rate? Optimising household panel surveys

The proportion of successfully surveyed households varies across waves, with response rate being lowest in the first wave. In the second year, approximately 20% of households drop out of the panel and this number (non-response) decreases with each subsequent wave.

Table 3 Successfully interviewed households and non-response (2022)

	Households			Response rate (%)		
	Total	1st wave	2nd–4th wave	Total	1st wave	2nd–4th wave
Response, total	8 605	2 358	6 247	79.2	54.9	95.2
Non-response, total	2 257	1 940	317	20.8	45.1	4.8
Refusals (unwillingness to give out information)	1 851	1 602	249	82.0	82.6	78.5
Household contacted, temporarily absent	199	185	14	8.8	9.5	4.4
Household unable to respond (health limitation)	114	78	36	5.1	4.0	11.4
Other reasons (linguistic etc.)	93	75	18	4.1	3.9	5.7

Source: CZSO

The main task of the *interviewer* is to retain all members of the household being surveyed throughout all waves of the survey. *Household tracing* is one of the problems that the interviewer has to deal with. This can occur when a household or its panel member (the person interviewed in the wave 1) moves during the course of the survey. It is necessary for the interviewer to obtain information on the location of the household and to trace it at its new address.

Another relevant aspect in terms of increasing response rate may be the relationship between the interviewer´s demographic characteristics and their response rate. For instance, are interviewers of a certain age or education more likely to successfully complete the entire questionnaire? The response rate could also be affected by who the interviewer is and who the respondent is. Should the interviewer network then correspond with population characteristics? However, there could be a completely different non-quantifiable dependency, for example, the interviewer´s personality or their current frame of mind. Can the dependencies be used to obtain information on what an optimal interviewing network should look like?

A co-operative *respondent* is another important aspect of obtaining data in household surveys. For the purpose of increasing response rate, it might be beneficial to determine the ideal day or time to visit the respondent, as well as to identify the ideal number of visits to the household in a survey period.

Another issue is the question of the optimal panel length for a respondent to be willing to voluntarily remain on the panel. Shortening the panel would probably bring the sample population closer to the structure of the base population, yet it could have negative consequences, too. In order to maintain the accuracy of the resulting data, a certain sample size must be maintained (currently set by Eurostat). If the number of waves were reduced, the sample size in wave 1 would have to be increased, which would probably result in an increase in survey costs. On the other hand, lengthening the panel could result in a reduction of the wave 1 sample, but keeping households in the panel for a longer period of time could imply a deterioration of the cross-sectional data and a separation of the sample frame from the population frame.

2.5 Results accuracy

When interpreting and analysing the results of the Living Conditions survey, it is important to bear in mind that the results are based on sample survey data and only then applied to the whole population. This means that all published data are statistical estimates based on a survey sample and therefore include possible sampling and non-sampling errors.

The non-sampling error occurs in all surveys and censuses. It can occur due to many reasons, most commonly of inaccurate methodological instructions, failure of interviewers to follow them, poor wording of questions, processing errors, reluctance to participate in the survey or giving deliberately biased answers. By carefulness in all phases of data collection and processing this component of bias can be significantly reduced. However, it is difficult, if not impossible to assess its impact on the results. Assuming well-defined auxiliary variables, their distribution in the sample can be compared with the known distribution in the whole population (census) (CSZO, 2023a).

The sampling error is a consequence of processing the results of not all units of the population, but of the sample data only. From the survey results obtained, it is necessary to derive data for the whole population. It can be evaluated using sampling theory. This type of error can be reduced by selecting a sufficiently large and representative sample. Sampling error can also be affected by other factors, namely the sampling design, the occurrence of the measured variable and its natural variance.

Relatively low willingness of households to participate in the survey has been a persistent problem. In the case of repeated visits in the panel, this can result in narrowing the range of households types in the data collected and processed. This bias is then corrected by calibration techniques described below (CZSO, 2023a).

2.6 Grossing up and weighting

In comparison with data from other statistics and registers, selected characteristics of the EU-SILC sample show that there is a phenomenon typical for household surveys – high non-response rates (in a rotating panel influenced by previous response) distort the proportions in the final dataset from which the results are acquired. The distortion of demographic characteristics and social structure of the sample does not allow the use of simple techniques of grossing up (post-stratification). To achieve a sufficient level of bias elimination, which is a prerequisite for obtaining good estimates, more sophisticated methods must be used.

In practice, the iteration method of weight calibration is used to minimize the difference between the known and the grossed up values of selected characteristics. Although it is a panel survey including data of four virtually independent samples (waves 1–4), a simple calibration method is used that does not distinguish between the waves but works with all households together. At the same time, in line with Eurostat's recommendations, the survey uses a standard system of integrated weights, i.e. a single set of grossing-up coefficients, which is then used to obtain results for both households and individuals (CZSO, 2023a).

The below-listed calibration variables are used as the foundation for calculations:

- Number of inhabited dwellings in each NUTS3 region, divided into family houses (detached and semidetached houses) and apartments is based on the 2011 Census results and the increases and decreases in the number of dwellings over the period 2011–2021 and the number of dwellings recorded in the 2021 Census.
- Population characteristics:
  Population totals in each NUTS3 region (according to demographic statistics).
  - Economic activity characteristics in each NUTS3 region.
    - Number of employees – derived from the number of employees in the economy based on the findings of Labour Force Survey (LFS) and company reports.
  - Economic activity characteristics in NUTS3 regions:
    - Number of employees – estimate based on the Labour Force Survey and on the number of employees in the National Economy,
    - Number of pensioners (excluding orphans´ pensions) – based on administrative data of the Ministry of Labour, Social Affairs and the Czech Social Security Administration (CSSA), and reduced by the pensioners living out of the dwellings (based on the 2021 Census),
    - Number of unemployed – registered unemployment from the Ministry of Labour and Social Affairs, adjusted for unregistered unemployment using the LFS data,
    - Number of self-employed – estimate based on the LFS and on the administrative data from the CSSA,
    - Number of children aged 0–15 – from demographic statistics.
  - Demographic characteristics in each NUTS3 region (based on the demographic statistics):
    - Age groups (0–15, 16–24, 25–34, 35–44, 45–54, 55–64, 65–74, 75+); Sex.
  - Municipality size (less than 2 000 inhabitants, 2 000–9 999, 10 000–49 999, 50 000 or more inhabitants) (CZSO, 2023a).

The target population of the survey are persons living in *private households*, thus the data from demographic statistics are adjusted by subtracting residents in residential institutions (from Social Security administrative data and Ministry of Justice) and persons living outside dwellings, based on the 2021 Census. Since the sampling unit is the dwelling, all weights are calculated for dwellings and then assigned to all persons and households in them (integrated weights).

The method described above successfully deals with non-response, i.e. it corrects for the bias caused by the specific composition of non-responding households. It improves demographic and social structure but also eliminates the distortions of income indicators that are related to these structures.

Another source of bias that needs to be addressed arises from the method of interviewing. Data on income and housing costs obtained in face-to-face interviews with household members tend to be underestimated or overestimated, while some sources of income or data on some components of income may be completely missing (item non-response). In order not to reduce the size of the processed dataset the missing income is imputed using correct statistical methods (CZSO, 2023a).

Underestimation of income is a natural consequence of the practice when respondents either tend to underreport or simply do not recall having certain irregular or small incomes. This is more or less a non-sampling error that is substantially influenced by the income itself and by its source. The options for eliminating this underestimation are limited. Before the survey results are processed, adjustments are made at the individual level only for those types of income for which it was possible to rely on other reliable statistical data, on tax or on other legislation.

When a respondent reports employment income as net, the net income often shows a significant bias (either under- or overestimation) and the non-sampling error increases. This can occur if the employer deducts a certain amount from the employee's wage/salary (e.g. alimonies or pension contributions). When calculating gross income, this bias is usually sufficiently compensated for by using additional information from the survey. Some respondents mistakenly report gross income as net (or vice versa) which can lead to significant year-to-year differences. In such cases, top/bottom coding is used or the data are adjusted (CZSO, 2023a).

Under the challenging conditions of the covid pandemic, the negative impact of survey errors was more pronounced than before. This became apparent when comparing the data obtained on gross earnings from employment with the corresponding data from labour statistics (annual wage growth) by sector. On this basis, appropriate adjustments were made to the data on employment incomes in several sectors.

Concerning social benefits, to which there is legal entitlement (parental leave, child birth benefit, death grant for families of the deceased, maternity leave), a check on their receipt by eligible households is applied and granted amounts are adjusted in accordance with the amounts set by the legislation.

Comparing aggregated income from this survey with the household sector aggregates of the national accounts (even after subtracting items not included in household income surveys) is problematic. In terms of its aggregated value the income obtained by direct households interviewing will always be lower. More important fact for assessing their credibility is that the trend in household income development follows the trends in the national accounts (CZSO, 2023a).

3 SURVEY OUTCOMES

The results of the Living Conditions survey are annualy published in a publication (which is issued by the CZSO) and are available at the official website of the CZSO. A short brochure is also published every year, covering the main findings of the previous year´s survey, which serves primarily as a feedback for the interviewed households. The findings of the survey show how the overall socio-economic situation of the country is reflected in the lives of specific types of households and appropriately complement the frequently cited macroeconomic indicators, which primarily include gross domestic product. At the national level, the results are used as a basis for setting the social policy of the state and for analysing its impact on the living conditions of Czech households, especially in relation to the level of income poverty (Pekárek and Kalmus, 2021).

The data are also used for specific analyses and for simulations of the impact of some basic government policies (tax, insurance and benefit systems). They are important not only from a macroeconomic point of view, but especially at the micro level of individual households or persons who depend on social transfers (old-age pensioners, families with children, low-income households).

Among the most important end-users of the survey outputs are (apart from Eurostat, to which the CZSO supplies data on a mandatory basis) the Ministry of Labour and Social Affairs, the Ministry of Regional Development and the Czech National Bank. The data are also widely used by academic institutions engaged in socio-economic or sociological research. These include, for example, the Research Institute of Labour and Social Affairs, CERGE-EI, the Institute of Sociology of the Czech Academy of Sciences, as well as colleges and universities, both Czech and foreign (Pekárek and Kalmus, 2021).

4 LIVING CONDITIONS SURVEYS IN THE CZECH REPUBLIC – A BRIEF OVERVIEW

In 2005, the Czech Republic joined the EU-SILC survey, which is conducted annualy as a national module under the title Living Conditions. However, regular surveys aimed at determining the current living situation of households have been carried out in the Czech Republic since 1956. Some elements of the socio-demographic composition of the population have historically been covered by the Census, but this is usually carried out once every ten years, which is too long for certain data. Therefore, in the Czechoslovakia of that time, sample surveys were organised in the periods between censuses under the name of Mikrocensus, which were additionally aimed at determining the income differentiation of households (Pekárek and Kalmus, 2021).

4.1 Microcensus

The Microcensus was a regular sample survey that was carried out over a time-varying period of 2 to 6 years, on a total of 14 occasions. The first one took place in 1956 with a sample of about 32 thousands households, the last one in spring 2003 with the participation of about 11 500 households. The purpose of the survey was to provide representative data on socio-economic structure, household income levels and their differentiation in order to monitor the social impact of the country's economic situation (Pekárek and Kalmus, 2021).

The survey made it possible to obtain demographic and social characteristics of households and individuals, data on cash and in-kind income, and possibly other supplementary information (furnishings, housing costs, etc.). Similarly to EU-SILC later, these data were collected through direct personal contact with households. For instance, 70 499 dwellings were included in Microcensus of 1988 (which took place in 1989), of which 67 552 dwellings were successfully surveyed, with the response rate reaching 95.8%.

Until the early 1990s, micro-census data were processed centrally in the Federal Statistical Office on large mainframe computers and only later on personal computers allowing interactive work. When the database of individual data for the household survey was created at the turn of 1992 and 1993 after the establishment of the independent CZSO, the micro-census data became an integral part of it. The earliest data available are for year 1988, for which it was possible to retrospectively obtain detailed data for individual households and some selected persons, as well as to convert them into a usable form (CZSO, 2004).

In the context of the integration of the CZSO into the European statistical system, as well as the overall integration of the Czech Republic into the EU, the classic income micro-census survey was to some extent replaced by a broader survey, the EU-SILC, specifically focused on other important aspects of household living conditions in addition to income.

4.2 Annual Životní Podmínky (EU-SILC) survey and its nation-state context

Although the EU-SILC is an integrated survey with uniform methodology for all of the participating states, it is important to take into account specific social and economic context at the national level. Table 4 below offers an in-depth overview of the most profound changes in the area of Czech social policy, social security or other socio-economic factors that might have contributed to the results of the survey in each year.

Table 4 Timeline of EU-SILC surveys in the Czech Republic and their socio-economic context

2003 – The *last Czech Microcensus*.

2004 – SILC pilot *testing*.

2005 – *First year of the SILC* survey in the Czech republic. When compared with data from Microcensus 2002, the average household income per capita has increased in all social groups, except for unemployed households. Self-employed households had the highest per capita income. At the same time, income differentiation has further deepened (CZSO, 2006).

2006 – Economic development, decrease in unemployment rates and rise in wages have been positively reflected in the *growth of total household income*. The highest per capita income was earned by households of employees with higher education. Although household incomes were rising, around *9%* of households reported that they *were struggling to make ends meet*. The trend in recent years – the preference for owning one's own home – is reflected in the structure of dwellings by legal reason for occupancy. While in 1999 almost 32% of households lived in rented flats, in 2006 only 23% did so. In relation to the privatisation of municipal flats and the transfer of cooperative flats to private ownership, the *share of privately owned flats has increased* (CZSO, 2007).

2007 – Income growth has been faster than in the previous year and was mainly supported by a *favourable economic development* and a continuing *decrease in unemployment* rates. The increase in social income was mainly driven by pensions, which grew at a higher rate than state social assistance benefits. Of these benefits, *parental allowance grew most dynamically*, mainly as a result of higher fertility rates in recent years. The previous trend of a deepening differentiation of households' net cash income has stopped, which was partly a result of the changes in the taxation of personal income (CZSO, 2008).

2008 – The economy was developing favourably, with *unemployment continuing to fall* and average *nominal wages rising at their fastest pace* since 2003. New legislation on subsistence wage and living wage came into force, together with the law on assistance in material distress and the law on social services. Benefits for parental allowance have increased significantly under the State Social Assistance Act. All of this has had an impact on household incomes and to some extent has also affected longer-term trends. The average amount of state social support *benefits increased* by 37,2%, following a more than doubling of the parental allowance, while pensions, after *valorisation* of both the fixed and percentage parts, have increased, too. At the same time, however, following the change in the subsistence wage level, a smaller group of households has reached the child benefit. Similarly to previous year, the income differentiation did not intensify, due to a whole complex of influences - changes in the taxation of personal income (lower rate of taxation of income up to 18 200 CZK), the possibility of earning extra income for unemployed persons, the possibility of unlimited earnings for persons receiving parental allowance and persons with partial disability pension, and finally, the more than doubling of parental allowance. *Qualitative aspects of housing* were improving, the share of households in dwellings with a larger number of living rooms (and therefore a larger living area) has grown (CZSO, 2009).

2009 – During this period (2008 and spring 2009), the emerging *global financial crisis* gradually began to manifest itself. The worsening of the economic situation was signalled by a *decline in GDP growth* and household final consumption, as well as a *rise in inflation*, which reached its highest rate in a decade. On the labour market, the positive development of previous years – a decrease in unemployment – was persisting, but this stopped at the end of the year and the number of job vacancies began to fall. Average gross monthly wages continued to rise, but, given inflation, *real wage growth was the lowest* in the last 8 years. The Czech Republic underwent a *public finance reform*, resulting mainly in changes in the tax system. The biggest impact was the introduction of a uniform 15% tax rate applied to the so-called super gross wage (superhrubá mzda) and related adjustments – an increase in *tax rebates* and the introduction of a ceiling for social and health insurance. Low-income households, especially those with dependent children, benefited most from the increase in tax rebates. In some cases, these households had a higher net income than gross income. Working pensioners also benefited, as they could now deduct the taxpayer rebate from their tax base. The *significant increase in tax rebates thus compensated* to some extent for the effects of the reform in the area of social spending, the increase in the lower VAT rate and the environmental tax. The conditions for the payment of certain social benefits have been tightened. The most affected were child allowances and funeral allowances, where the changes resulted in a narrowing of the circle of beneficiaries, and childbirth allowances, with the introduction of a single amount of benefit for each child. *Social income was higher* in volume than in the previous year, but to a large extent due to pensions rising after the valorisation in 2008. State social assistance benefits decreased by around 17% year-on-year, with changes in child benefits being particularly significant. The reduction in the household's subsistence minimum for eligibility and the introduction of benefits according to the age of the child significantly reduced the number of recipients and the volume of paid benefits (CZSO, 2010).

2010 – The year 2009 was marked by the *impact of the global financial crisis*, which was somewhat delayed in the Czech Republic. Although the worsening of the economic situation was already visible in the development of macroeconomic indicators in 2008, it was only in 2009 that it took on *more significant dimensions*. It particularly affected the *self-employed households* and gradually affected other household groups, too. The development had a significant impact on the labour market, mainly leading to significant *increase in unemployment rate*. There was a growth in the volume of social income, which was mainly due to an increase in unemployment benefits, which roughly doubled compared to 2008, also housing allowances, which increased by about half, and an increase in pensions due to their valorisation. The share of income from employment or business has decreased slightly. The self-employed had worse sales rate for their products or services compared to previous years, thus reducing their average earnings, while in the employment sector, people with lower incomes were laid off, which increased average earnings. There has been a reversal in the long-standing trend of reducing the level of *vulnerability to income poverty*. A total of 936.4 thousand persons were at risk of income poverty, i.e. 50 thousand more than a year ago (CZSO, 2011).

Table 4 (continuation)

2011 – The *impact of the economic crisis on the situation of households was even more prominent*. Most of the households were more likely to be unable to afford the surveyed expenses and to perceive housing costs as a greater burden for their budget. Household incomes increased only slightly on average, while the share of those whose incomes decreased has grown. The annual amount of *child allowance was increased*, resulting in more households receiving a tax bonus, which was on average higher than in the previous year. The only dynamic increase was in the *housing allowance*, for which the Ministry of Labour and Social Affairs budget spent half as much as in 2009. Significant changes occurred in the area of *rental housing*: rent levels were deregulated in all municipalities except Prague, regional cities (except Ostrava and Ústí nad Labem) and cities in the Central Bohemian Region with more than 10 000 inhabitants. This measure resulted in a swap between the share of households paying market rent and the share of households paying regulated rent (CZSO, 2012).

2012 – There have been changes in the social and tax systems that have affected the income distribution of households and, as a consequence, the evolution of the income poverty rate. First of all, *pensions were valorised* – these increases have moved pensioner households closer to the median in the income distribution, and the overall level of exposure to income poverty has fallen slightly. The second change was the application of the so-called "*flood tax*" (povodňová daň) in the form of a reduction in the tax credit per taxpayer, which increased the tax burden on wage earners. The so-called *middle class was affected by this change the most*, because it resulted in an increase in the proportion of people below the poverty line. Incomes rose for all groups except for *self-employed households*. Their situation was negatively affected by the *worse economic situation* in the country, coupled with overall lower sales of goods and services. During this economically unfavourable period, some of the previously unemployed started new businesses and their income was initially limited. The amount of additional social allowances paid has been significantly reduced. The additional social allowance (sociální příplatek) is a benefit that was limited to families with disabled children during 2011 and was abolished completely as of 31 December 2011. The proportion of households perceiving housing costs as a major burden has increased. The generally more difficult financial situation is also reflected in *households' greater concern about going further into debt* – fewer households than in the previous year had any loan. More households could not afford to pay for an unexpected expense or at least a week's holiday for all household members (CZSO, 2013).

2013 – Although nominal household incomes rose slightly in 2012, they experienced a slight decline in real terms the following year. In the context of changes in the tax system, which have favourably affected workers' incomes, *income differentiation has fallen*, resulting in a reduction in the vulnerability to income poverty. This was primarily due to the *abolition of the 'flood tax'*. At the same time, tax benefits for dependent children have increased. As a consequence, the *tax burden on working people has been reduced*. The income of self-employed households rose year-on-year for the first time since 2008. In the context of the increase in tax credits, incomes also rose for household groups most at risk of poverty, which, combined with the reduction in income differentiation, meant that the *number of people at risk of poverty fell* both in these household groups and in the population as a whole. While the poverty rate declined, the share of households with incomes below the subsistence level increased slightly compared to the previous year. This increase is mainly related to an increase in the subsistence levels (CZSO, 2014).

2014 – Nominal household incomes had risen, and *for the first time since 2009 real incomes had also increased* year-on-year, bringing their real value to the 2008 level. The *improvement in households' financial situation* was also reflected in the declining share of households that could not afford to pay for holidays for all household members, eat meat at least every other day, heat their home sufficiently or pay for unexpected expenses due to financial reasons (CZSO, 2015).

2015 – In terms of head of household status, *incomes increased for all household groups*, the slowest growth of the average net annual income being in the households of the self-employed. The improvement in the financial situation of households was also reflected in the way they managed their incomes. While 31.2% of households were struggling or finding it very difficult to make ends meet in 2014, only 27.3% of households were doing so in 2015 (CZSO, 2016).

2016 – The *highest increase in income was among self-employed* households, with an average increase of 13 thousand CZK per person (7.8%) to 185.8 thousand CZK, which is the result of minimal growth in the previous year. The overall level of material deprivation decreased compared to the previous year (CZSO, 2017).

2017 – There were no significant legislative changes in the area of social security and social benefits compared to the previous year. There was newly only a *slight advantage for families with more children* in the form of a tax credit for the second and additional child in the household, which may have slightly improved the income situation of households with children, but in general these did not have a major impact on the overall income level of the Czech households. The overall level of material deprivation decreased compared to the previous year and thus continued to maintain a downward trend (CZSO, 2018).

2018 – Self-employed households had the absolute highest average annual income. The income of households of *non-working pensioners* increased to 156.1 thousand CZK per person and thus *grew again* at a slightly higher rate than in the previous year. The *minimum wage increased* and *pensions rose*. Mainly households of the unemployed and pensioners were significantly more likely than in the previous year to say that they were managing their income easily or very easily. Practically one tenth of Czech households (440 thousand) spent more than 40% of their disposable income on housing and energy (CZSO, 2019).

2019 – *Tax benefits for children were increased* and the possibility of *faster drawing of parental allowance* was introduced. This edition of the Publication captured a *new indicator "Level of material and social deprivation"*. In addition to some of the original material deprivation items, it expands the range of items to include objects for personal use (2 pairs of shoes, new clothes), contact with friends or relatives, paid leisure activities, spending a certain amount of money for personal use or internet access. There are 13 items in total and a person is considered materially and socially deprived if they cannot afford 5 or more items for financial reasons. In 2019, this indicator reached 5.3%, which is 0.7% lower than in 2018 (CZSO, 2020).

Table 4 (continuation)

2020 – The year 2020 was exceptional due to the *pandemic situation*. The country's state of emergency and the limited possibility of personal contacts *complicated the fieldwork*. Average household net cash income increased year-on-year. There was a larger *increase in pensions* than has been usual in recent years. The basic rate was increased from 9% of the average wage in the country to 10%, i.e. the percentage of pensions increased by 3.4%. *People over 85 years of age started to receive an extra 1 000 CZK* on top of their pension. The statutory minimum wage increased, as well as the care allowance for persons in stages III and IV of dependency on the assistance of another person (CZSO, 2021).

2021 – An unfavourable epidemic situation persisted in the Czech Republic. Quarantines and limited possibility of personal contacts continued to complicate the conduct of the survey in households. Since January, there has been a further *increase in pensions* (boosted by a one-off benefit, the so-called "rouškovné", of 5 thousand CZK), the minimum wage and all levels of the guaranteed wage. After 12 years, the *total amount of parental allowance has increased* from the original 220 000 CZK to 300 000 CZK. People in financial need due to the coronavirus could apply for a *one-off emergency assistance benefit* (MOP COVID-19). The Government has offered a number of programmes to support sectors of the economy, entrepreneurs, tradesmen and employees affected by the pandemic. The at-risk-of-poverty indicator has fallen below 9% after 8 years (CZSO, 2022).

2022 – Net cash income grew fastest for the households of employees, mainly due to lower taxation of their labour income as a result of the *abolition of the super-gross wage* (superhrubá mzda). All pensions in payment were *valorised* (the basic rate increased by 60 CZK and the percentage rate by 7,1%) and, for the first time in history, based on, among other things, consumer price indexes for pensioner households. The basic *rates of child benefits were increased*, making families with income up to 3.4 times the Living Wage now eligible for this benefit. However, the objective increase in households' income did not correspond to how households perceived their income subjectively. The proportion of income that households spent on housing has been declining over recent years, with household incomes rising faster on average than housing costs, but this trend did not continue in 2022. As *housing costs have risen*, so has worsen the perception of these costs as a burden on family budgets. The indicator of the *level of exposure to income poverty increased*, reaching the highest level since the beginning of monitoring this indicator in the Czech Republic. The exposure to income poverty affected 1 046.4 thousand people in the Czech Republic, which is approximately 100 thousand more than in the previous year (CZSO, 2023a).

Source: Authors

5 LIVING CONDITIONS SURVEY IN HOUSEHOLDS DURING THE COVID-19 PANDEMIC

Obtaining sufficient quality information on the living conditions of Czech households is essential in all circumstances. The EU-SILC survey was therefore not stopped even when the epidemic situation first occured in the country. The situation in the Czech Republic in the spring of 2020 was anything but conducive to social contacts between people and visits to households. However, face-to-face contact is the basis for the survey. Despite the unfavourable epidemic circumstances, in a period of a state of emergency and strict government restrictions, the survey has been managed very well during the pandemic years.

During the first pandemic year (2020), the rate of the number of surveyed households did not decrease compared to previous years. There was a slight deterioration in the newly selected households in the first wave (a decrease of 0.9 percentage points compared to the previous year). For repeat visits, the examination rate has further increased. All of this has taken place at the cost of only slight concessions to the usual situation. The main organisational measure was to postpone the fieldwork until the end of July. Even with this time handicap for data processing, it was possible to meet Eurostat's requirements to have preliminary results available as usual by the end of the calendar year (Pekárek, 2021).

The main principle of the SILC survey remains the face-to-face meeting. It cannot be changed if a unique set of information and data unbiased by any form of mediation is to be maintained. However, all those involved in the survey are aware that this is not easy, especially in the pandemic times. Surveying conditions directly in households can place a burden on both interviewers and respondents. Even though the immediate contact is irreplaceable, in some cases (but with exceptions only for repeat visits) telephone contact was used instead of face-to-face contact.

Prior to the 2020 survey, a methodological training of new interviewers was held every year. This time it was conducted remotely by means of an audio presentation, which was then made available to the individual regions. The situation surrounding the pandemic, coupled with the long-term ban on free movement of people, did not allow for personal visits until Easter. The interviewers tried

to contact the selected households at least remotely to arrange the specific form of the survey. Most interviews were conducted by telephone. In the case of personal delivery of questionnaires or other printed materials, interviewers strictly respected all security guidelines. In accordance with all hygiene measures, interviewers were only allowed to return to the field after the end of the state of emergency, i.e. from 12 April 2021, to recruit contacts and arrange the survey modalities (Pekárek, 2021).

In 2022, the survey realisation has been significantly complicated not only by another strong wave of the covid-19 pandemic, but also by the beginning of the war in Ukraine and the emerging energy crisis in the country. Despite these complications and the limited possibility of personal contacts, CZSO interviewers managed to obtain representative data (CZSO, 2023b).

CONCLUSION

EU-SILC survey and its Czech national version Životní podmínky is a sample design survey, aimed at mapping income and living conditions of households. The article discussed the main methodological principles of the survey, as well as the legal basis for its execution, which is partly based on the IESS and European Commission regulations. Secondly, the article focused on the contemporary history of household living conditions and income surveys that have been conducted regularly before the introduction of EU-SILC in the Czech Republic.

The results of the EU-SILC survey can serve as a basis for social policy in nation states, but can be also used for comparison between countries involved in the survey. The household surveys micro-data that are obtained though direct contact of interviewers with the members of households can complement other macro-economic data on income and other spheres. What is more, the findings contribute to the determination of the material and social deprivation rates, as well as the income differentiation. They can also help identify which types of households are at risk of income poverty and set more optimal social policy measures.

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